COMPARATIVE SURVIVAL STUDY (CSS) of PIT-tagged Spring/Summer Chinook and Summer Steelhead 2012 Annual Report

BPA Contract #19960200

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Final 11/30/2012

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Executive Summary

The 2012 Comparative Survival Study (CSS) annual report is an update of the time series of smolt-to-adult survival rate data and related parameters with additional years of data since the completion of the CSS Ten-year Retrospective Summary Report (Schaller et al. 2007). The current report specifically addresses the constructive comments of the most recent regional technical review conducted by the Independent Scientific Advisory Board and Independent Scientific Review Panel (ISAB and ISRP 2007) and the comments on the CSS study from the ISAB (2012). This report includes complete return data for smolt outmigration year 2008 for wild and hatchery Chinook and steelhead (all Snake River returns are to Lower Granite Dam). For wild and hatchery spring Chinook, this report provides completed 3-salt returns from smolt migration year 2009 and 2-salt returns from smolt migration year 2010. For wild and hatchery steelhead, completed 2-salt returns are provided from the 2009 smolt migration and 1-salt returns from 2010. Finally, for hatchery Snake River sockeye, completed 2-salt returns are provided for the 2010 smolt migration. Finally for Snake River Fall Chinook, completed 5-salt returns are provided for the 2006 smolt migration. Adult returns included in this report are through September 10, 2012.

New in this annual report are analyses that characterize how detection probability varies with environmental conditions for yearling hatchery Chinook and combined hatchery and wild steelhead juveniles from the Snake River, passing McNary Dam (Chapter 2). In addition, this chapter presents analyses of PIT-tag data to estimate fish guidance efficiency, which is then used to predict route-of-passage proportions. These predicted route-of-passage proportions are then compared to estimates derived from radio tag data. This method may effectively define the spill for fish passage variable for future analyses and mainstem passage evaluations.

Results of analyses of juvenile passage characteristics and environmental variables in 2012 are consistent with past year's analytical results. Across the species and reaches that were evaluated, consistent patterns emerged. Juvenile fish travel time was consistently fastest when water transit time

(WTT) is reduced (i.e., higher water velocity) and spill levels are high. The effect of spill percentages most likely influenced 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. The instantaneous mortality rates tend to be lowest under conditions of fast WTT and high spill levels. In addition, mortality rates tend to increase over the migration season. We found some evidence that the increased number of dams with surface passage structures in the spillways may be reducing mortality rates. These analyses continue to suggest that there is opportunity to reduce fish travel time and increase survival throughout the Federal Columbia River Power System (FCRPS) through increases in spill levels up to the tailrace dissolved gas limits.

Overall smolt-to-adult return rates from Lower Granite to Lower Granite and from Lower Granite to Bonneville dams are CSS metrics that are reported annually for Snake River salmon and steelhead. SARs for other regional groups are reported for the first mainstem juvenile PIT tag detection site encountered to adults at Bonneville Dam. In general, across species and populations overall SARs were somewhat lower for the 2009 outmigration compared to the 2008 outmigration. The only exception was John Day wild steelhead. Overall PIT-tag SARs across the complete time series 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 and 2% minimum for recovery. 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. 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. SARs for hatchery (Carson and Cle Elum) and wild spring Chinook 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 upstream of McNary Dam on the upper Columbia River, most Upper Columbia SAR time series are presented as McNary-to-Bonneville, which overstates survival within the juvenile migration corridor because it does not account for juvenile mortality occurring between Rock Island and McNary projects. The CSS has begun to estimate SARs from Rocky Reach Dam to address this issue. The CSS continues to evaluate differences between SARs derived from alternative methods for Snake River stocks. 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.

Overall Smolt-to-adult-return rates for Snake River subyearling fall Chinook were very low in the years analyzed in this report. Fall Chinook overall SARs excluding two-year-old jacks ranged from 0.12% to 0.56% for sub-yearling hatchery releases in 2006 and 0.0% to 0.3% in 2007. By study group, SARs were also quite low and based on Transport-in-River ratios (TIRs) no statistically significant benefit to transport was evident in the 2006 returns. Returns for more recent years are not complete but the pattern of little or no transport benefit is consistent in those data.

Patterns in age at maturity among individual stocks are consistent with previous years analyses. Some general characteristics of the sixteen Chinook stocks emerged when stocks were summarized together. The age structure of hatchery or wild spring Chinook stocks, are typically dominated by the age-4 cohort of returning adults. This appears to be consistent for hatchery and wild stocks within the Columbia and Snake River basins. A larger proportion of age-5 adults was present in the Snake River basin wild Chinook as compared to their hatchery counterparts. McCall and Imnaha, hatchery summer Chinook stocks within the Snake River basin, had a relatively high number of jacks along with Pahsimeroi hatchery summer Chinook and Sawtooth Hatchery, spring Chinook . This update of the age at maturity datasets for wild and hatchery Chinook (seven additional groups) strengthened the findings that both stock and year factors influence both the age at maturity and the jack percentage of spring Chinook. The highest jack percentages for Chinook occurred in 2003, 2007, and 2008 from Imnaha and 2008 from McCall hatcheries and ranged from 45% to 55%. This implies that, nearly all adult males returned as age-3 (jacks) assuming a 50/50 sex ratio. The summary of current PIT tag data shows that Oxbow hatchery sockeye adult returns include a much higher component of age-3 (1-salt) adults and therefore a lower age at maturity than their Sawtooth hatchery counterparts. Both sockeye stocks appear to consist mostly of age-4 adults.

Chapter 1 Introduction

The Comparative Survival Study (CSS; BPA Project 199602000) began in 1996 with the objective of establishing a long term dataset of annual estimates of the survival rate 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 with the express need 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 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.efw.bpa.gov/searchpublications/index.aspx?projid

The completion of this annual report for the CSS signifies the 15th outmigration year of hatchery spring/summer Chinook salmon marked with Passive Integrated Transponder (PIT) tags as part of the CSS. This is also the 13th complete brood year return as adults of those PIT-tagged fish, covering adult returns from 1997-2010 hatchery Chinook juvenile migrations. In addition, the CSS has provided PIT-tags to on-going tagging operations for wild Chinook since 2002 (report covering adult returns from 1994-2010 wild Chinook juvenile migrations). The CSS tagged wild steelhead on the lower Clearwater River and utilized wild and hatchery steelhead from other tagging operations in evaluations of transportation, covering adult returns from 1997-2009 wild and hatchery steelhead migrations.

The primary purpose of the 2012 annual report is to update the time series of smolt-to-adult survival rate data and related parameters with additional years of data since the completion of the CSS Ten-year Retrospective Summary Report (Schaller et al. 2007). The 10-yr 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 most recent regional technical review conducted by the Independent Scientific Advisory Board and Independent Scientific Review Panel (ISAB and ISRP 2007) and the comments on the CSS study from the ISAB (2011). This report includes complete return data for smolt outmigration year 2008 for wild and hatchery Chinook and steelhead (all Snake River returns are to Lower Granite Dam). For wild and hatchery Chinook, this report provides 3-salt returns from smolt migration year 2009 and 2-salt returns from smolt migration year 2010 through September 10, 2012. For wild and hatchery steelhead, 2-salt returns are provided from the 2009 smolt migration and

1-salt returns from 2010 through September 10, 2012. Finally, for hatchery Snake River sockeye, 2-salt returns are provided for the 2010 smolt migration through September 10, 2012.

The Chinook salmon evaluated in the CSS study exhibit both stream-type and ocean-type life histories. 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 several locations of the Snake and Columbia rivers. The number of individuals detected from a population of tagged fish decreases over time, allowing estimation of survival rates. Comparisons of estimated survival rates over different life stages between fish with different experiences in the hydrosystem (e.g., transportation vs. in-river migrants and migration through various numbers of dams) are possible as illustrated in Figure 1.1. The location of all tagging sites is identified in Figure 1.2 and a detailed map of watersheds included in these sites is shown in Figure 1.3.

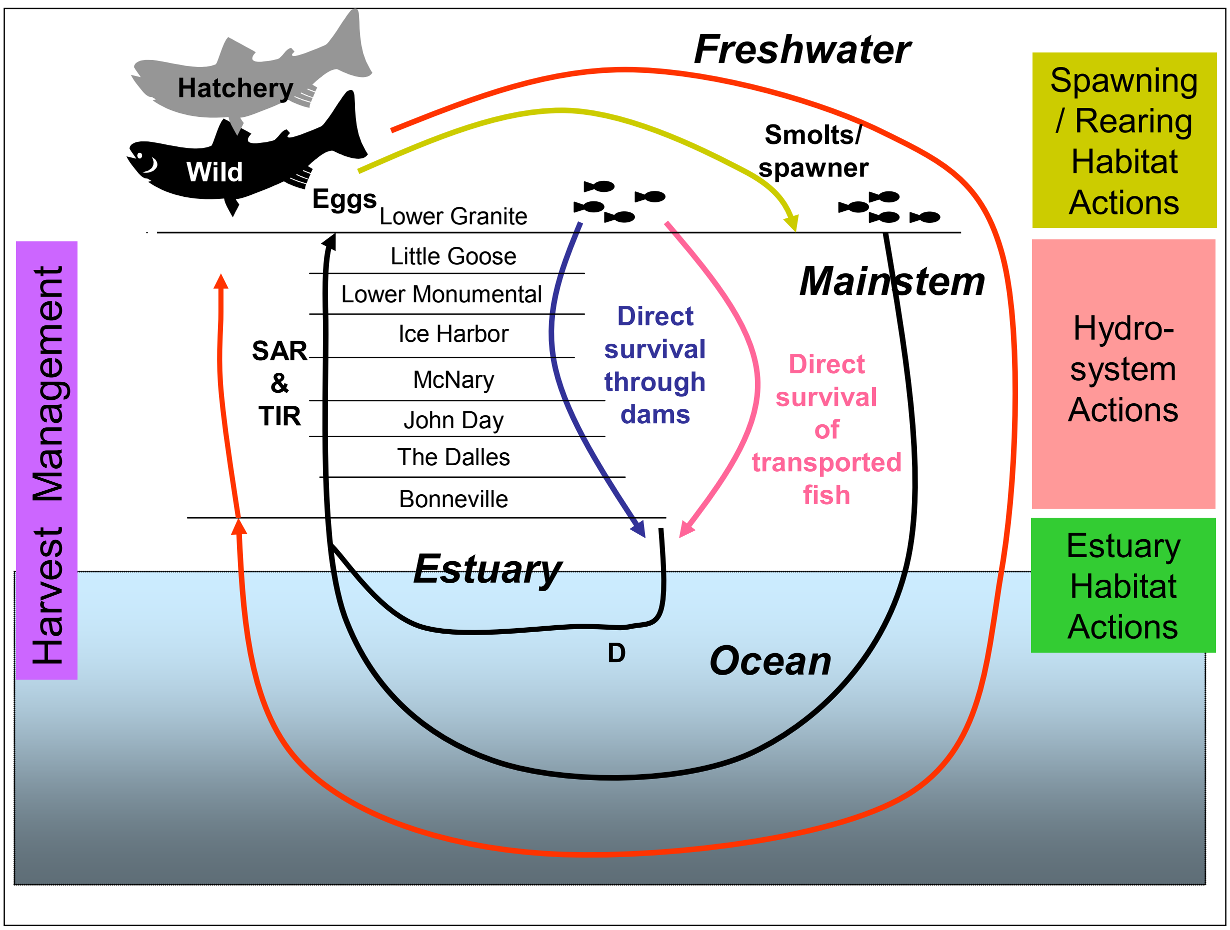

Figure 1.1. Salmonid life cycle in the Snake River and lower Columbia River basins (Source: Marmorek et al. 2004). Acronyms for metrics are: smolt-to-adult return rate from Lower Granite Dam to Lower Granite Dam (SAR), SAR comparisons between transport and in-river migration routes (TIR), and SAR comparisons between transport and in-river migration routes from Bonneville Dam back to Lower Granite Dam (D).

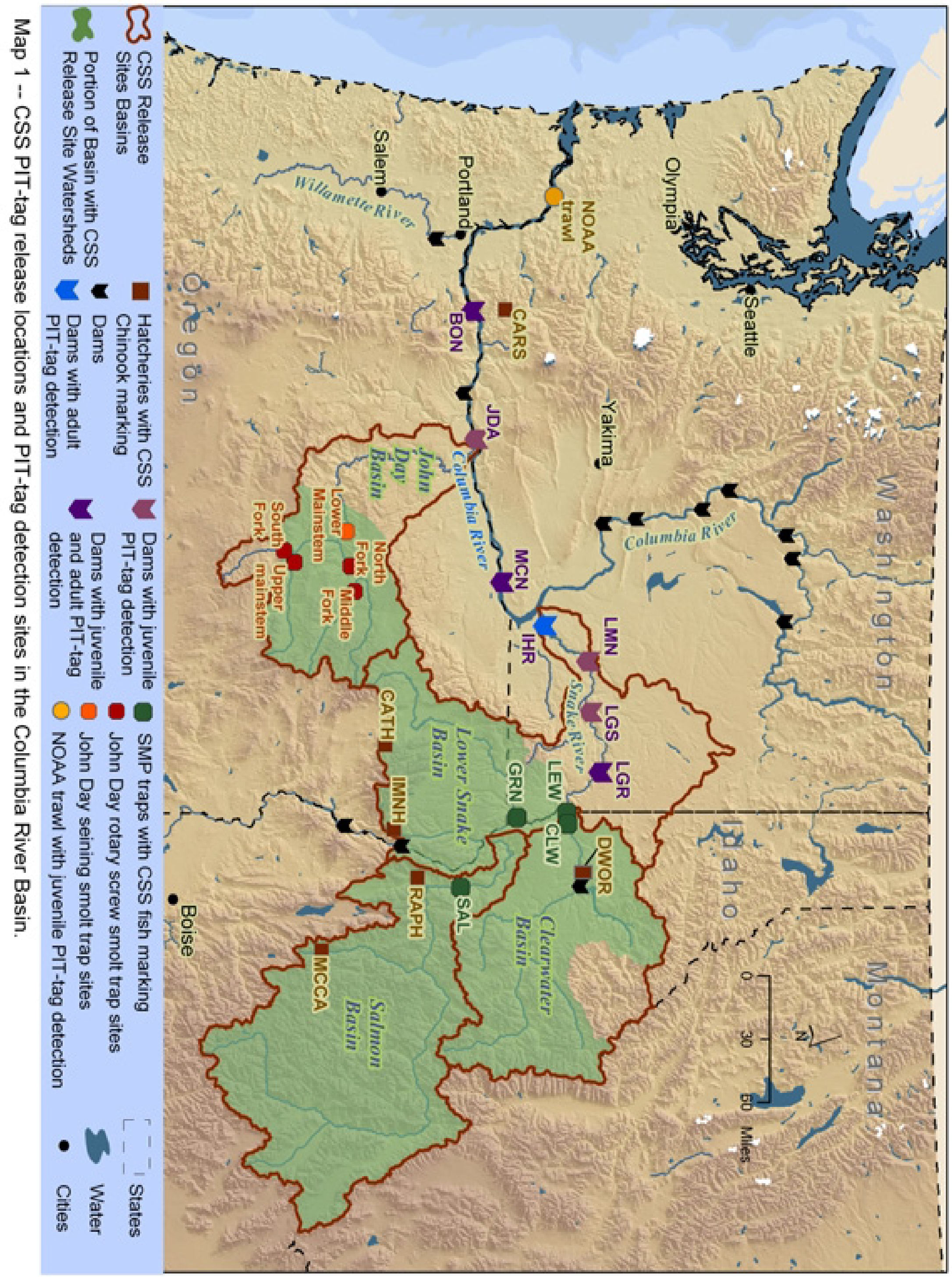

Figure 1.2. CSS PIT-tag release locations and PIT-tag detection sites in the Columbia River Basin.

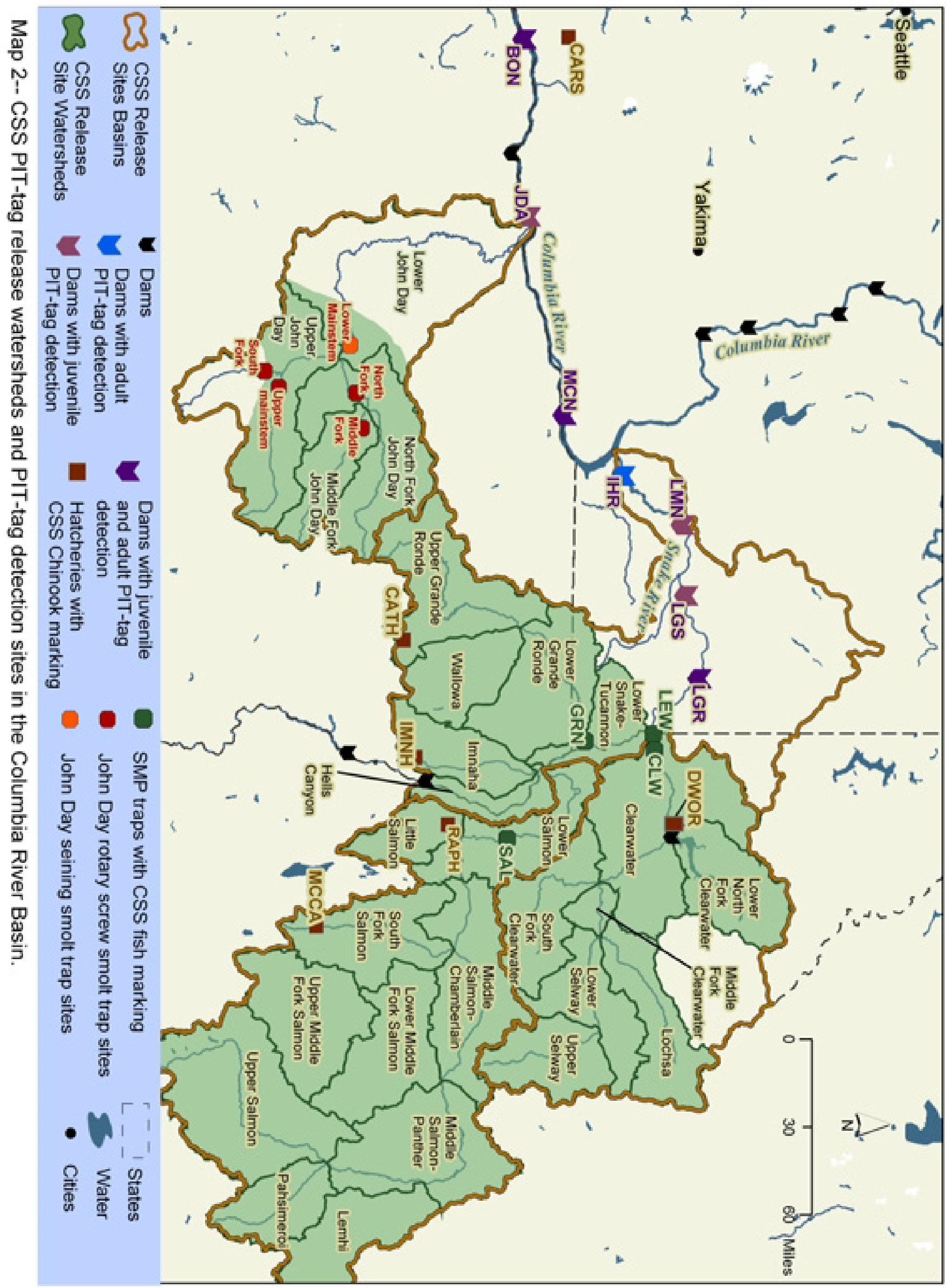

Figure 1.3. Detailed watershed map of CSS PIT-tag release locations in the Columbia River Basin; PIT-tag detection sites are also shown.

Throughout this report we organized groups of stocks primarily according to distinct population segment (DPS)/evolutionarily significant unit (ESU) boundaries (e.g., Snake River, Mid Columbia River, Upper Columbia River). However, we add the caveat that our presentations of Snake River 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 main stem during the 1950s and 1960s were all but closed by the mid 1970s. In 1992, the Snake River spring/summer Chinook salmon Evolutionarily Significant Unit (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 rate (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?" Therefore we measure $SARs_{(LGR\text{-}to\text{-}LGR)}$ against the regional management goal to maintain SARs between 2 and 6%, where 2% is a minimum requirement and an average of 4% is maintained over multiple generations (NPCC 2009). The secondary objective is to answer: "is the survival of transported fish (SAR) higher than the survival (SAR) of fish migrating in-river?" Combining these objectives, effectiveness of transportation is assessed by whether 1) the survival (SAR) of fish collected at Snake River dams and diverted into barges is higher than the SAR of fish that migrate through reservoirs and pass these dams via the spillways and turbines; and 2) the SAR meets the regional objective (2-6%) for the ESU.

The design and implementation of the CSS improved upon shortcomings of the methods that had previously been used to estimate and compare survival rates 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 fish 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 individual fish 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 main stem outmigrant traps upstream of the FCRPS (Figures 1.2 and 1.3). 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 and 1.3). With sufficient numbers of fish tagged, survival rates throughout the life-cycle can be compared across release groups, subbasins, ESUs, races (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 surviving to the tailrace of Lower Granite Dam and their subsequent survival through the hydrosystem.

Data generated in the Comparative Survival Study

The Comparative Survival Rate Study (CSS) is a management-oriented, large scale monitoring study of spring/summer Chinook and steelhead. 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 spring/summer Chinook and steelhead. 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 towards recovery goals. Monitoring survival rates 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 rates and evaluates the hypothesized mechanisms for variations in those rates.

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 LGR (Lower Granite), LGS (Little Goose), LMN (Lower Monumental), MCN (McNary), JDA (John Day), and BON (Bonneville) (Figures 1.2 and 1.3). Upon arrival at LGR, LGS and LMN, Snake River smolts can travel through three different routes of passage: over the spillway via typical spillway or removable spillway weir (RSW), or into the powerhouse and subsequently through the turbines, or diversion with screens and pipes into the collection and bypass facility. Those smolts that pass over the spillway or through the turbines are not detected, but the bypass facility does detect and record the fish identification number and the time and date detected. During transportation operations, smolts without PIT-tags that enter the collection facility are generally put in trucks or barges and transported to below BON. Prior to 2006, Snake River groups of PIT-tagged fish were assigned an “action code” that determined their route in the bypass facility (e.g., in-river or transport). Starting in 2006, researchers submitted groups of PIT-tagged fish Snake River fish that would then follow the same route as untagged fish or, if not submitted, would follow the default return to river route. Transportation at MCN begins in July after the completion of the spring outmigration and does not affect the Columbia River groups currently studied in the CSS (e.g., spring outmigrating steelhead and Chinook). There is not a transportation program at JDA, TDA (The Dalles), 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, MCN, and

IHR (Ice Harbor) in recent years allowing for additional analyses.

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, SARs from LGR to the adult detector at BON (BOA) are provided. 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, under 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 rate 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;
2. tagged fish collected at Snake River dams and returned to the river (C_1), or
3. tagged fish never 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 until May 1 from 2007 through 2009 and in 2011. During 2010, transportation began on April

25th. 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 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-assigns 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, the electronics at the dams were used to route fish during the out-migration either to raceways or back-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, and these tagged fish are routed in Monitor-Mode in order to go the same direction 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 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, on 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 work in this report, we use Group CRT to estimate CJS reach survival rates and detection probabilities. These CJS reach survival rate and collection probability parameter estimates are then used to generate key parameters for both the component groups T and R.

The transport category of fish passage can fall into two sub-categories. 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 6 for formula). 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 provides 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 rate estimates (through the hydrosystem) and assumed average direct transport survival rate from empirical studies.

To evaluate different aspects of the effectiveness of transportation relative to in-river migration, annual SAR ratios between T_0 (or T_X) and C_0 fish are compared, first from passage at LGR as smolts to their return as adults to LGR (TIR). This represents the direct effects of transportation versus in-river migration on survival in the freshwater migration corridor as well as the indirect effects (i.e., delayed effects) in the estuary, ocean, and during the adult escapement to LGR. The second comparison is with *D* which represents only the delayed differential survival effects in the estuary, ocean, and during the adult upstream migration between transported and in-river juvenile outmigrants.

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 as adults (LGR-to-GRA SAR); survival from smolt outbound arrival 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 rates and ratios is necessary to describe the precision of these estimates for statistical inference and to help monitor actions to mitigate effects of the hydrosystem. 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, we developed a nonparametric bootstrapping approach (Efron and Tibshirani 1993), where first the point estimates are calculated from the population, then the data are re-sampled with replacement to create 1,000 simulated populations. These 1,000 iterations are 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, non-parametric 80%, 90%, and 95% confidence intervals 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 were chosen for reporting in the recent CSS annual reports 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 in comparisons among study groups of fish for the various parameters of interest.

CSS PIT-tagging operations and sources of study fish

Wild and hatchery smolts are marked with glass-encapsulated, passively induced transponders that are 11-12 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 2011. The sample sizes for each group with tags provided by the CSS from 1994-2011 are presented in Appendix B at the end of this report. During 2010, tagging operations began in cooperation with the Washington Department of Fish and Wildlife 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. Beginning in 2009, the CSS is also contributing PIT-tags to additional LSRCP hatcheries including spring Chinook from Clearwater Hatchery in the Clearwater River basin and summer Chinook from Pahsimeroi Hatchery and spring Chinook from Sawtooth Hatchery in the Salmon River basin. The LSRCP hatchery program operations changed in 2011 by adding a PIT-tagged Clearwater River summer Chinook group. The new summer Chinook group will be analyzed separately from the Clearwater River spring Chinook group in future CSS reports.

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 2011. Hatchery steelhead from each tributary, plus PIT-tag releases in the mainstem Snake River at the Lewiston trap and below Hells Canon 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 Spring 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 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. In general, for Snake River wild Chinook, we found that limiting the tagging season to a 10-month period from ~ July 25 to ~ May 20 each 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. 2005; 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 all wild steelhead marked under coordinator Wayne Wilson of ODFW at sites within the John Day River north fork, south fork, middle fork, and mainstem. For these groups, we employed dates from July through June when marking took place (up to 11 months) and length constraints that increased from approximately 90 to 120 mm across this date range. For example, in migration year 2007 for John Day wild steelhead, we included marks from 10/01/2006 to 12/31/2006 over 100 mm and all marks from 01/01/2007 through 06/15/2007 over 110 mm.

Several new groups were added in this report. Chapter 4 includes overall SAR estimates for Warm Springs hatchery spring Chinook from the Deschutes River basin and Yakima River basin aggregates of wild Chinook and wild steelhead. Also included are a hatchery-wild steelhead aggregate, a hatchery-wild yearling Chinook aggregate, and a hatchery-wild subyearling Chinook aggregate all marked and released at Rock Island Dam as part of the SMP program. Finally, various estimates for new hatchery and wild subyearling fall Chinook groups are presented in Chapter 5.

Based on past estimates of SARs, sufficient numbers of smolts were tagged to ensure enough returning adults to compute statistically rigorous SAR estimates. Required samples sizes for SAR estimates are discussed in Appendix B of the CSS 2008 annual report. All attempts were made to ensure that the PIT-tagged fish are representative of their untagged cohorts. The origins of the wild Chinook, wild steelhead, and hatchery steelhead in the PIT-tag aggregates appear to be well spread across the drainages above LGR. At trapping sites, sampling and tagging occur over the entire migration season. At the hatcheries, fish were obtained across a wide set of ponds and raceways to most accurately represent production. Tag loss and mortality of PIT-tagged fish were monitored before release, and the tagging files were transferred to the regional PTAGIS database in Portland, OR. Until 2006, PIT-tagged fish in the C_1 and transport study groups were not routed at collector projects in the same proportions as untagged fish. Consequently, weighting factors were assigned to each study group to estimate an overall SAR that represented the untagged run-at-large population (Chapter 4). Beginning with migration year 2006, PIT-tagged fish were randomly pre-assigned to routes of passage so PIT-tagged fish would represent untagged fish, and assigning weighting factors would no longer be required to estimate an overall SAR for the run-at-large.

Coordination and pre-assignments during 2012

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 2012 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 Lower Snake River Compensation Plan. Specifically this includes Idaho Fish and Game, Oregon Department of Fish and Wildlife, and Washington Department of Fish and Wildlife (Table 1.1). Additionally, the CSS has collaborated with Idaho Power Company (IPC) and the U.S. Fish and Wildlife Service (USFWS).

Coordination and cooperation has 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 Washington Department of Fish and Wildlife; 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 this report. During 2011, Clearwater hatchery began marking and releasing summer Chinook into the Crooked River within the Snake River basin.

Fish to be utilized in the CSS from groups planned for other research studies during 2012 are shown in Table 1.3. Two of the Snake River groups are pre-assigned by the CSS through coordination with the marking agency – the CTUIR marking in Grande Ronde basin and the SBT marking in the Salmon River basin. 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 1.1. Snake River hatchery groups marked for the 2012 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	Total PIT-tags
Rapid River	Chinook		32,000	20,000				52,000
McCall	Chinook	20,000	32,000					52,000
Clearwater	Chinook	51,000	21,800					72,800
Pahsimeroi	Chinook		6,400	15,000				21,400
Sawtooth	Chinook	15,000	6,400					21,400
Magic Valley	Steelhead	24,600	11,900					36,500
Hagerman	Steelhead	19,000	8,100					27,100
Niagara Springs	Steelhead		28,300					28,300
Clearwater	Steelhead	16,800	7,000					23,800
Lookingglass (Imnaha AP)	Chinook		21,000					21,000
Lookingglass (Catherine AP)	Chinook		21,000					21,000
Irrigon (Grande Ronde, Imnaha)	Steelhead		14,000		31,400			45,400
Dworshak	Chinook		52,000					52,000
Dworshak	Steelhead		9,000			19,900		28,900
Lyon's Ferry (Cottonwood AP)	Steelhead		2,000				4,000	6,000
Grand Total		146,400	272,900	35,000	31,400	19,900	4,000	509,600

[1] Agencies 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), and Lower Snake River Compensation Plan (LSRCP)

Table 1.2. Wild fish marked for the 2012 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	Total PIT-tags
Clearwater/Salmon tributaries	Ch./St.		24,000	40,000		64,000
Snake & Salmon Traps	Ch./St.	23,400	7,000			30,400
Clearwater Trap	Ch./St.		5,200			5,200
Grande Ronde Trap	Ch.	9,000	1,400			10,400
Grande Ronde tributaries	Ch.		2,200		6,000	8,200
Chiwawa Trap, Lower Wenatchee Trap	Ch./St.		30,000			30,000
Grand Total		32,400	69,800	40,000	6,000	148,200

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

Table 1.3. Groups marked for the 2012 smolt outmigration that do not include PIT-tags provided by the CSS but are included in the study. The CSS does random pre-assignments for some groups. The location of marking/hatchery, species, primary marking agency and tag totals are shown for each.

		PIT-Tag Marking Agency[1]							
Location/Hatchery	Species	CTUIR	SBT	NPT	ODFW	COE	USFWS	YINN	SMP
Wild Groups									
Lookingglass Creek (Grande Ronde basin)	Ch./St.	3,500*							
East Fork Salmon, West Fork Yankee Rivers (Salmon basin)	Ch./St.		1,300*						
Imnaha Trap (Imnaha basin)	Ch./St.			15,000**					
John Day River	Ch./St.				~9,300				
Trout Creek (Deschutes basin)	St.				~1,300				
Yakima (Rosa Dam)	Ch.							~2,000	
Yakima (Satus, Toppenish, & Ahtanum Creeks)	St.							~1,300	
Hatchery Groups									
Snake River	Sock.					62,000***			
Carson	Ch.						30,000		
Cle Elum	Ch.							40,000	
Leavenworth	Ch.								15,000
Warm Springs	Ch.						15,000		
Hatchery + Wild									
RIS yearling	Ch.								~1,800
RIS subyearling	Ch.								~3,500
RIS	St.								~4,000
Grand Total		3,500	1,300	15,000	10600	62,000	45,000	43,300	24,300

* The CSS pre-assigns these groups through cooperative efforts with the primary marking agency

** Pre-assigned by NPT

*** Pre-assigned by COE

[1] Agencies are: Confederated Tribes of the Umatilla Indian Reservation (CTUIR), Shoshone-Bannock Tribes (SBT), Nez Perce Tribe (NPT), Oregon Department of Fish and Wildlife (ODFW), Corps of Engineers (COE), U.S. Fish and Wildlife Service (USFWS), Yakima Indian Nation (YINN), and Smolt Monitoring Program (SMP). Ch = wild Chinook and St = wild steelhead, 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.

Snake River hatchery sockeye and fall Chinook

Included in this year's report is a continuation of the adult metrics for the Snake River hatchery sockeye marked during 2009, 2010, and 2011 at Sawtooth and Oxbow hatcheries (Chapter 4 and Appendix A). The 2009 out-migration was the first year with a large enough sample size that would likely meet the requirements of the analytical frameworks applied in the CSS (for sample size discussion see Appendix B of the 2008 CSS report). This was in response to a request by the Shoshone-Bannock Tribe to include sockeye in the CSS (Appendix D, CSS 2009 Annual Report) and should meet regional

RME needs in regards to Snake River hatchery sockeye. If these groups continue to be marked the CSS should be able to provide a consistent time series of smolt to adult return data and other demographic data towards the research, management and evaluation of these stocks.

Also included in Chapter 5 of this year's report is an expansion of the analyses for Snake River fall Chinook groups that were included in the CSS 2011 Annual Report (Chapter 8 of the CSS 2011 Annual Report). These analyses were conducted in response to a request from Oregon Department of Fish and Wildlife to include analyses of fall Chinook in the CSS reports (Appendix F, CSS 2010 Annual Report).

Historic in-river conditions and transportation

The environmental conditions experienced by out-migrating juvenile yearling Chinook and steelhead have varied considerably over the 18-year historical context of the CSS (Figure 1.4). 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. During 2007 for the first occasion in the time-series, low flows were accompanied by high spring spill percentages and low transportation percentages; 2010 was similar in this regard. In contrast, 2008, 2009, and 2011 had relatively high flows accompanied with high spill.

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, May 1 in 2007-2009 and 2011, and April 25 in 2010. These years included a similar but lagged start date at LGS and LMN. The delayed start date was combined with an increased spill percentage from 2004 and 2005, and resulted in a lower proportion of wild smolts being transported. Smolt out-migration timing also would affect transportation percentage and these results vary by stock (see Chapter 2 for details on timing). The highest transport percentages of CSS PIT-tagged wild smolts occurred in 2001, 2004, and 2005. Conversely, 2007 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 in 2007 than other low flow years. The 2008 through 2011 migration years were very similar for wild smolts and about 40 percent of the PIT-tagged Snake River wild stocks were transported.

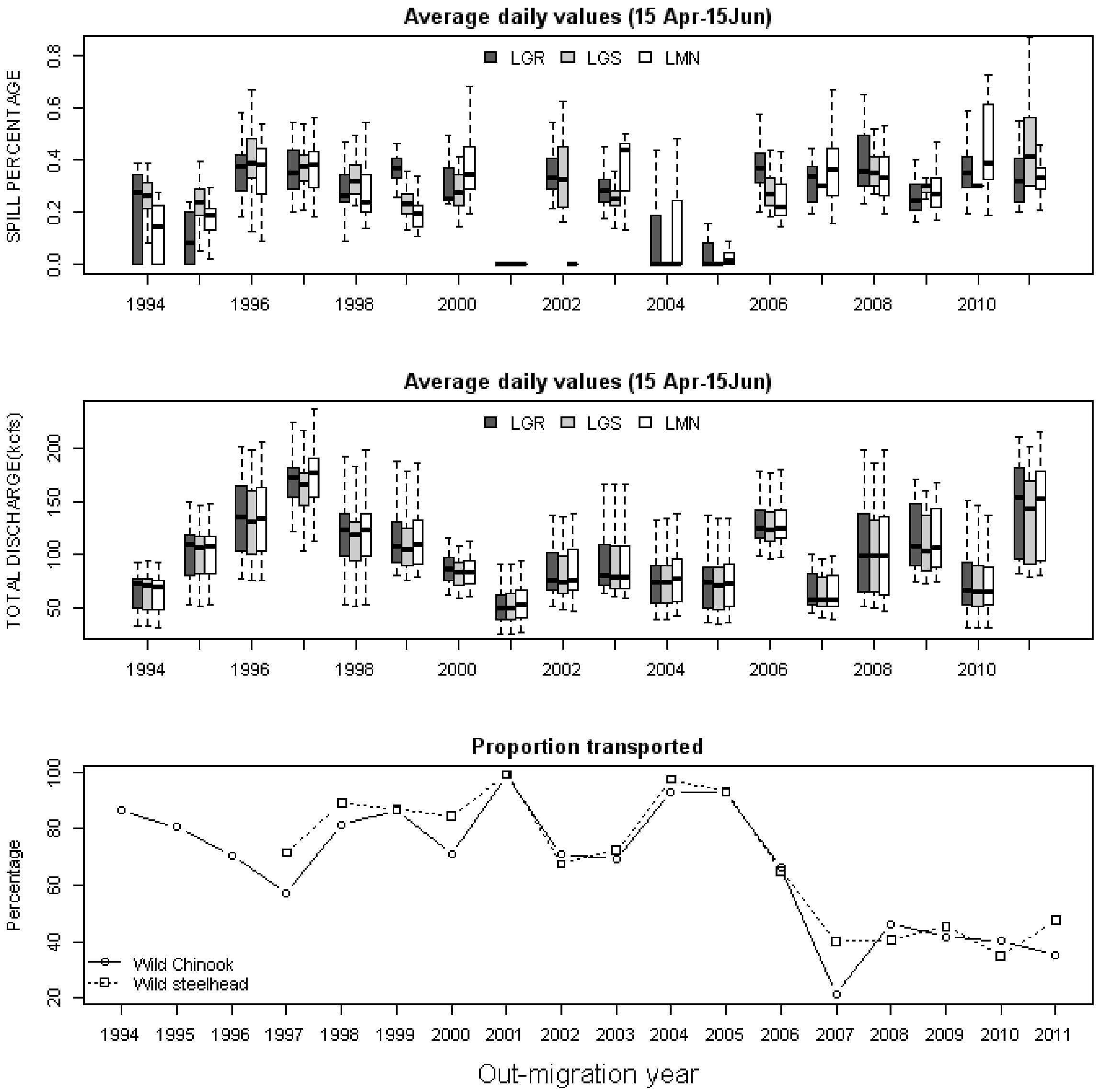

Figure 1.4. The top, middle, and bottom panels are summaries of spill percentage, flow, and the proportion transported over the historical context of the CSS at Lower Granite (LGR), Little Goose (LGS), and Lower Monumental (LMN) dams. The top two panels are boxplot summaries of average daily spill percentages 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 Table C.1 2010 CSS annual report). The proportion transported for migration year 2011 was estimated for this report.

Report Organization

This report has six chapters, including this introduction, followed by eight 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 analyses that characterize how detection probability varies with environmental conditions for yearling hatchery Chinook and combined hatchery and wild steelhead juveniles from the Snake River, passing McNary Dam. In addition, this chapter presents analyses of PIT-tag data to estimate fish guidance efficiency, which is then used to predict route-of-passage proportions. These predicted route-of-passage proportions are then compared to estimates derived from radio tag data.

Chapter 3 updates multiple regression models of fish travel time, instantaneous mortality rates and survival rates for Snake River wild and hatchery spring/summer Chinook and steelhead. The chapter similarly provides analyses on Snake River hatchery fall Chinook, Snake River hatchery and wild sockeye, and upper Columbia hatchery and wild spring Chinook and steelhead.

Chapter 4 presents time series of overall SARs for Snake River, mid-Columbia River and upper Columbia River hatchery and wild spring/summer Chinook and steelhead relative to NPCC 2-6% SAR objectives. The overall SARs for Snake River hatchery sockeye are presented for 2009-2010. Snake River wild spring/summer Chinook SARs based on PIT-tags and run reconstruction are compared, and potential causes of bias in both methods are considered.

Chapter 5 presents SARs by route of passage and TIRs for Snake River fall Chinook from migration years 2006 to 2009. 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.

Chapter 6 updates age at maturity datasets and analyses of patterns of variation in age at maturity for hatchery and wild Chinook. Age at maturity for hatchery sockeye is also presented.

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

Appendix B updates describes sources of PIT tagged fish in the study.

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

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

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

Appendix F summarizes the 2012 CSS annual meeting held on April 12, 2012 at the Embassy Suites in Portland, OR.

Appendix G includes the CSS Oversight Committee responses to comments on the draft 2012 CSS report.

Appendix H updates analyses of adult passage success rates by migration and return year and between transported and in-river out-migrants for Snake River spring/summer Chinook and steelhead. Some of these data were presented in Chapter 5 of the 2011 CSS Report.

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Chapter 2

Using PIT-tag detection probabilities to estimate route-of-passage proportions at hydropower dams

Introduction

The Cormack-Jolly-Seber (CJS) mark-recapture model is commonly used within the FCRPS to estimate survival rates for juvenile salmon and steelhead. The model uses multiple detections of individual marked fish at mainstem dams with PIT-tag detection capabilities to separate the confounding that occurs between the survival process and the recapture/detection process. Typically, the estimated survival rates are the focus for monitoring and evaluation purposes. However, the estimated detection probabilities also contain useful information for monitoring and evaluation purposes.

The juvenile PIT-tag detection systems are integrated within the smolt collection and bypass systems at the FCRPS dams. Because of this, juvenile PIT-tagged fish can only be detected if they enter the smolt collection system, which effectively has 100% efficiency for detecting PIT-tagged individuals that enter the system. Within the CJS estimation framework, the estimated detection probability represents the proportion of individuals within the population estimated to be alive and that are captured and detected. Because the CJS detection probabilities are representing the proportion of living individuals that are recaptured/detected, and the detection systems are only located within the smolt collection systems, the CJS detection probabilities are reflecting the proportion of the living individuals that enters the smolt collection system at each dam. Those living individuals that are not detected therefore pass through either spillways or turbine routes, which do not have PIT-tag detection capability.

Determining route-of-passage proportions is important for several reasons. First, the turbine passage route has consistently been shown to have low direct survival rates (Muir et al. 2001), and therefore minimizing the proportion of fish passing through turbines should improve overall survival rates for fish passing dams. Second, several research studies have found that juvenile fish that enter the smolt collection system and are bypassed have reduced survival at later life stages (Tuomikoski et al. 2010, Buchanan et al. 2011, McMichael et al. 2010). Based on these studies, minimizing the proportion of fish entering smolt collection systems may help increase survival at later life stages. Consistent with these findings on increased immediate or delayed mortality for fish that enter turbines or smolt collection/bypass systems (i.e., the powerhouse), Petrosky and Schaller (2010) found that the estimated number of powerhouse passages experienced by outmigrating smolts was an important factor explaining variability in ocean survival rates and overall smolt-to-adult survival rates for Snake River yearling Chinook salmon and steelhead. Similarly, Haeseker et al. (2012) found that average spill percentage, which serves as an index of the proportion of the population that passes through spillways, was an important factor for explaining variability in freshwater, ocean, and overall smolt-to-adult survival rates for Snake River yearling Chinook salmon and steelhead. Given these findings, improved methods for estimating route-of-passage proportions and the effects of spill and flow on those proportions could improve understanding on the effects of operational decisions on immediate and delayed survival rates of juvenile salmon and steelhead.

In this analysis we use available PIT-tag detection probability data, combined with information on environmental factors (seasonality, flow, percent spill, and spillway surface passage structures), to first characterize how detection probability varies with environmental conditions. Second, we use PIT-tag data to estimate fish guidance efficiency (FGE) and we subsequently use the FGE estimates to predict route-of-passage proportions. Third, we compare predicted route-of-passage proportions derived from PIT-tag data with those estimated from radio tag data. We use McNary Dam as a case study to illustrate the methodology and to evaluate its performance.

Methods

Because of the availability of comparable radio telemetry estimates (see below) this analysis focused on hatchery yearling Chinook and the combined hatchery and wild steelhead. Using the same weekly cohorts used to estimate survival and fish travel time for the LGR-MCN reach (see Chapter 3), we estimated the CJS detection probability at the McNary (MCN) Dam detection site. For each release cohort, environmental conditions at MCN were averaged over a seven day window centered on the median arrival date at MCN. Environmental conditions consisted of Julian day of release at Lower Granite Dam, flow volume, spill volume, spill proportion, water transit time, and forebay elevation. In addition, we developed an indicator variable representing whether the temporary spillway weir was in place or not.

We used linear regression to develop models for characterizing associations between the environmental conditions and the CJS detection probabilities. We used a logit transformation of the detection probabilities to reduce heteroscedasticity, approximate normality of the residuals, and constrain predicted probabilities between zero and one. Due to differences in the precision of the estimated detection probabilities, we use inverse-coefficient of variation weighting in fitting the models. We used Akaike's information criterion adjusted for small sample sizes (AICc) to evaluate model fit, selecting the model with the lowest AICc. The best fitting model was used to generate estimates of predicted detection probabilities.

In years when spill did not occur at MCN, it was not possible for fish to pass through the spillway passage route. Therefore, the CJS detection probability estimates reflect the proportion of the living fish passing the powerhouse that were detected in the smolt collection system, which is a common metric known as fish guidance efficiency (FGE). Those living fish that were not detected in the smolt collection system passed MCN through the turbines. For both yearling Chinook and steelhead, there were multiple cohorts with estimated detection probabilities that occurred under zero spill. We used the average of these detection probabilities as the PIT-tag based estimate for FGE. We assume that FGE remains relatively constant across flow and spill conditions. In support of this assumption, Moursund et al. (2006) found that FGE at McNary dam did not vary across spill levels ranging from 0% to 80%.

To estimate the total powerhouse passage, we divided the predicted detection probabilities (i.e., the predicted smolt collection proportions, $\hat{p}$) by the PIT-tag based estimate for FGE ($F\hat{G}E_{PIT}$):

$$Powerhouse = \frac{\hat{p}}{F\hat{G}E_{PIT}} \ . \qquad [2.1]$$

Spillway passage was estimated as:

$$Spillway = 1 - Powerhouse \ . \qquad [2.2]$$

Turbine passage was estimated as:

$$Turbine = Powerhouse - \hat{p} \ . \qquad [2.3]$$

Perry et al. (2006, 2007) conducted radio telemetry studies at MCN in 2004 and 2005 using hatchery yearling Chinook and steelhead. These studies provided route-of-passage estimates that were used to compare with the PIT-tag based estimates derived using the logit regression model predictions, $F\hat{G}E_{PIT}$, and equations 2.1-2.3. To evaluate bias and accuracy of our methodology, we calculated the mean raw error and mean absolute error between the radio telemetry and PIT-tag based estimates for spillway, turbine, bypass, and powerhouse passage proportions.

Results

The models for both species captured a high degree of the intra- and inter-annual variability in detection probabilities (Figure 2.1). For hatchery yearling Chinook, the model accounted for 79% of the variability in the CJS detection probability estimates. For hatchery and wild steelhead, the model accounted for 73% of the variability in the CJS detection probability estimates. The largest errors between the CJS detection probabilities and the model-based detection probabilities occurred when there was low precision in the CJS estimates. The best fitting models (based on AICc) for both yearling Chinook and steelhead showed that detection probability (i.e., collection probability) declined with increasing spill levels, increased with increasing flow levels, and declined over the season.

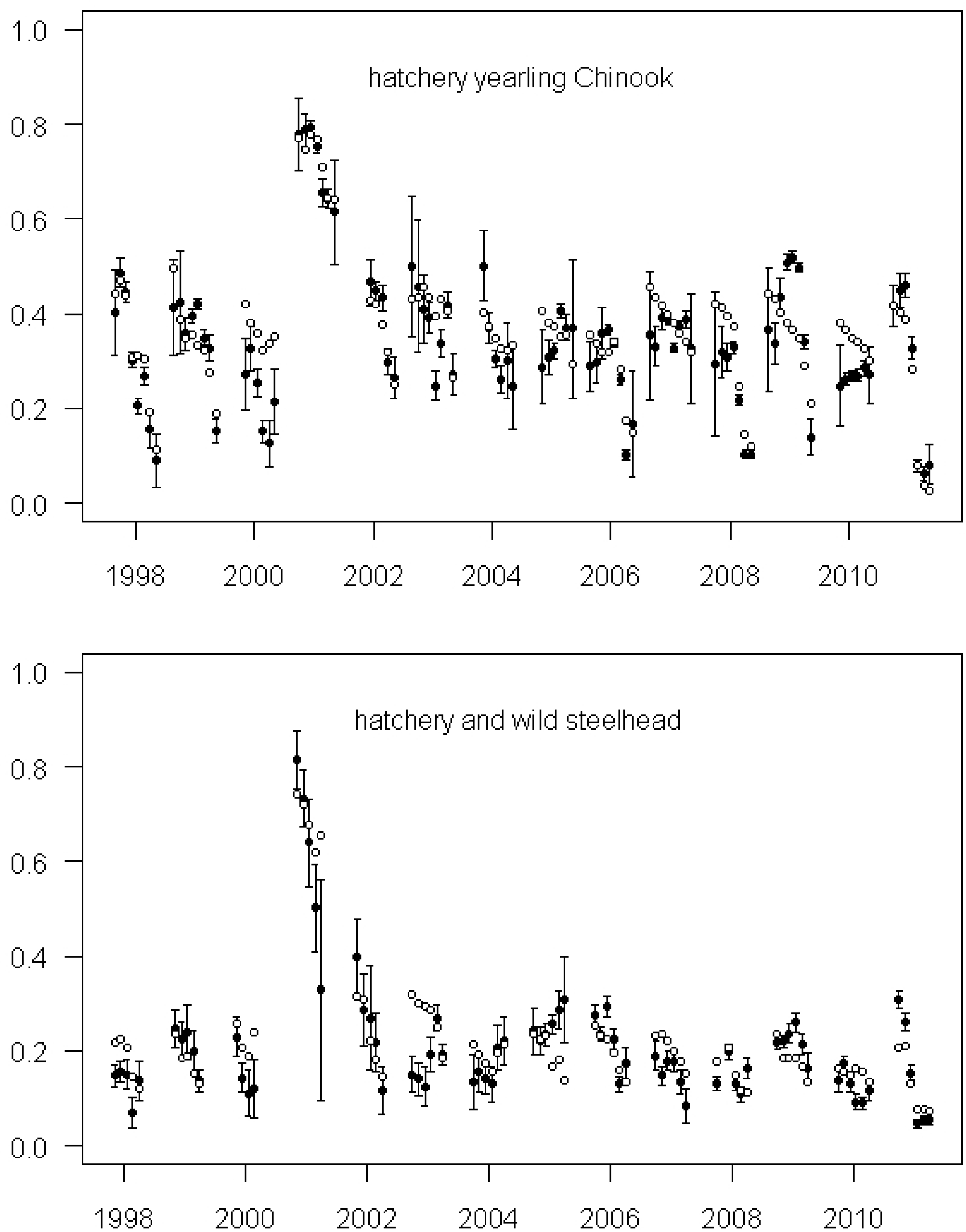

Figure 2.1 CJS detection probabilities (black circles) and predicted detection probabilities (open circles) for hatchery yearling Chinook salmon (top panel) and combined hatchery and wild steelhead (bottom panel) across release cohorts 1998-2011. Error bars represent 95% confidence intervals on the detection probabilities.

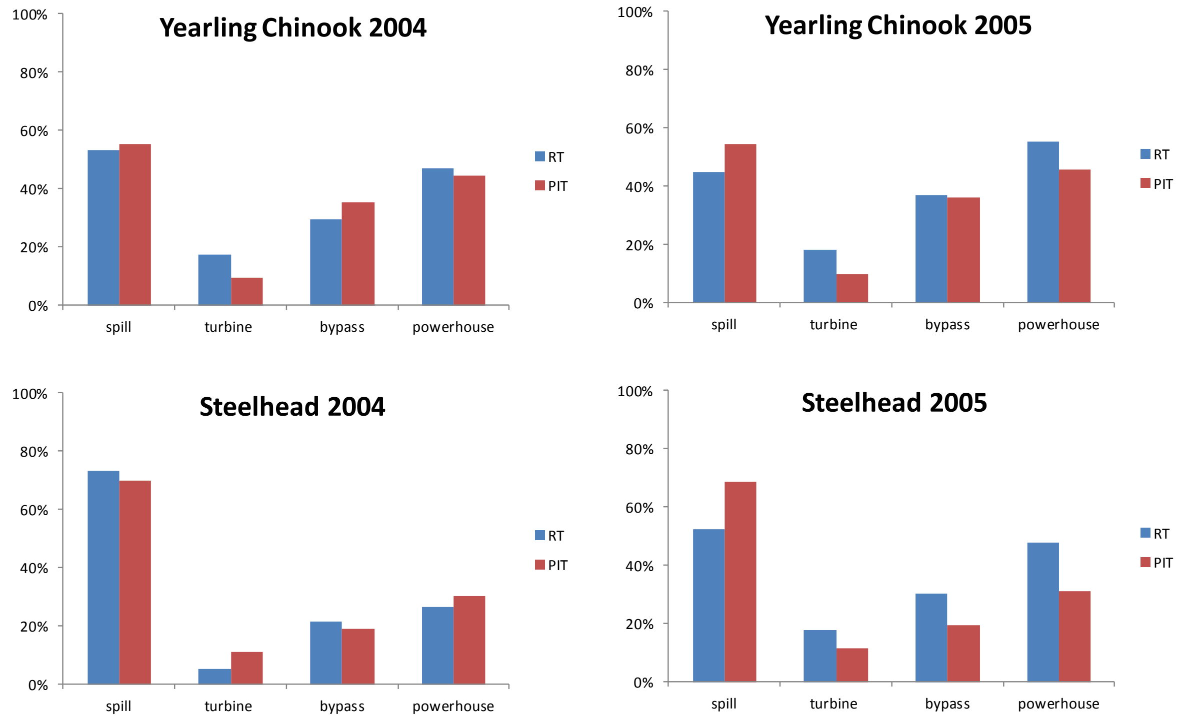

Figure 2.2 Radio-tag and PIT-tag based estimates of the proportion of yearling Chinook and steelhead passing through spillway, turbine, bypass and powerhouse passage routes during 2004 and 2005.

Under conditions of no spill, the average of the PIT-tag based detection probabilities (FGE) was 0.78 for hatchery yearling Chinook and 0.63 for hatchery and wild steelhead (Tables 2.1 and 2.2). Using these estimates for FGE, the model-based predictions for detection probabilities, and Equations 2.1-2.3, we calculated the route-of-passage proportions for comparison with the radio-tag based estimates in 2004 and 2005 (Figure 2.2). The estimates had negligible bias, with a mean raw error of -2%. In terms of the accuracy, the mean absolute error was 7%, indicating that on average, the route-of-passage proportions were within 7% of each other.

Table 2.1 Detection probabilities used to calculate average FGE with their associated standard errors for cohorts of hatchery and wild steelhead, along with the flow (kcfs) and percent spill at McNary Dam during 2001.

Species	Year	Release	Flow	Spill %	Detection Probability	SE
STH	2001	2	130.6	0%	0.82	0.03
STH	2001	3	136.8	1%	0.73	0.03
STH	2001	6	125.8	1%	0.33	0.12
				Average:	0.63	

Table 2.2 Detection probabilities used to calculate average FGE with their associated standard errors for cohorts of hatchery yearling Chinook salmon, along with the flow (kcfs) and percent spill at McNary Dam during 2001.

Species	Year	Release	Flow	Spill %	Detection Probability	SE
CHN	2001	2	120.3	0%	0.78	0.04
CHN	2001	3	117.5	0%	0.79	0.02
CHN	2001	4	130.6	0%	0.79	0.01
CHN	2001	5	136.8	1%	0.75	0.01
				Average:	0.78	

Discussion

In this chapter we have developed a promising methodology for estimating route-of-passage proportions using only derived from PIT-tags. The regression models were capable of accounting for the majority of the variability in the CJS detection probabilities and provided useful insights into the effects of operations such as flow and spill on the proportion of fish that enter the smolt collection system. As expected, the proportion entering the smolt collection system declined as spill proportions increased. However, at a given spill proportion, the model also estimated that the proportion entering the smolt collection system increased with flow. These types of insights have not previously been identified nor have they been quantified to the degree that they have here.

Using the methodology described in this chapter, we were able to estimate the route-of-passage proportions with little apparent bias and a 7% average level of accuracy. Some of the differences between the radio-tag estimates and the PIT-tag estimates may be due to differences in study timing or arrival at MCN between the two tagged populations, differences in hatchery versus wild rearing type, or differences in smolt size or condition between the two studies. However, we believe that this methodology holds promise for improving understanding of the effects of project operations on route-of-passage proportions. The same methodology can be applied at any dam that has PIT-tag detection capability in the smolt collection system (7 of 8 dams for Snake River migrants). The accuracy can be compared to telemetry estimates in any year that a telemetry study was conducted. In cases where there are no PIT-tag estimates of detection probability under zero spill conditions, an alternative approach would be to use telemetry or hydroacoustic estimates of FGE for use in equation 2.1.

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 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 multi-model inference techniques (Burnham and Anderson 2002) to update the multiple regression models of fish travel time, instantaneous mortality rates and survival rates from Chapter 3 of the 2011 Annual Report (Tuomikoski et al. 2011). 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 and subyearling 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 rates, 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. 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: 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 rates 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).

Multiple regression modeling

The goal of the multiple regression models is to evaluate finer-scale analyses of the relationships between survival and specific operational actions or environmental features during the juvenile outmigration. Towards this goal, we calculated and summarized within-year (weekly or multi-weekly) travel time, instantaneous mortality and survival rate estimates for juvenile yearling Chinook, subyearling Chinook, and steelhead across years of the CSS. We also calculated and summarized seasonal estimates of travel time, instantaneous mortality rates and survival rates 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 Lower Granite Dam (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 production fish tagged at the 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 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 fish travel time as the number of days between release at LGR until detection at MCN for each fish subsequently detected at MCN. For statistical reasons (described below), we calculated the mean FTT_i for each weekly release cohort instead of the median FTT that was presented in previous reports (Schaller et al. 2007, Tuomikoski et al. 2009). 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 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 seasonal estimates of LGR-MCN *FTT* and RIS-MCN *FTT* for sockeye. For yearling Chinook and steelhead in the RIS-MCN reach, three, two-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, two-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.

Survival

We estimated the survival rates 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 1998-2011. We also estimated seasonal survival rates for sockeye in the LGR-MCN reach over 1998-2011. Due to lower numbers of PIT-tagged fish detected and released at MCN, we developed survival estimates for three, two-week cohorts for yearling Chinook and two, three-week cohorts for steelhead in the MCN-BON reach over migration years 1999-2011. For hatchery subyearling Chinook in the LGR-MCN reach we developed survival estimates for four, two-week release cohorts over migration years 1998-2011. In the RIS-MCN reach, we developed survival estimates for three, two-week release cohorts of yearling Chinook and steelhead. We calculated Chi-square adjusted variances (using the $\hat{c}$ variance inflation factor) for each survival rate estimate ($\hat{S}$) (Burnham et al. 1987:244-246). Using this delineation for the cohorts, the average coefficient of variation (CV) across the survival rate estimates (Table 3.1) was lowest for hatchery and wild yearling Chinook salmon in the LGR-MCN reach (7%) and was highest for hatchery and wild sockeye salmon in the RIS-MCN reach (43%).

Table 3.1. Number of survival cohorts and average coefficient of variation (CV) of survival across release cohorts by reach, species and rearing type.

Reach	Species	Rearing type	Cohorts	Survival CV
LGR-MCN	steelhead	hatchery and wild	78	0.12
LGR-MCN	yearling Chinook	wild	95	0.07
LGR-MCN	yearling Chinook	hatchery	91	0.07
LGR-MCN	sockeye	hatchery and wild	13	0.20
LGR-MCN	subyearling Chinook	hatchery	43	0.14
RIS-MCN	steelhead	hatchery and wild	38	0.18
RIS-MCN	yearling Chinook	hatchery and wild	31	0.20
RIS-MCN	sockeye	hatchery and wild	13	0.43
MCN-BON	steelhead	hatchery and wild	22	0.25
MCN-BON	yearling Chinook	hatchery and wild	32	0.13

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 2003-1). Consistent with that suggestion, we developed an approach for estimating instantaneous mortality rates for juvenile salmonids (Schaller et al. 2007, Tuomikoski et al. 2009). 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 rate, 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}. Eqn. 3.1 is the solution to the differential equation

$$\frac{\partial N}{\partial t} = -ZN \qquad [3.2]$$

and the instantaneous mortality rate Z is interpreted as the rate of exponential population decline. Eqn. 3.1 has been called the “first principle” or “first law” of population dynamics (Turchin 2003), and serves as a foundational basis for most fisheries population assessment models (Quinn and Deriso 1999).

The exponential law of population decline provides a useful framework for understanding the interrelationships between instantaneous mortality rates, time, and survival. Over a fixed period of time, an increase in Z will result in lower survival over that time period. Similarly, for a fixed Z, survival will decrease with increasing time. At time $t = 0$, survival is 1.0 and survival declines toward zero as t increases. 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, Z can be estimated as

$$\hat{Z} = \frac{-\log_e(\hat{S})}{t}. \qquad [3.3]$$

In our application, we calculated instantaneous mortality rates (in units of d^{-1}) for each survival cohort using Eqn. 3.3. We used the CJS estimates of survival for each cohort ($\hat{S}_i$) in the numerator and used the mean $F\hat{T}T_i$ in the denominator of Eqn. 3.3. In previous reports (Schaller et al. 2007, Tuomikoski et al. 2009) we used median $F\hat{T}T_i$ in the denominator of Eqn. 3.3. However, simulation analyses indicated that using mean $F\hat{T}T_i$ in the denominator of Eqn. 3.3 provides more accurate estimates of the underlying instantaneous mortality rate than using median $F\hat{T}T_i$ (Steven Haeseker, USFWS, unpublished data). 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. 3.3 to characterize the cohort-level central tendency in the amount of time required to travel a reach. Combining the cohort-level survival rate 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. 3.3.

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):

$$\mathrm{var}(\hat{Z}_i) = \mathrm{var}\left(\frac{-\log(S)}{FTT}\right) \cong \left(\frac{-\log(S)}{FTT}\right)^2 \left(\frac{\mathrm{var}[-\log(S)]}{-\log(S)^2} + \frac{\mathrm{var}[FTT]}{FTT^2} - \frac{2cor(-\log(S), FTT)\cdot\sqrt{\mathrm{var}[-\log(S)]\cdot\mathrm{var}[FTT]}}{-\log(S)\cdot FTT}\right), \qquad [3.4]$$

To estimate the variance of –log(S), we used the approximation provided by Blumenfeld (2001) for log-normally distributed random variables:

$$\mathrm{var}[-\log_e(S)] = \log_e(1 + [CV(S)]^2) \qquad [3.5]$$

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 group between dams was estimated, and we calculated the average spill percentage, temperature (based on tailwater total dissolved gas monitoring data, downloaded from the COE website (http://www.ndwc.usace.army.mil/perl/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 seven-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. 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 spillway surface passage structures (e.g., removable spillway weirs [RSWs] or temporary spillway weirs [TSWs]) in place over the years of observation.

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. 2011) as being associated with *FTT* and/or *Z*: Julian day of release, spill, water transit time, temperature, spillway surface passage structures, percent hatchery composition, and an interaction between Julian day of release and water transit time. 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 (AICc) for each combination of the predictor variables. In cases where all seven variables were applicable, there were 128 possible model combinations of the predictor variables. In cases where some of the variables were not applicable (e.g., Julian day for sockeye or percent hatchery for wild Chinook), there were fewer possible model combinations of the variables. As mentioned above, Box-Cox power transformations indicated that a log-transformation was most appropriate for the *FTT* data. Therefore we modeled log(*FTT*) as the dependent variable in all analyses. The $\log_e$ transformations were also implemented to help reduce heteroscedasticity and improve linearity. These regressions were of the form:

$$\log(F\hat{T}T_i) = \beta_0 + \beta_1 \cdot X_{1,i} + \beta_2 \cdot X_{2,i} + ... + \varepsilon_i\,, \qquad [3.6]$$

where β_0, β_1,..., β_n are estimated parameters used to describe the relationship between environmental variables X_1, X_2, ..., X_n and log(*FTT*), and $\varepsilon_i \sim N(0, \sigma^2)$. 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. Depending on the species-reach being evaluated, the Box-Cox analyses typically indicated that either a log transformation or a square-root transformation was most appropriate. These regressions were of the form:

$$\hat{Z}_i = \beta_0 + \beta_1 \cdot X_{1,i} + \beta_2 \cdot X_{2,i} + ... + \varepsilon_i\,, \qquad [3.7]$$

where β_0, β_1,..., β_n are estimated parameters used to describe the relationship between environmental variables X_1, X_2, ..., X_n and *Z*, and $\varepsilon_i \sim N(0, \sigma^2)$. 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 AICc, the model with the minimum AICc was identified, and Akaike weights (wi) were calculated for each model (Burnham and Anderson 2002). Using the AICc-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:

$$\hat{\bar{\theta}} = \sum_{i=1}^{R} w_i \hat{\theta}\,, \qquad [3.8]$$

where $\hat{\bar{\theta}}$ 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).

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 AICc, relative to the other variables that were considered. The relative variable importance for variable *j* among a set of *R* models is calculated as

$$\sum_{i=1}^{R} w_i I_j(g_i)\,, \qquad [3.9]$$

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 rates 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 predictions for Z^*_i and FTT^*_i *(Eqns. 3.6 and 3.*7), predicted survival rates were calculated as:

$$S^*_i = e^{-Z^*_i \cdot FTT^*_i}, \qquad [3.8]$$

where Z^*_i is the predicted instantaneous mortality rate, FTT^*_i is the predicted mean FTT_i, and S^*_i is the predicted survival rate for period *i*, calculated by exponentiating the negative product of Z^*_i and FTT^*_i.

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 3.1, 3.2, and 3.3. In the LGR-MCN reach, mean $F\hat{T}T_i$, $\hat{Z}_i$ and $\hat{S}_i$ varied considerably over the period of 1998-2011, both within- and across-years. While there were some special cases, mean $F\hat{T}T_i$ generally decreased over the season, $\hat{S}_i$ either increased or 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 1998-2011 timeframe.

In the MCN-BON reach, cohorts of yearling Chinook and steelhead demonstrated withinyear 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 3.1, 3.2, and 3.3). 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 3.4 and 3.6). 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 $\hat{S}_i$.

For hatchery subyearling fall Chinook salmon in the LGR-MCN reach, there was a dramatic reduction in FTT following the implementation of court-ordered spill in the summer of 2005 (Figure 3.1). Excluding the 2001 drought year, the geometric mean FTT across release groups during 1998-2004 was 21.3 days, while the geometric mean FTT across release groups during 2005-2011 (the years of court-ordered summer spill) was 10.7 days (Table 3.2). Survival also increased dramatically following the implementation of summer spill (Figure 3.3), with the geometric mean survival increasing from 0.54 to 0.70 (Table 3.2). These dramatic changes in FTT and survival are most likely attributable to the changes in spill levels at Little Goose and Lower Monumental dams (Figure 3.6). During the 1998-

2004 period, subyearling fall Chinook salmon experienced spill levels that averaged 7% at Little Goose Dam and 4% at Lower Monumental Dam, while during the 2005-2011 period spill levels increased to approximately 30% at both dams. Telemetry studies have shown that subyearling fall Chinook salmon can experience substantial forebay delay when spill is not provided. During periods of zero spill in 1995-1997, Venditti et al. (2000) found that 51% of the subyearling fall Chinook salmon detected in the forebay of Little Goose Dam made upstream excursions and 10-20% had forebay residence times greater than seven days. Although spill levels have dramatically increased at Little Goose and Lower Monumental Dams, likely reducing forebay delays, there has been an overall reduction in spill at Ice Harbor, with average spill being reduced from 75% during 1998-2004 (excluding the 2001 drought year and a spill test conducted in 2003) to 55% during 2005-2011. The data indicate that the observed improvements in FTT and survival in the LGR-MCN reach would likely have been even greater if spill levels had not been reduced at Ice Harbor during 2005-2011.

Based on the relative variable importance values, the best fitting models for *FTT* consistently had model forms with Julian day, water transit time and spill (Figure 3.4). 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. 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 the LGR-MCN reach and steelhead and yearling Chinook in the MCN-BON reach, we observed an effect of the number of spillway surface passage structures in place on *FTT*, with the increasing number of surface passage structures at Little Goose, Lower Monumental, Ice Harbor and John Day dams reducing *FTTs*. Hatchery subyearling Chinook also demonstrated a reduction in *FTT* associated with the presence of surface passage structures in combination with high spill levels. We identified an effect of the percentage of hatchery steelhead in the LGR-MCN reach, with hatchery steelhead taking two days longer on average to migrate through the LGR-MCN reach than wild steelhead. Steelhead, sockeye and yearling Chinook in the RIS-MCN reach all had faster *FTT* when WTT was reduced. The model-averaged predictions that were developed captured a very high degree of the variation in mean *FTT* of all species and reaches (Table 3.3).

Based on the relative variable importance values, the best fitting models for *Z* also had model forms primarily with Julian day, water transit time and spill (Figure 3.5). The coefficient signs indicated that mortality rates increased over the migration season, and were higher when WTT was long or spill levels were low. For sockeye, steelhead, and wild yearling Chinook in the LGR-MCN reach, the number of dams with spillway surface passage structures appears to have reduced instantaneous mortality rates. Increases in water temperature were associated with increases in Z for sockeye in the LGR-MCN and RIS-MCN reaches, as well as steelhead in the MCN-BON reach. There was little indication that mortality rates varied with the percent hatchery composition. The interaction between Julian day of release and WTT was important for steelhead and wild yearling Chinook in the LGR-MCN reach. The model-averaged predictions that were developed 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 rates for the species-reach combinations that we examined (Table 3.3). 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, 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 rates of yearling and subyearling Chinook, steelhead and sockeye.

Table 3.2. Geometric mean fish travel time (FTT) and survival between Lower Granite Dam and McNary Dam across release groups of hatchery subyearling fall Chinook salmon before (1998-2004, excluding 2001) and after (2005-2011) the implementation of court-ordered summer spill at the Snake River collector dams (LGR, LGS and LMN).

Period	FTT	Survival
1998-2004	21.3	0.54
2005-2011	10.7	0.70

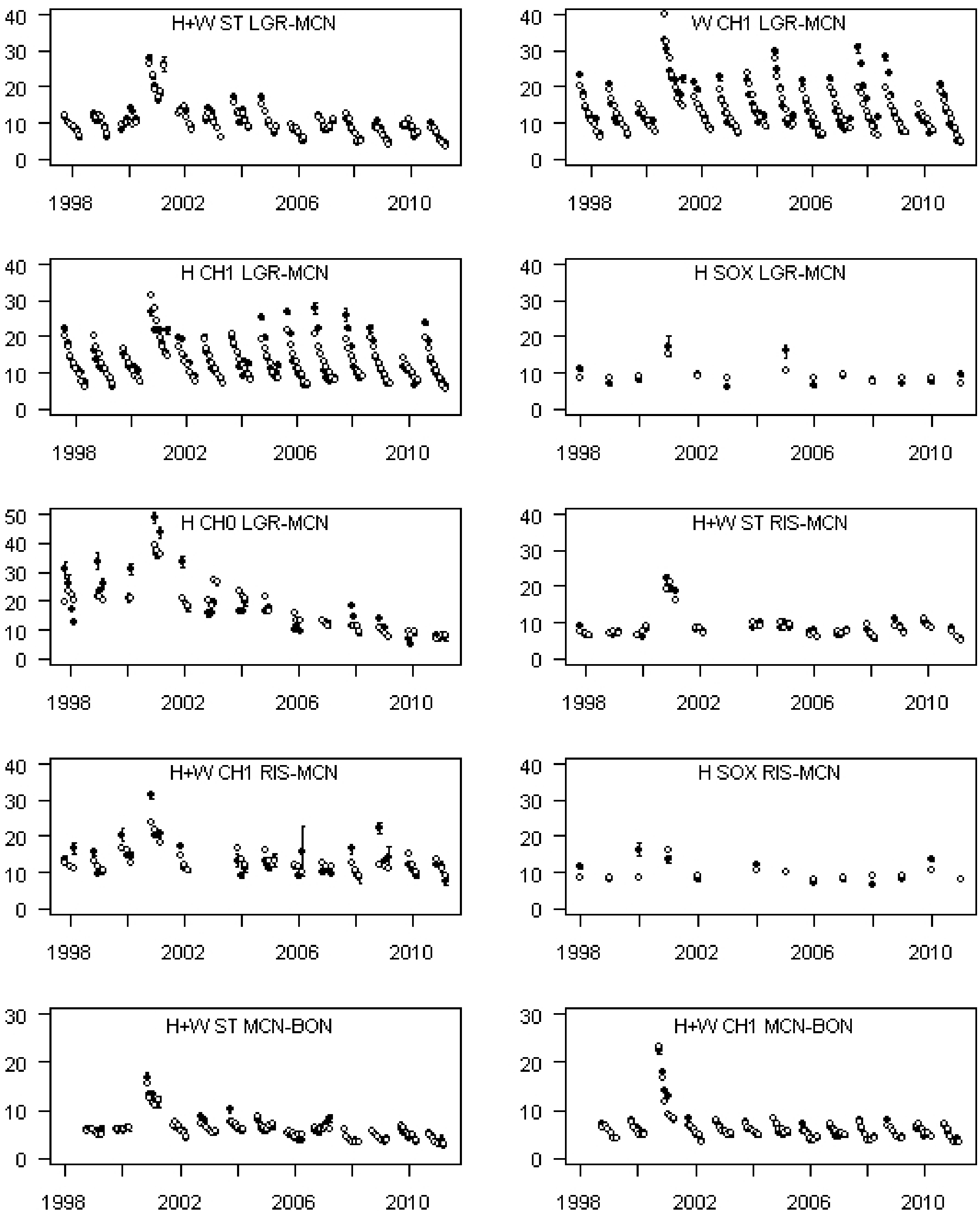

Figure 3.1 Estimates of mean FTT (in days, black circles) and predicted mean FTT (open circles) for release cohorts of hatchery (H) and wild (W) steelhead (ST), yearling Chinook (CH1), subyearling Chinook (CH0), sockeye (SOX) in the LGR-MCN, RIS-MCN and MCN-BON reaches, 1998-2011. The error bars represent +/- 1 SE.

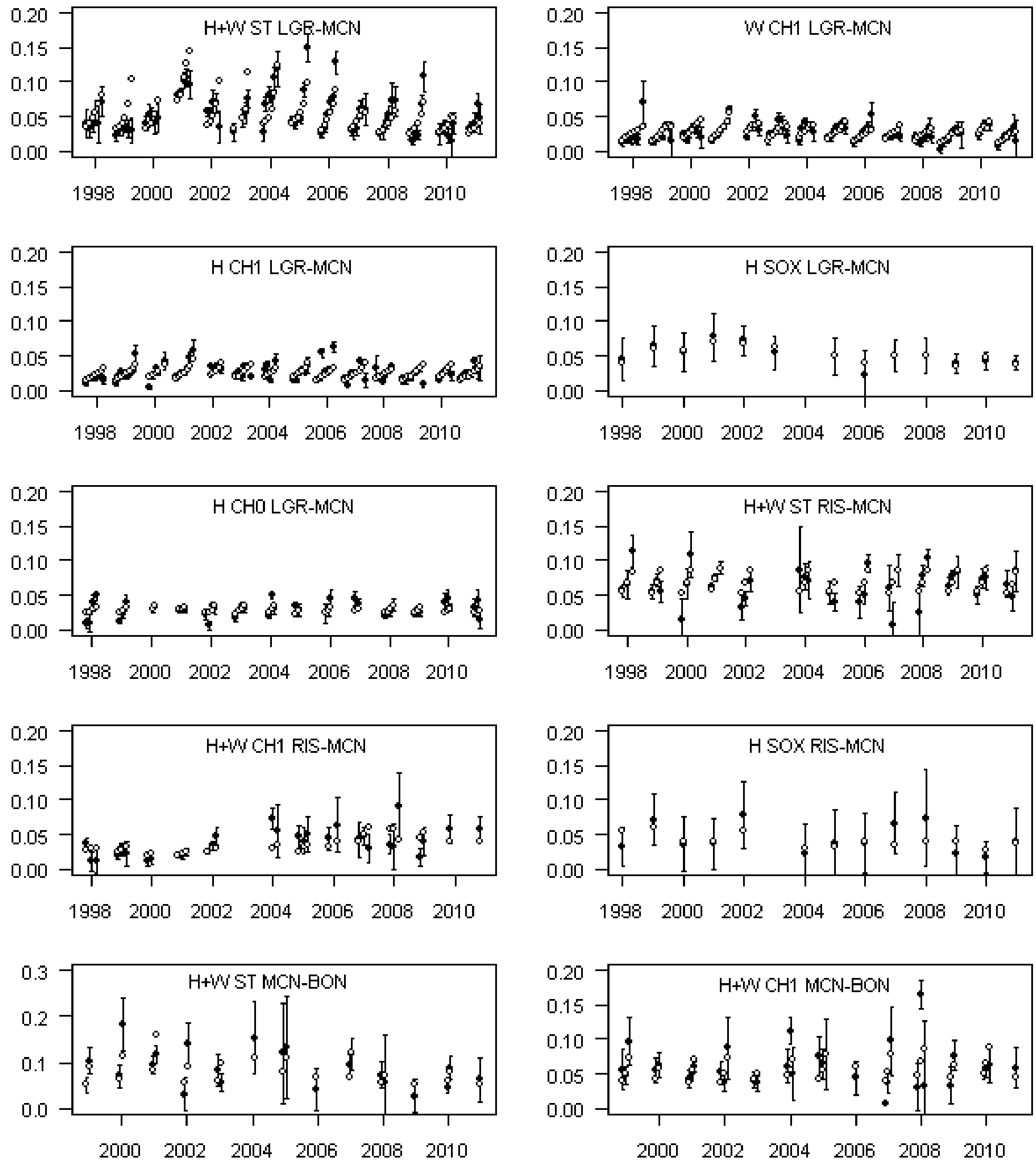

Figure 3.2 Estimates of instantaneous mortality rates, Z (d^{-1}, black circles) and predicted Z (open circles) for release cohorts of hatchery (H) and wild (W) steelhead (ST), yearling Chinook (CH1), subyearling Chinook (CH0), sockeye (SOX) in the LGR-MCN, RIS-MCN and MCN-BON reaches, 1998-2011. The error bars represent +/- 1 SE.

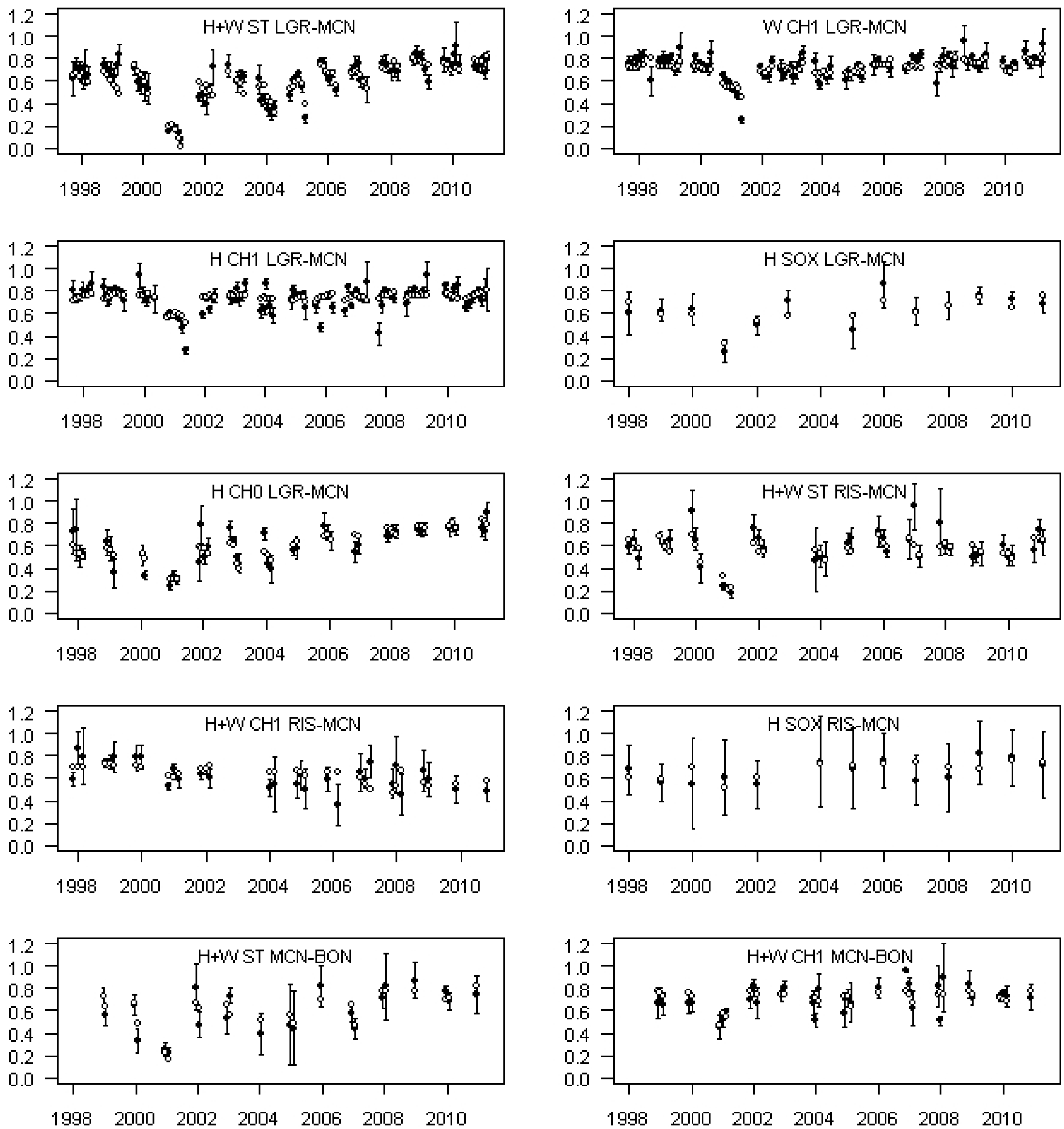

Figure 3.3 Estimates of in-river survival rates (black circles) and predicted in-river survival rates (open circles) for release cohorts of hatchery (H) and wild (W) steelhead (ST), yearling Chinook salmon (CH1), subyearling Chinook salmon (CH0), and sockeye salmon (SOX) in the LGR-MCN, RIS-MCN and MCN-BON reaches, 1998-2011. The error bars represent +/- 1 SE.

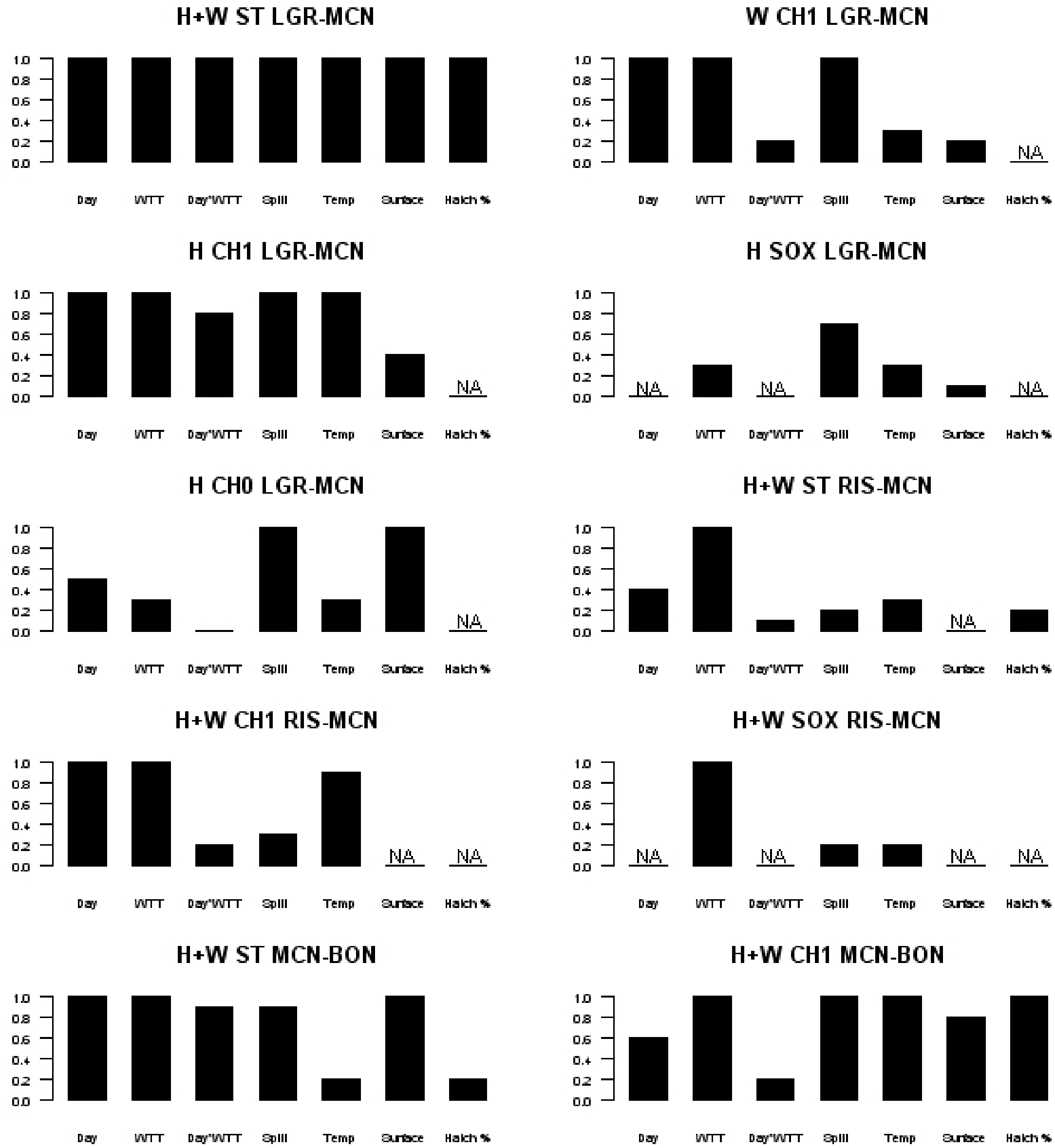

Figure 3.4 Relative variable importance values for models characterizing mean FTT across release cohorts of hatchery (H) and wild (W) steelhead (ST), yearling Chinook salmon (CH1), subyearling Chinook salmon (CH0), and sockeye salmon (SOX) in the LGR-MCN, RIS-MCN and MCN-BON reaches. Variables considered included Julian day of release (Day), water transit time (WTT), an interaction between Julian day of release and water transit time (Day*WTT), average percent spill (Spill), water temperature (Temp), the number of surface passage structures (Surface), and percent hatchery composition (Hatch %). Variables that were not applicable are indicated by a NA.

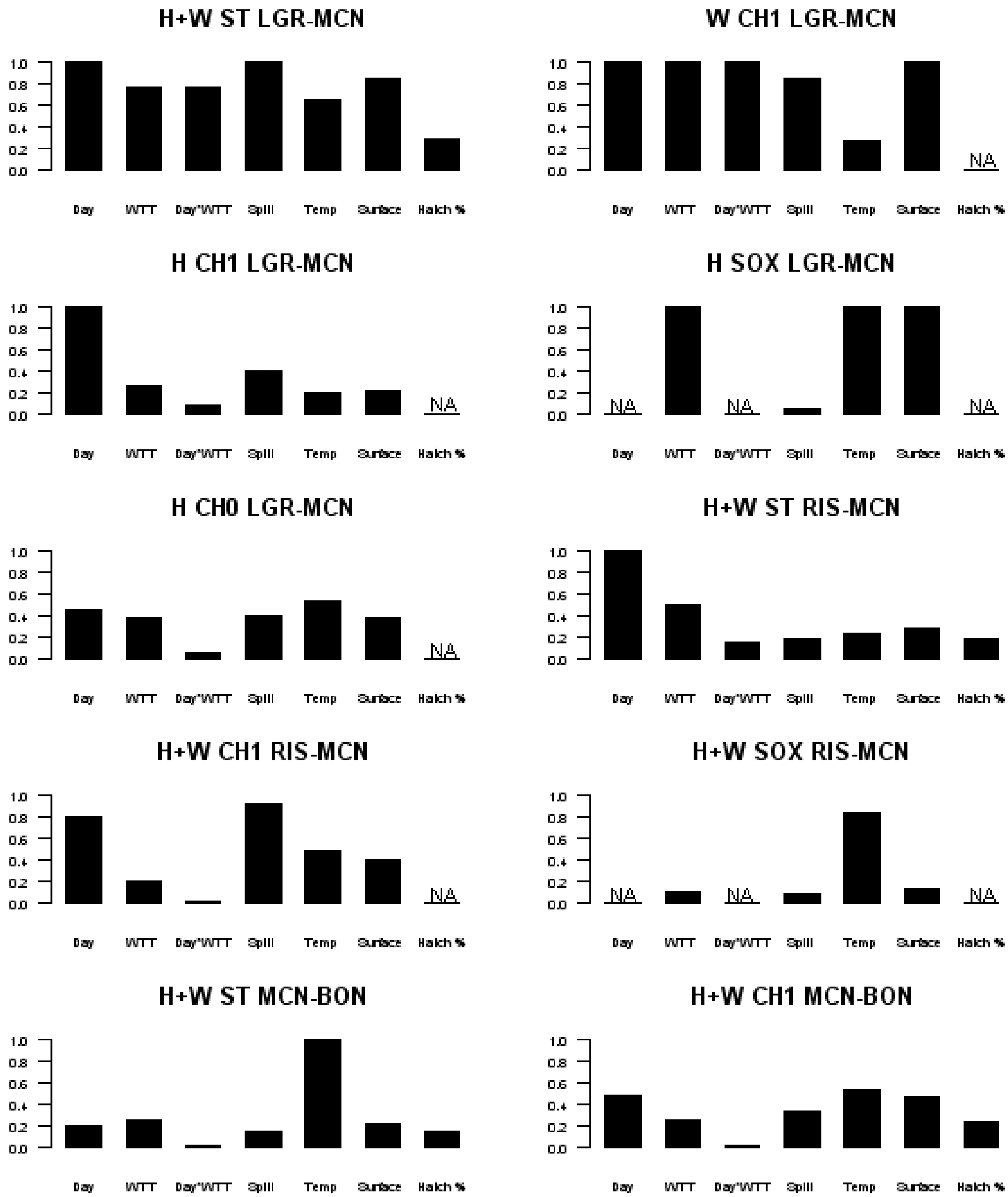

Figure 3.5 Relative variable importance values for models characterizing instantaneous mortality (Z) across release cohorts of hatchery (H) and wild (W) steelhead (ST), yearling Chinook salmon (CH1), subyearling Chinook salmon (CH0), and sockeye salmon (SOX) in the LGR-MCN, RIS-MCN and MCN-BON reaches. Variables considered included Julian day of release (Day), water transit time (WTT), an interaction between Julian day of release and water transit time (Day*WTT), average percent spill (Spill), water temperature (Temp), the number of surface passage structures (Surface), and percent hatchery composition (Hatch %). Variables that were not applicable are indicated by a NA.

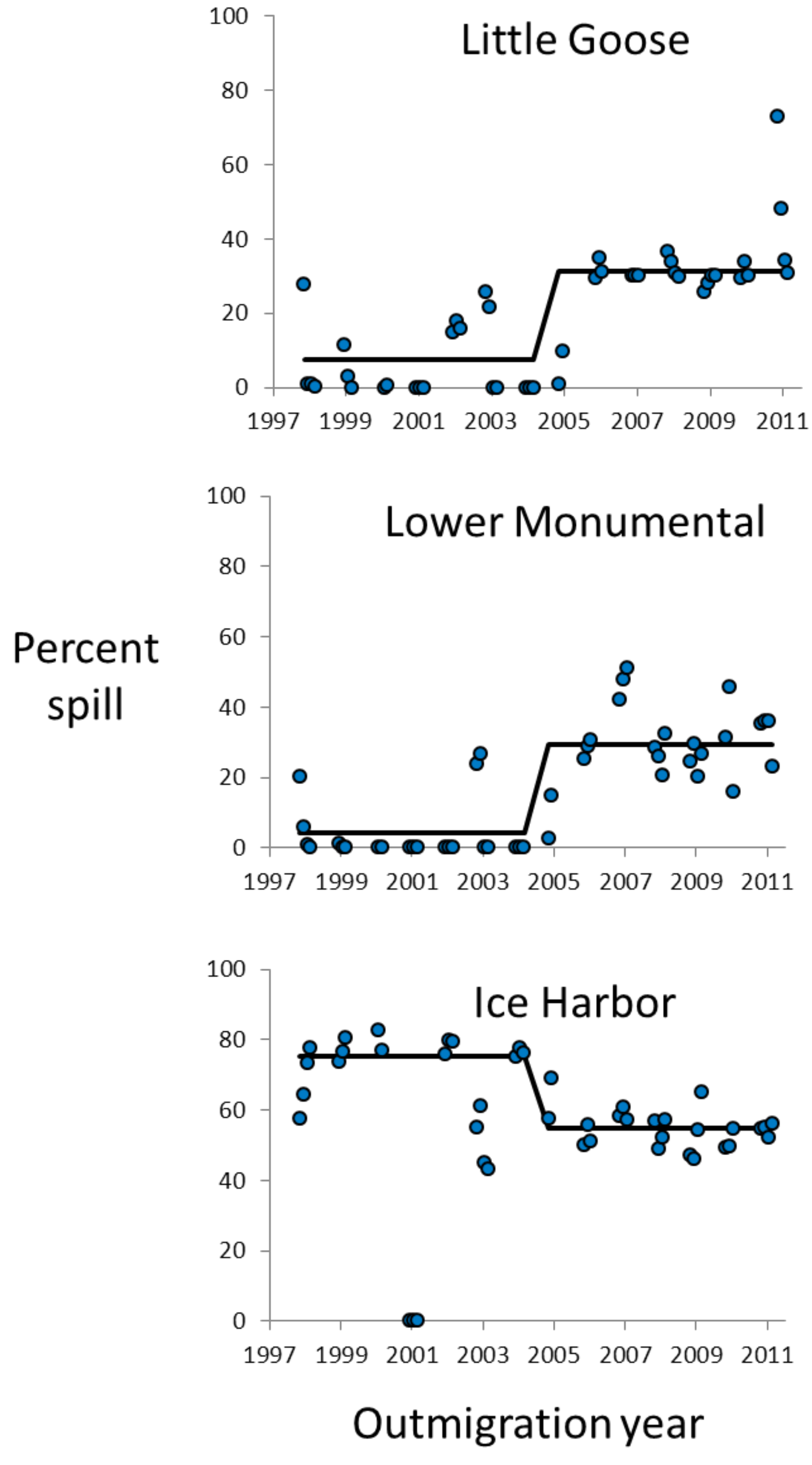

Figure 3.6 Average percent spill experienced by hatchery subyearling fall Chinook salmon release cohorts at Little Goose, Lower Monumental, and Ice Harbor dams, 1998-2011. The black lines represent the average spill levels during 1998-2004 (excluding 2001 and 2003) and the court-ordered spill period of 2005-2011.

Table 3.3. Proportions of variation explained (r2 values) in relationships characterizing yearling and subyearling Chinook, steelhead and sockeye mean FTT, instantaneous mortality rates (Z) and in-river survival rates within the LGR-MCN, RIS-MCN and MCN-BON reaches.

Reach	Species	Rearing type	Mean FTT	Z	Survival
LGR-MCN	steelhead	hatchery and wild	0.94	0.50	0.74
LGR-MCN	yearling Chinook	wild	0.80	0.47	0.57
LGR-MCN	yearling Chinook	hatchery	0.80	0.26	0.41
LGR-MCN	sockeye	hatchery and wild	0.58	0.81	0.67
LGR-MCN	subyearling Chinook	hatchery	0.75	0.18	0.69
RIS-MCN	steelhead	hatchery and wild	0.91	0.39	0.65
RIS-MCN	yearling Chinook	hatchery and wild	0.54	0.09	0.11
RIS-MCN	sockeye	hatchery and wild	0.22	0.28	0.23
MCN-BON	steelhead	hatchery and wild	0.92	0.49	0.76
MCN-BON	yearling Chinook	hatchery and wild	0.94	0.15	0.33

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. Fish travel time has consistently been 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. 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. The instantaneous mortality rates tend to be lowest under conditions of fast WTT and high spill levels. In addition, mortality rates tend to increase over the migration season. Potential mechanisms for the pattern of increasing mortality rates over the migration season could include declining smolt energy reserves or physiological condition over the migration season, increasing predation rates on smolts over the migration season, increases in disease susceptibility or disease-related mortality over the migration season, or some combination of these often interrelated mechanisms.

We found some evidence that the increased number of dams with surface passage structures in the spillways may be reducing mortality rates. 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 3.4 and 3.5).

These results indicate that improvements to fish travel time, mortality rates and survival are 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 this reach if these four projects were to operate at their minimum operating pools. The data also indicate that there is 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-h basis. If all the projects were to do so, the data indicate that fish travel times would be reduced, mortality rates would be reduced and survival rates would increase.

To illustrate the changes in survival that would be expected under alternative operations of the hydrosystem, we used the model-averaged coefficients from the FTT and the instantaneous mortality (Z) models to forecast the survival rates (Equation 3.8) that would be expected for yearling Chinook salmon and steelhead in the LGR-MCN and MCN-BON reaches across a range of water transit times and spill levels (Tables 3.4 - 3.7). Within these analyses, all other variables were held at their mean values across the time series while we evaluated the expected changes in survival that would occur under alternative levels of water transit time and average percent spill. Conditions that have been observed over the data series in terms of water transit time and spill are represented by grey shading, while conditions that have not been tested and that indicated survival improvements are represented by black shading (Tables 3.4 – 3.7). For both species and both reaches, the models indicate that survival improvements are expected as water transit time is reduced and spill levels are increased. The analyses also indicate that high spill levels may be able to mitigate for low-flow conditions. Especially in the Snake River where much of the flow is determined by snowpack and runoff timing, high spill levels could help keep survival rates high during low-flow periods.

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 and migration rates. However, improvements in the precision of the survival estimates in the MCN-BON reach and the RIS-MCN reach would be useful. There are two means for improving 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.

Table 3.4. Predicted survival rates under various water transit times (WTT) and average percent spill levels for yearling Chinook in the LGR-MCN reach. Cells highlighted in grey represent conditions that have been observed in the historical dataset and cells highlighted in black represent conditions that could be tested using adaptive management experiments. Blank cells represent conditions that would be infeasible due to powerhouse flow limitations.

	Average percent spill						
WTT	0	10	20	30	40	50	60
20	0.54	0.56	0.59	0.61	0.64	0.66	0.68
17	0.59	0.62	0.64	0.66	0.68	0.70	0.72
14	0.64	0.66	0.68	0.70	0.72	0.74	0.75
11	0.69	0.71	0.73	0.74	0.76	0.77	0.79
8		0.75	0.76	0.78	0.79	0.80	0.82
5			0.80	0.81	0.82	0.83	0.84

Table 3.5. Predicted survival rates under various water transit times (WTT) and average percent spill levels for steelhead in the LGR-MCN reach. Cells highlighted in grey represent conditions that have been observed in the historical dataset and cells highlighted in black represent conditions that could be tested using adaptive management experiments. Blank cells represent conditions that would be infeasible due to powerhouse flow limitations.

	Average percent spill						
WTT	0	10	20	30	40	50	60
20	0.23	0.35	0.44	0.51	0.58	0.64	0.69
17	0.29	0.42	0.50	0.57	0.63	0.69	0.73
14	0.36	0.48	0.56	0.62	0.68	0.73	0.77
11	0.42	0.54	0.61	0.67	0.72	0.77	0.80
8		0.60	0.67	0.72	0.76	0.80	0.83
5			0.71	0.76	0.80	0.83	0.86

Table 3.6. Predicted survival rates under various water transit times (WTT) and average percent spill levels for yearling Chinook in the MCN-BON reach. Cells highlighted in grey represent conditions that have been observed in the historical dataset and cells highlighted in black represent conditions that could be tested using adaptive management experiments. Blank cells represent conditions that would be infeasible due to powerhouse flow limitations

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	Average percent spill				
WTT	15	25	35	45	55
12	0.44	0.53	0.58	0.60	0.61
10	0.49	0.58	0.62	0.64	0.65
8	0.53	0.62	0.66	0.68	0.69
6	0.58	0.66	0.69	0.71	0.72
4		0.69	0.73	0.74	0.75

Table 3.7. Predicted survival rates under various water transit times (WTT) and average percent spill levels for steelhead in the MCN-BON reach. Cells highlighted in grey represent conditions that have been observed in the historical dataset and cells highlighted in black represent conditions that could be tested using adaptive management experiments. Blank cells represent conditions that would be infeasible due to powerhouse flow limitations.

	Average percent spill				
WTT	15	25	35	45	55
12	0.49	0.53	0.55	0.57	0.59
10	0.55	0.59	0.62	0.63	0.65
8	0.62	0.65	0.67	0.69	0.70
6	0.67	0.70	0.72	0.74	0.75
4		0.75	0.76	0.78	0.79

Appendix 3.1. Multimodel inference results for models characterizing variation in mean fish travel time. Results are shown for models within 3 AICc points of the top fitting model. The species, rearing type, reach, and transformation used are identified in the first line above each table.

STHW, LGR-MCN

Intercept	day	wtt	sqrt(spill)	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
4.274	-0.014	-0.079	-0.060	0.281	-0.143	-0.047	0.001	9	0.92	0.92	-122.3	0.0	0.92

CH1W, LGR-MCN

Intercept	log(day)	wtt	spill	pct.hatch	surface	temp	log(day)*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
13.100	-2.178	0.024	-0.012	NA				5	0.82	0.82	-59.1	0.0	0.36
13.450	-2.280	0.023	-0.012	NA		0.012		6	0.82	0.82	-57.4	1.7	0.15
13.690	-2.304	-0.033	-0.012	NA			0.012	6	0.82	0.82	-57.2	1.9	0.14
13.100	-2.178	0.024	-0.012	NA	0.004			6	0.82	0.82	-57.2	1.9	0.14

CH1H, LGR-MCN

Intercept	log(day)	wtt	sqrt(spill)	pct.hatch	surface	temp	log(day)*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
18.200	-3.207	-0.389	-0.094	NA		0.004	0.084	7	0.84	0.83	-77.7	0.0	0.42
18.410	-3.253	-0.409	-0.090	NA	-0.017	0.004	0.088	8	0.84	0.83	-77.3	0.5	0.33
14.150	-2.354	0.012	-0.097	NA		0.003		6	0.83	0.82	-74.8	3.0	0.10

SOXH, LGR-MCN

Intercept	day	wtt	sqrt(spill)	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
3.020	NA		-0.137	NA			NA	3	0.44	0.39	4.5	0.0	0.24
1.714	NA		-0.109	NA		0.087	NA	4	0.49	0.39	5.3	0.9	0.16
2.772	NA	0.015	-0.117	NA			NA	4	0.45	0.34	6.3	1.8	0.10
3.018	NA		-0.137	NA	-0.003		NA	4	0.44	0.33	6.5	2.0	0.09
1.634	NA	0.065		NA			NA	3	0.32	0.26	7.0	2.6	0.07
1.551	NA		-0.111	NA	0.021	0.099	NA	5	0.50	0.33	7.2	2.8	0.06
1.721	NA	-0.003	-0.113	NA		0.091	NA	5	0.49	0.32	7.3	2.9	0.06

CH0H, LGR-MCN FTT

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
4.520	-0.005		-0.022	NA	-0.230			5	0.77	0.75	14.0	0.0	0.25
4.181			-0.022	NA	-0.248	-0.029		5	0.76	0.75	15.3	1.4	0.13
3.603			-0.020	NA	-0.229			4	0.75	0.74	15.4	1.4	0.13
4.527	-0.006	0.005	-0.020	NA	-0.224			6	0.77	0.75	15.5	1.6	0.12
4.530	-0.006		-0.021	NA	-0.224	0.009		6	0.77	0.75	15.9	1.9	0.10
4.304		0.012	-0.020	NA	-0.250	-0.051		6	0.77	0.75	16.1	2.1	0.09
5.499	-0.012	-0.072	-0.020	NA	-0.224		0.000	7	0.78	0.75	16.4	2.5	0.07

STHW, RIS-MCN

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
1.119		0.162			NA			3	0.88	0.88	-58.7	0.0	0.15
0.875	0.002	0.165			NA			4	0.88	0.88	-58.0	0.7	0.10
0.674	0.006	0.175			NA	-0.034		5	0.89	0.88	-57.8	0.8	0.10
1.067		0.164		0.075	NA			4	0.88	0.88	-57.5	1.1	0.08
1.065		0.162			NA	0.005		4	0.88	0.87	-56.9	1.8	0.06
1.129		0.163	0.000		NA			4	0.88	0.87	-56.8	1.9	0.06
1.199	0.002	0.088			NA	-0.037	0.001	6	0.89	0.88	-56.5	2.2	0.05
1.269	-0.001	0.102			NA		0.000	5	0.88	0.87	-56.3	2.4	0.05
0.871	0.002	0.166	-0.001		NA			5	0.88	0.87	-56.3	2.4	0.04
0.894	0.002	0.165		0.015	NA			5	0.88	0.87	-56.0	2.7	0.04
0.681	0.006	0.175	0.000		NA	-0.032		6	0.89	0.88	-55.9	2.8	0.04
0.681	0.006	0.175		0.005	NA	-0.034		6	0.89	0.88	-55.8	2.8	0.04
1.079		0.165	-0.001	0.083	NA			5	0.88	0.87	-55.8	2.9	0.03

Appendix 3.1. (continued)

CH1HW, RIS-MCN

Intercept	log(day)	wtt	spill	pct.hatch	surface	temp	log(day)*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
12.600	-2.421	0.068		NA	NA	0.116		5	0.50	0.45	-0.8	0.0	0.36
11.930	-2.261	0.069	0.002	NA	NA	0.100		6	0.50	0.44	0.7	1.5	0.17
9.329	-1.754	0.600		NA	NA	0.117	-0.109	6	0.50	0.44	1.0	1.8	0.15

SOXHW, RIS-MCN

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
0.139	NA	0.073	0.011	NA	NA	0.128	NA	5	0.53	0.37	2.0	0.0	0.30
1.599	NA	0.102		NA	NA		NA	3	0.32	0.26	2.7	0.7	0.21
1.137	NA	0.090		NA	NA	0.053	NA	4	0.38	0.26	3.5	1.5	0.14
0.108	NA		0.014	NA	NA	0.166	NA	4	0.38	0.26	3.5	1.5	0.14
1.520	NA	0.102	0.003	NA	NA		NA	4	0.34	0.20	4.4	2.4	0.09

STHW, MCN-BON

Intercept	day	wtt	log(spill)	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
1.117	0.006	0.311	-0.254		-0.283		-0.001	7	0.89	0.88	-105.9	0.0	0.35
1.135	0.007	0.314	-0.269		-0.288	-0.008	-0.001	8	0.89	0.88	-104.0	1.8	0.14
1.137	0.006	0.308	-0.257	0.029	-0.286		-0.001	8	0.89	0.88	-104.0	1.9	0.14

CH1HW, MCN-BON

Intercept	day	wtt	log(spill)	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AICc	weight
5.198	-0.003	0.077	-0.715	-0.288	-0.059	-0.054		8	0.91	0.90	-122.5	0.0	0.30
5.179		0.082	-0.757	-0.294	-0.073	-0.078		7	0.91	0.90	-122.5	0.0	0.30
4.808	-0.001	0.127	-0.702	-0.270	-0.063	-0.053	0.000	9	0.91	0.90	-120.9	1.5	0.14
5.279	-0.005	0.075	-0.732	-0.274		-0.039		7	0.91	0.90	-120.5	2.0	0.11

Appendix 3.2. Multimodel inference results for models characterizing variation in instantaneous mortality (Z). Results are shown for models within 3 AICc points of the top fitting model. The species, rearing type, reach, and transformation used are identified in the first line above each table.

STHW, LGR-MCN, log(Z)

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
-8.984	0.045	0.305	-0.014		-0.044	0.080	-0.002	8	0.68	0.66	48.9	0.0	0.23
-8.792	0.051	0.303	-0.015		-0.061		-0.002	7	0.67	0.65	49.5	0.6	0.17
-9.055	0.043	0.304	-0.016			0.114	-0.003	7	0.67	0.65	49.7	0.8	0.15
-8.837	0.044	0.299	-0.014	-0.103	-0.039	0.086	-0.002	9	0.69	0.65	50.5	1.6	0.10
-8.793	0.041	0.294	-0.015	-0.176		0.119	-0.002	8	0.68	0.65	50.6	1.7	0.10
-8.731	0.051	0.300	-0.015	-0.039	-0.060		-0.002	8	0.67	0.65	51.4	2.5	0.06

CH1W, LGR-MCN, sqrt(Z)

Intercept	log(day)	wtt	sqrt(spill)	pct.hatch	surface	temp	log(day)*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
-0.211	0.070	-0.063	0.003	NA	-0.004		0.014	7	0.64	0.62	-459.6	0.0	0.49
-0.124	0.046	-0.064	0.003	NA	-0.004	0.003	0.014	8	0.64	0.62	-458.4	1.2	0.27

CH1H, LGR-MCN, log(Z)

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
-5.721	0.017			NA				3	0.32	0.31	50.1	0.0	0.15
-5.834	0.014			NA		0.042		4	0.33	0.32	50.5	0.5	0.12
-5.627	0.017		-0.003	NA				4	0.33	0.32	50.6	0.5	0.11
-5.687	0.017			NA	-0.015			4	0.33	0.31	51.4	1.3	0.08
-5.733	0.017	0.001		NA				4	0.32	0.31	52.1	2.0	0.05
-5.736	0.015		-0.002	NA		0.027		5	0.33	0.31	52.2	2.1	0.05
-5.488	0.017	-0.007	-0.004	NA				5	0.33	0.31	52.2	2.2	0.05
-5.784	0.013	-0.004		NA		0.046		5	0.33	0.31	52.4	2.4	0.05
-5.806	0.014			NA	-0.006	0.037		5	0.33	0.31	52.5	2.4	0.05
-5.622	0.017		-0.003	NA	-0.007			5	0.33	0.31	52.5	2.4	0.05

SOXH, LGR-MCN, Z

Intercept	day	wtt	sqrt(spill)	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
0.199	NA	0.003	-0.003	NA	-0.005	-0.011	NA	6	0.88	0.82	-90.0	0.0	0.63
0.172	NA	0.004		NA	-0.005	-0.011	NA	5	0.84	0.79	-88.7	1.3	0.32

CH0, LGR-MCN, sqrt(Z)

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
0.048			0.001	NA		0.006		4	0.24	0.20	-190.1	0.0	0.19
0.030			0.001	NA	0.003	0.007		5	0.26	0.20	-189.1	0.9	0.12
0.066	0.000		0.001	NA		0.008		5	0.25	0.19	-188.5	1.6	0.08
0.055	-0.001		0.001	NA	0.004	0.010		6	0.27	0.20	-188.1	1.9	0.07
0.048		0.000	0.001	NA		0.006		5	0.24	0.18	-188.1	2.0	0.07
0.030		0.000	0.001	NA	0.003	0.007		6	0.26	0.18	-187.1	2.9	0.04

STHW, RIS-MCN, sqrt(Z)

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
-0.001	0.002							3	0.43	0.42	-153.4	0.0	0.09
-0.036	0.002	0.002						4	0.45	0.42	-152.8	0.6	0.07
-0.048	0.002	0.003			0.011			5	0.48	0.43	-152.4	1.1	0.05
-0.195	0.003	0.025					0.000	5	0.47	0.43	-152.1	1.3	0.05
-0.001	0.002				0.006			4	0.44	0.41	-152.0	1.5	0.04
-0.083	0.003	0.004				-0.007		5	0.47	0.42	-151.7	1.8	0.04
0.001	0.002					0.002		4	0.44	0.40	-151.6	1.8	0.04
-0.199	0.003	0.025			0.011		0.000	6	0.49	0.43	-151.6	1.8	0.04
-0.003	0.002		0.000					4	0.43	0.40	-151.5	2.0	0.03
-0.004	0.002			-0.003				4	0.43	0.40	-151.4	2.0	0.03
-0.017	0.002		0.000		0.017			5	0.46	0.41	-151.2	2.2	0.03
-0.038	0.002	0.002	0.000					5	0.46	0.41	-151.0	2.4	0.03
-0.085	0.003	0.005			0.010	-0.006		6	0.48	0.42	-150.9	2.5	0.03
-0.233	0.004	0.026				-0.006	0.000	6	0.48	0.42	-150.9	2.5	0.03
-0.033	0.002	0.002		0.003				5	0.45	0.41	-150.8	2.6	0.02
-0.050	0.002	0.002	0.000		0.017			6	0.48	0.42	-150.7	2.7	0.02
0.004	0.002				0.009	0.003		5	0.45	0.40	-150.5	2.9	0.02
-0.213	0.003	0.030		0.021			0.000	6	0.48	0.41	-150.5	2.9	0.02
-0.206	0.004	0.027	0.000				0.000	6	0.48	0.41	-150.5	3.0	0.02

Appendix 3.2. (continued)

CH1HW, RIS-MCN, log(Z)

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
-4.514	0.024		-0.016	NA		-0.120		5	0.44	0.38	39.8	0.0	0.13
-3.683	0.013		-0.033	NA	-0.434			5	0.44	0.37	40.1	0.3	0.11
-4.236	0.013		-0.021	NA				4	0.40	0.35	40.1	0.3	0.11
-4.024	0.022		-0.026	NA	-0.347	-0.099		6	0.46	0.38	40.5	0.7	0.09
-3.997	0.012	-0.031	-0.018	NA				5	0.41	0.35	41.4	1.6	0.06
-4.604	0.025	0.008	-0.016	NA		-0.131		6	0.44	0.35	41.8	2.0	0.05
-3.625	0.012	-0.015	-0.031	NA	-0.390			6	0.44	0.35	41.9	2.1	0.05
-2.652			-0.020	NA				3	0.31	0.29	42.2	2.3	0.04
-4.232	0.026	0.025	-0.028	NA	-0.392	-0.132		7	0.47	0.36	42.2	2.4	0.04
-2.099			-0.032	NA	-0.433			4	0.35	0.31	42.4	2.6	0.04

SOXHW, RIS-MCN, log(Z)

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
-0.776	NA			NA		-0.231	NA	3	0.32	0.26	18.2	0.0	0.20
-0.073	NA			NA	0.351	-0.313	NA	4	0.41	0.30	18.2	0.0	0.19
0.527	NA		-0.013	NA		-0.317	NA	4	0.38	0.26	18.9	0.7	0.14
-0.599	NA	-0.050		NA		-0.217	NA	4	0.35	0.22	19.5	1.3	0.10
-0.058	NA	-0.023		NA	0.317	-0.299	NA	5	0.42	0.23	20.1	1.9	0.08
-0.071	NA		0.000	NA	0.351	-0.314	NA	5	0.41	0.22	20.2	2.0	0.07
0.460	NA	-0.032	-0.011	NA		-0.296	NA	5	0.40	0.19	20.6	2.5	0.06
-3.078	NA			NA			NA	2	0.00	0.00	21.2	3.0	0.04

STHW, MCN-BON, 1/(Z)

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
45.500						-2.434		3	0.43	0.40	137.8	0.0	0.11
41.250					2.403	-2.160		4	0.46	0.40	138.9	1.1	0.07
21.820	0.401	1.182				-5.417		5	0.50	0.42	139.0	1.2	0.06
45.950		0.309				-2.640		4	0.45	0.39	139.2	1.4	0.06
44.300				1.305		-2.416		4	0.43	0.37	139.8	2.0	0.04
43.460	0.032					-2.611		4	0.43	0.37	139.8	2.0	0.04
45.670			-0.003			-2.440		4	0.43	0.37	139.8	2.0	0.04
34.330		0.823	0.203			-2.572		5	0.47	0.38	140.3	2.5	0.03
41.830		0.289			2.313	-2.363		5	0.47	0.38	140.4	2.6	0.03
44.480	0.248	-1.858				-5.550	0.022	6	0.51	0.39	140.6	2.8	0.03
43.390			-0.042		2.631	-2.218		5	0.46	0.37	140.8	3.0	0.03

Appendix 3.2. (continued)

CH1HW, MCN-BON, 1/sqrt(Z)

Intercept	day	wtt	spill	pct.hatch	surface	temp	day*wtt	k	R.sq	Adj.R.sq	AICc	delta AIC	weight
12.400			-0.060		-0.825	-0.440		5	0.23	0.15	118.4	0.0	0.05
11.170	-0.050				-0.785			4	0.18	0.12	118.4	0.0	0.05
8.929					-1.088	-0.329		4	0.18	0.12	118.6	0.2	0.05
9.006		0.151			-1.016	-0.424		5	0.23	0.14	118.6	0.2	0.05
12.380			-0.081			-0.403		4	0.17	0.12	118.7	0.3	0.04
10.460	-0.047							3	0.11	0.09	118.9	0.5	0.04
12.570			-0.107	3.349		-0.556		5	0.21	0.12	119.4	1.0	0.03
12.550			-0.083	2.746	-0.748	-0.562		6	0.25	0.14	119.5	1.1	0.03
11.930	-0.049		-0.035					4	0.14	0.08	119.9	1.5	0.02
10.680	-0.029				-0.952	-0.169		5	0.19	0.10	120.0	1.6	0.02
8.113		0.192		2.129	-1.015	-0.511		6	0.24	0.13	120.0	1.6	0.02
11.160	-0.061			1.738	-0.760			5	0.19	0.10	120.1	1.7	0.02
11.230		0.079	-0.039		-0.879	-0.451		6	0.24	0.12	120.1	1.7	0.02
11.670	-0.051		-0.014		-0.695			5	0.18	0.10	120.3	1.9	0.02
12.170	0.012		-0.069		-0.844	-0.519		6	0.23	0.12	120.3	1.9	0.02
7.385		0.172				-0.335		4	0.13	0.07	120.3	1.9	0.02
10.940	-0.050	0.028			-0.749			5	0.18	0.09	120.3	1.9	0.02
10.480	-0.060			2.125				4	0.13	0.07	120.4	2.0	0.02
9.991	-0.047	0.064						4	0.13	0.07	120.5	2.1	0.02
8.135	0.015	0.180			-1.071	-0.523		6	0.23	0.11	120.5	2.1	0.02
8.891				0.089	-1.089	-0.332		5	0.18	0.09	120.6	2.2	0.02
7.164						-0.219		3	0.07	0.03	120.6	2.2	0.02
11.860		0.035	-0.072			-0.407		5	0.17	0.09	120.6	2.2	0.02
12.370	0.001		-0.081			-0.408		5	0.17	0.08	120.7	2.3	0.02
4.257								2	0.00	0.00	120.8	2.4	0.02
10.590	-0.051					0.035		4	0.12	0.05	120.9	2.5	0.02
12.280	-0.067		-0.042	2.998				5	0.17	0.08	120.9	2.5	0.01
11.060		0.102	-0.059	3.046	-0.809	-0.589		7	0.26	0.12	121.0	2.6	0.01
11.590		0.067	-0.092	3.577		-0.573		6	0.21	0.09	121.2	2.8	0.01
4.447					-0.670			3	0.05	0.02	121.2	2.8	0.01
12.860	-0.014		-0.098	3.553		-0.471		6	0.21	0.09	121.3	2.9	0.01

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 2009) adopted a goal of achieving overall SARs (including jacks) in the 2-6% range (minimum 2%; average 4%) 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) 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 (2009) 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. 2011). 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 100-year interim survival standard required a median SAR of at least 2%. The NPCC (2009) 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. 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 CSS are 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 fish (e.g., Lower Granite Dam; GRA).

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 an SAR objective was defined narrowly for population persistence or more broadly to maintain productive natural populations with sustainable fisheries. An 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). The SAR estimates in this report are based on smolts at the uppermost FCRPS dam (Lower Granite, McNary, John Day or Bonneville), and adults at either Bonneville Dam or the uppermost dam. Smolts 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; smolt migration mortality that occurs upstream of MCN is not accounted for in these SAR estimates. We have made preliminary comparisons of the overall SAR estimates 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.

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 spring/summer Chinook and steelhead based on smolts at the uppermost dam to adult returns to the Columbia River mouth for the 1964-2010 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 objective for Snake River wild and hatchery spring/summer Chinook and steelhead is to update the long-term SAR data series for CSS study fish. 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 was represented by the Group T (Chapter 1). Prior to 2006, we estimated the proportion of run at large represented by each study group $T_{0,}$ C0 and C1. The CSS 2009 Annual Report (Tuomikoski et al. 2009) found good agreement between overall SARs computed with the pre-2006 and new-2006 methods applied to smolt migration years 2006 - 2010. Lastly, the overall SARs with jacks included are presented for all 17 years of PIT-tagged wild spring/summer Chinook data and 14 years of PIT-tagged hatchery spring/summer Chinook data (except for Catherine Creek hatchery Chinook, which has a 10-year history). The effect of including jacks in the overall SAR estimates are presented for the wild Snake River spring/summer Chinook aggregate and each of the five CSS Snake River hatchery groups. Overall SARs for Snake River aggregate wild and aggregate hatchery steelhead are presented for 13 years beginning in 1997.

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) and Pahsimeroi Hatchery summer Chinook (2008). 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), Salmon River B-run (SAL-B), and Clearwater River B-run (CLW-B) steelhead groups.

The objective for Snake River sockeye is to begin a data series of SARs. PIT tagging of Snake River hatchery sockeye began in migration year 2009 as a Corps of Engineers study; we report the overall SAR for migration years 2009-2010.

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

Overall SARs are presented for migration years 2000-2010 for John Day River wild spring Chinook, Carson Hatchery spring Chinook, and Cle Elum Hatchery spring Chinook. Overall SARs are also presented for migration years 2004-2009 for John Day wild steelhead and 2006-2009 for Deschutes River wild steelhead. The CSS added SAR data series for three new populations to the mid-Columbia in this annual report: Yakima River wild spring Chinook (1999-2010); Warm Springs (Deschutes) hatchery spring Chinook (2007-2010); and Yakima River wild steelhead (2002-2009).

The primary objective for upper Columbia River (above PRD) wild and hatchery spring Chinook and steelhead is to update existing and establish additional SAR data series for subbasins in this region. We estimated SARs for wild spring Chinook from the Entiat/Methow River (2006-2010) and Wenatchee River (2007-2010), for Leavenworth hatchery spring Chinook (2000-2010), for wild steelhead (Wenatchee, Entiat and Methow rivers from 2006 to 2009), and for hatchery steelhead released into the Wenatchee River (2003-2009). Due to limited detection capability of juvenile out-migrants upstream of MCN, most SAR data series are presented as MCN-to-BOA. In future reports, we will also present SARs from smolts at MCN to adults at the uppermost dam. The CSS has begun to estimate SARs of Upper Columbia wild spring Chinook and steelhead from populations upstream from Rocky Reach Dam (RRE), using smolt abundance estimates at RRE and adult counts at BOA for migration years 2008-2010. In addition, we have included time series of SARs from the FPC Smolt Monitoring Program (SMP) tagging at Rock Island Dam for combined hatchery/wild groups of yearling Chinook, subyearling Chinook, and steelhead.

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. 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 tj 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. The total estimated number transported across the three Snake River collector dams in LGR equivalents equals $T_{0*} = t_2 + t_3 / S_2 + t_4 / (S_2 S_3)$, 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,

$$C_1^* = \left(T_0 + C_1\right) - T_0^*$$

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

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

is the transported smolt proportion,

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

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

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

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 represent adult returns through September 10, 2012.

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 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 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. Number of PITtagged spring Chinook smolts from Carson Hatchery is 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 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 10, 2012.

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

The CSS has compiled a historic 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 (2008) 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 1996-2009, 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 wild Snake River 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. 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 mostly expressed 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 1998), and assigns all ocean survival rate variability to the S.o1 life stage. Estimates of S.oa and 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).

Results

Snake River Overall SARs

Historic wild Snake River 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 1985-1991 due to insufficient marking those years (Petrosky et al. 2001). The geometric mean SAR during 1964-1969 was 4.3% compared to 0.8% during 1992-1999 and 1.2% since 2000.

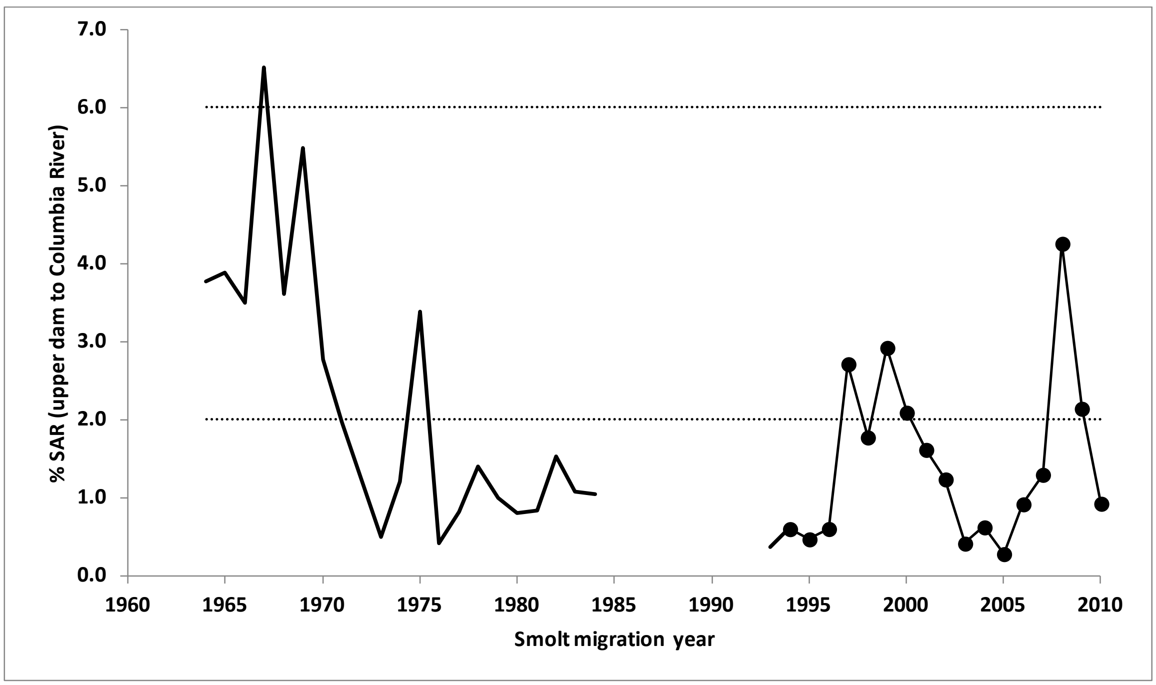


Figure 4.1. SARs from smolts at uppermost Snake River dam to Columbia River returns (including jacks) for wild Snake River spring/summer Chinook, 1964-2010. SARs based on run reconstruction (1964-1993) and CSS PIT tags (1994-2010). The NPCC (2009) 2%-6% SAR objective for listed wild populations is shown for reference; SAR for 2010 is complete through 2-ocean returns only.

SARs (LGR-to-GRA, jacks included) of PIT-tagged Snake River wild spring/summer Chinook had a geometric mean of 0.89% and exceeded the NPCC's minimum SAR objective of 2% in only two migration years (1999 and 2008) during the period 1994-2010 (Table 4.1; Figure 4.2 top left plot). LGR-GRA SARs with jacks included were about 8% higher (geometric mean of SAR ratios) than SARs with jacks excluded (Table 4.1). SARs based on jack and adult returns to BOA were about 26% greater (geometric mean of SAR ratios) than SARs based on returns to GRA (Table 4.2) because of the combined effect of dam passage loss, straying and Zone 6 harvest. The CSS plans to investigate the feasibility of estimating Snake River wild spring/summer Chinook SARs at finer geographic scales (e.g., Major Population Groups) in future reports.

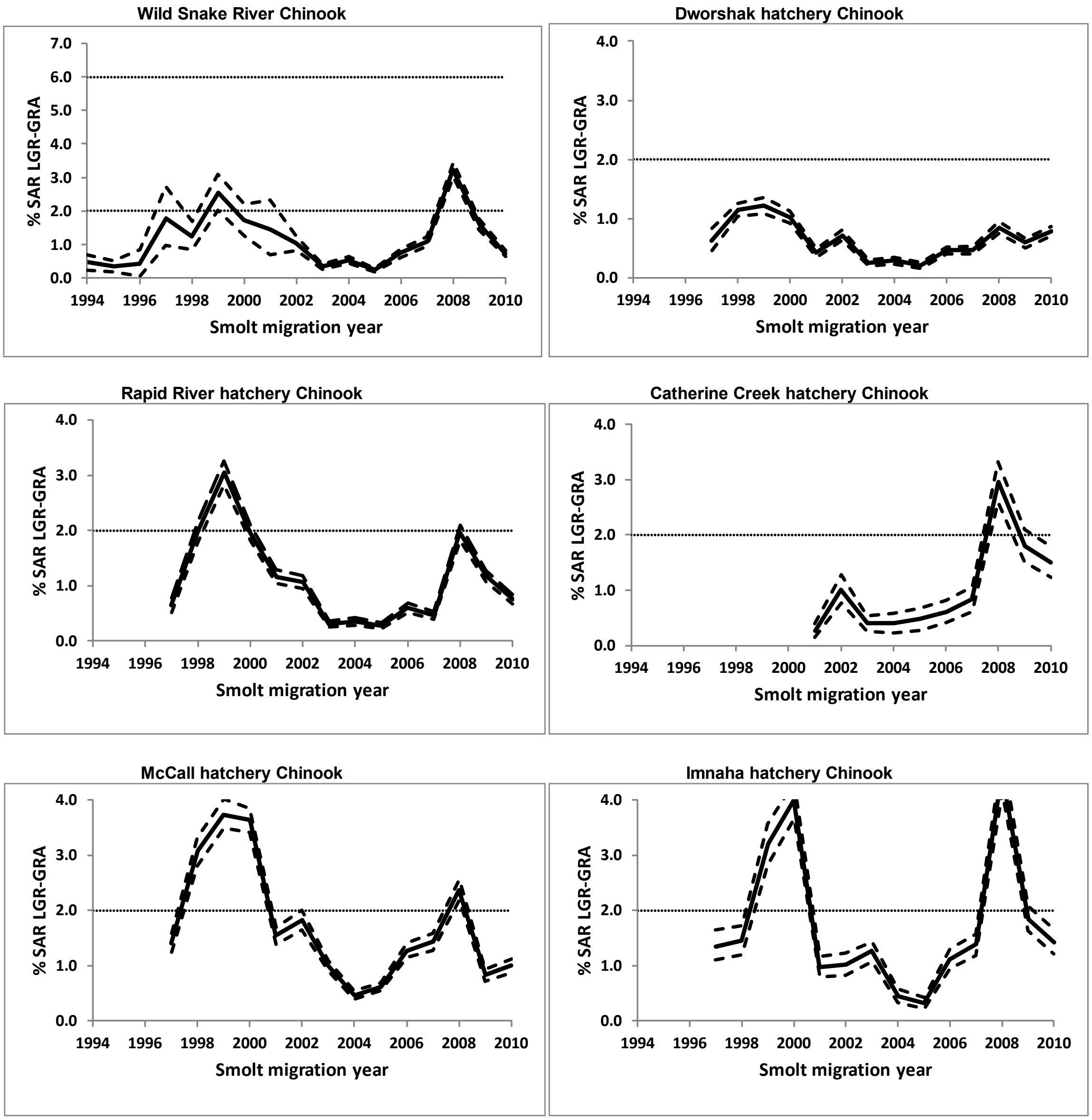


Figure 4.2. Bootstrapped LGR-to-GRA SAR (with jacks included) and upper and lower CI for Snake River wild spring/summer Chinook and five Snake River hatchery groups for migration years 1994-2010. Migration year 2010 is complete through 2-ocean returns only. The NPCC (2009) 2-6% SAR objective or minimum 2% SAR 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 4.3-4.12). LGR-GRA SARs (jacks included) for Dworshak hatchery spring Chinook averaged (geometric mean) 0.56% and did not exceed 2% in any year during 1997-2010 (Table 4.3). LGR-GRA SARs for Rapid River hatchery spring Chinook averaged 0.87% and exceeded 2% in a single year (1999; Table 4.5). Catherine Creek hatchery Chinook SARs from 2001 through 2010 averaged 0.78% and exceeded 2% only in 2008 (Table 4.7). 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) 1.44% and exceeded 2% in four years (1998-2000 and 2008; Table 4.9). LGR-GRA SARs for Imnaha hatchery summer Chinook averaged 1.37% and exceeded 2% in three years (1999, 2000 and 2008; Table 4.11). 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 = 0.78) during 1997-2010.

The estimated overall SARs for additional Snake River hatchery spring and summer Chinook groups for migration years 2006-2010 are presented in Figure 4.3 and Tables 4.13-4.18. LGR-GRA SARs (jacks included) for Clearwater hatchery spring Chinook, Sawtooth hatchery spring Chinook and Pahsimeroi Hatchery summer Chinook varied by year within a range similar to other CSS hatchery Chinook groups.

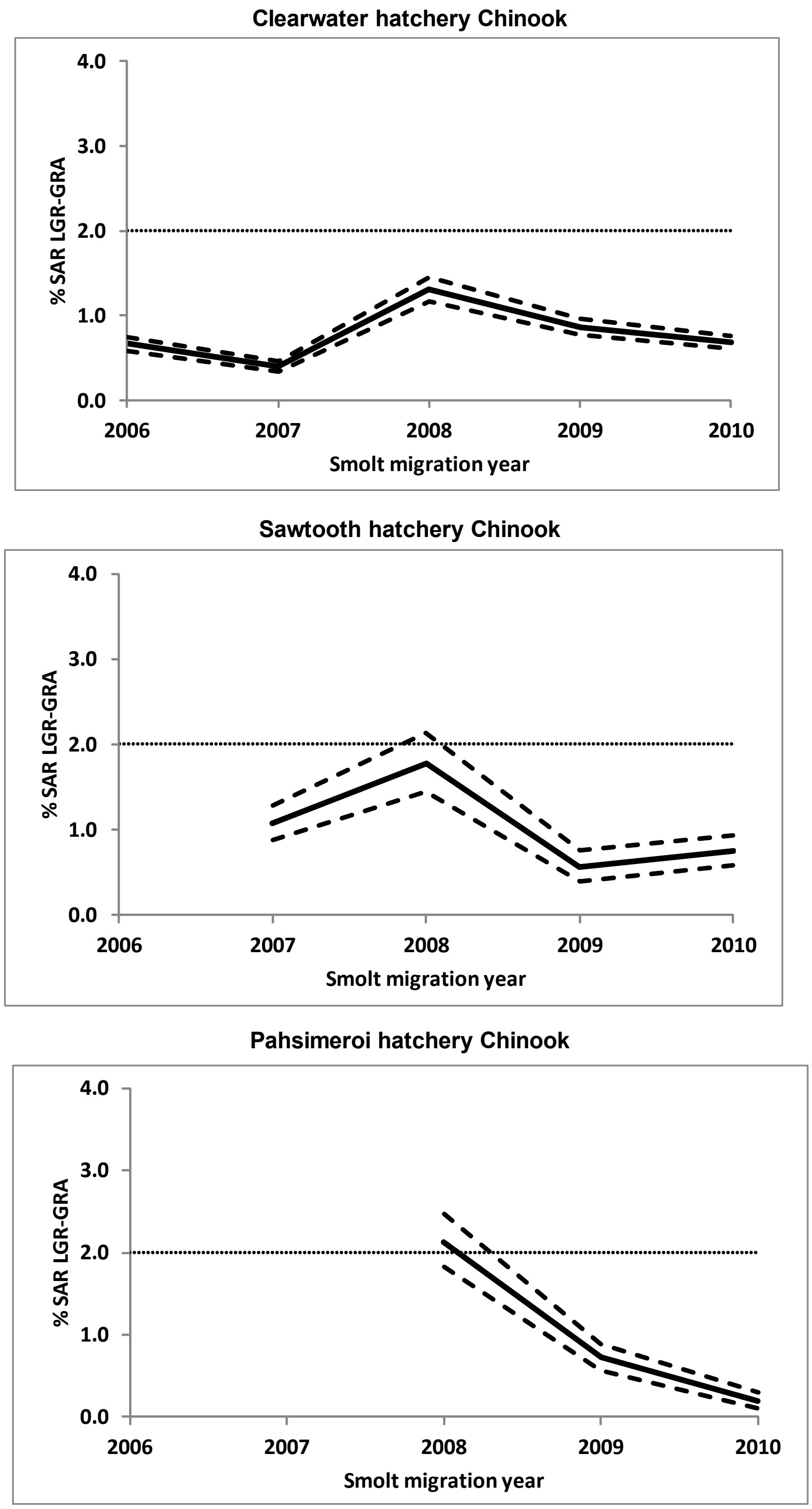


Figure 4.3. Bootstrapped LGR-to-GRA SAR (with jacks included) and upper and lower CI for three additional Snake River hatchery groups for migration years 2006-2010. Migration year 2010 is complete through 2-ocean returns only. The NPCC (2009) minimum 2% SAR for listed wild populations is shown for reference.

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 4.4). The geometric mean SAR during 1964-1969 was 7.2% compared to 1.7% during 1990-1999 and 2.4% during 2000-2009. Snake River wild steelhead and wild spring/summer Chinook SARs were highly correlated (r = 0.73) during the 1964-2009 period when aligned by smolt migration year.

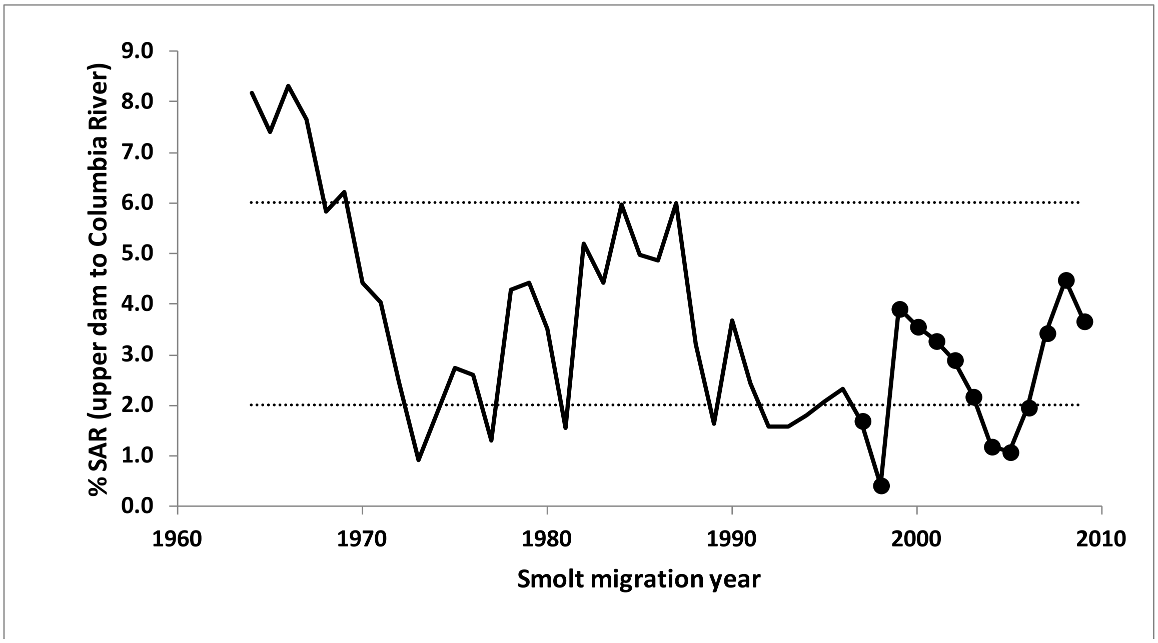
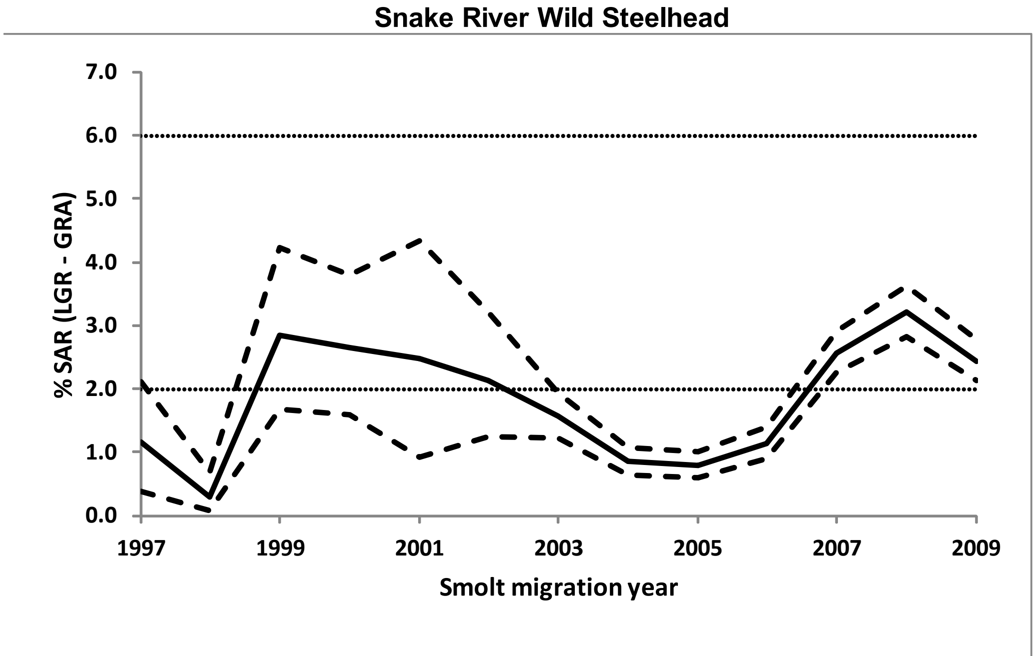


Figure 4.4. SARs from smolts at uppermost Snake River dam to Columbia River returns for wild Snake River steelhead, 1964-2009. SARs based on run reconstruction (1964-1996, solid line) and CSS PIT tags (1997-2009, dots and solid line). The NPCC (2009) 2%-6% SAR objective for listed wild populations is shown for reference.

The geometric mean SAR (LGR-to-GRA) of PIT-tagged Snake River wild steelhead was 1.57% during the period 1997-2009 (Table 4.19; Figure 4.5 top plot); SAR point estimates exceeded the NPCC's minimum SAR objective of 2% in seven of 13 migration years (statistically significant in three years). SARs based on adult returns to BOA were about 36% greater (when comparing geometric mean of SAR ratios) than SARs based on returns to GRA (Table 4.19) because of the combined effect of adult dam passage loss, straying and Zone 6 harvest. The CSS plans to investigate the feasibility of estimating Snake River wild steelhead SARs at finer scales (e.g., Major Population Groups or A-run/B-run) in future reports.

The estimated overall SARs (LGR-to-GRA) for Snake River hatchery steelhead averaged 1.29% (geometric mean for 1997-2009) and exceeded 2% only in 2004 and 2008 (Table 4.20; Figure 4.5, bottom plot). Overall SARs (LGR-to-GRA) of Snake River wild and hatchery steelhead aggregate groups were not strongly correlated (r = 0.31) during 1997-2009.

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 and 2009 (Table 4.20).



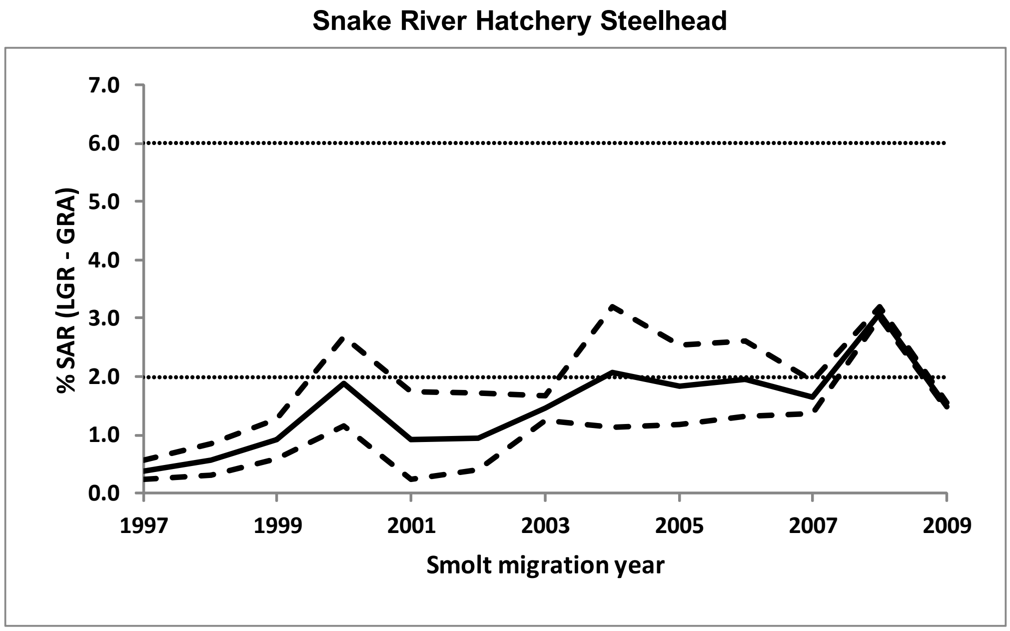


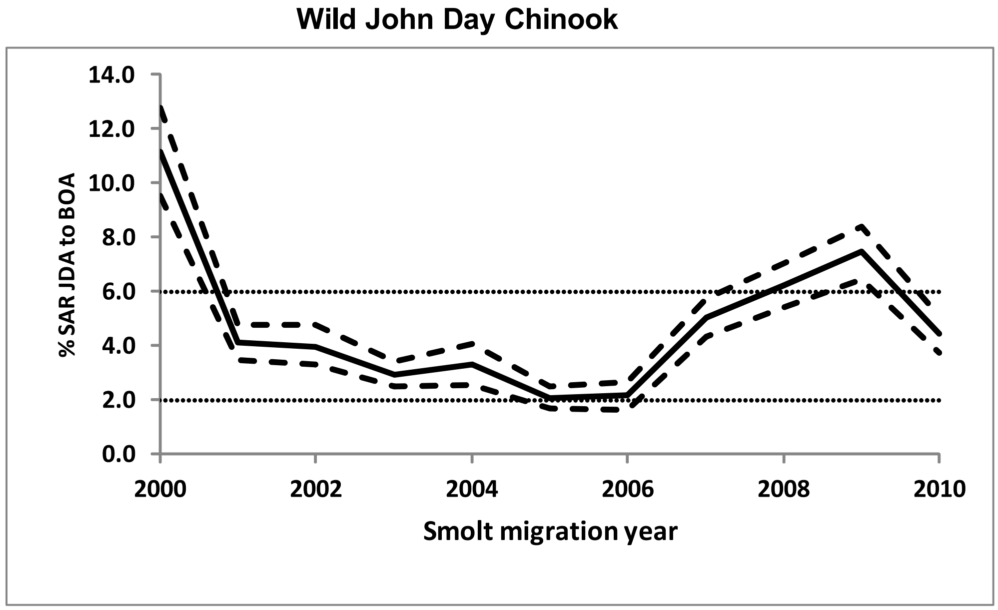
Figure 4.5. Bootstrapped LGR-to-GRA SAR and upper and lower CI for Snake River wild and hatchery steelhead for migration years 1997-2009. The 2008-2009 hatchery steelhead estimates represent the weighted mean for the 5 groups. The NPCC (2009) 2-6% SAR objective for listed wild populations is shown for reference.

The first juvenile migration year with sufficient numbers of PIT-tagged smolts to estimate SARs for Snake River hatchery sockeye is 2009. The hatchery sockeye SAR (LGR-GRA) for migration year 2009 was 1.15% for Sawtooth hatchery-reared sockeye and 2.03% for Oxbow hatchery-reared sockeye (Table 4.21). The estimated SAR LGR-to-BOA for Sawtooth sockeye in 2010 was 1.34% compared to 1.81% in 2009 (Table 4.21). In 2010 all PIT-tagged sockeye were routed in-river. There were very few incidentally transported PIT-tagged fish in 2010, therefore, an estimate of overall SAR LGR-to-GRA was not possible for the Sawtooth hatchery group. Sample size was limited for the Oxbow hatchery sockeye group both years, and estimation of SAR to either GRA or BOA was not possible for the Oxbow group in 2010.

Mid Columbia River Overall SARs

In contrast to Snake River spring/summer Chinook and steelhead, no historic 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. The CSS will explore incorporating these run reconstruction SAR estimates into a long-time series for mid-Columbia spring Chinook in future analyses.

The geometric mean SAR (JDA-to-BOA, including jacks) of PIT-tagged John Day River wild spring Chinook was 4.25% during the 11-year period 2000-2010 (Table 4.22; Figure 4.6). John Day wild spring Chinook SAR point estimates exceeded the NPCC's minimum SAR objective of 2% in all migration years, and were significantly greater than 2% in all but two years (2005 and 2006). 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-BOA) of Yakima River wild spring Chinook was 3.11% during 2000-2009 (no PIT tagged smolts were released in 2010). Yakima wild spring Chinook SAR point estimates exceeded the minimum 2% in six of ten migration years, and were significantly greater than 2% in five years Table 4.23). SARs of John Day and Yakima River wild spring Chinook averaged (geometric mean of ratio) nearly five times and three times, respectively, those of Snake River wild spring/summer Chinook (Table 4.1), and the wild SARs were correlated (average r = 0.72) between regions during the period 2000-2010.



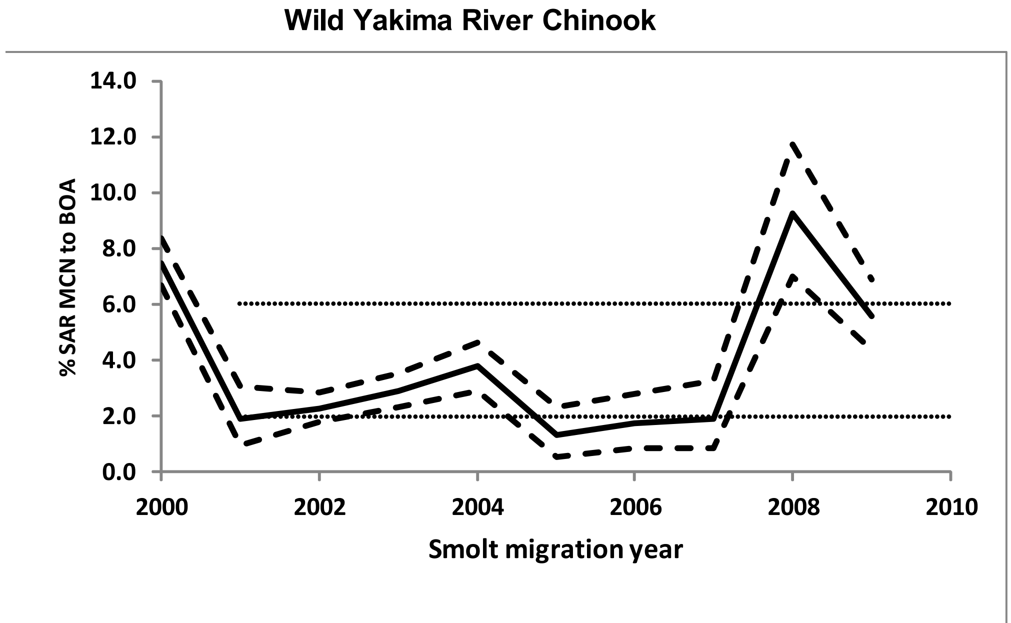
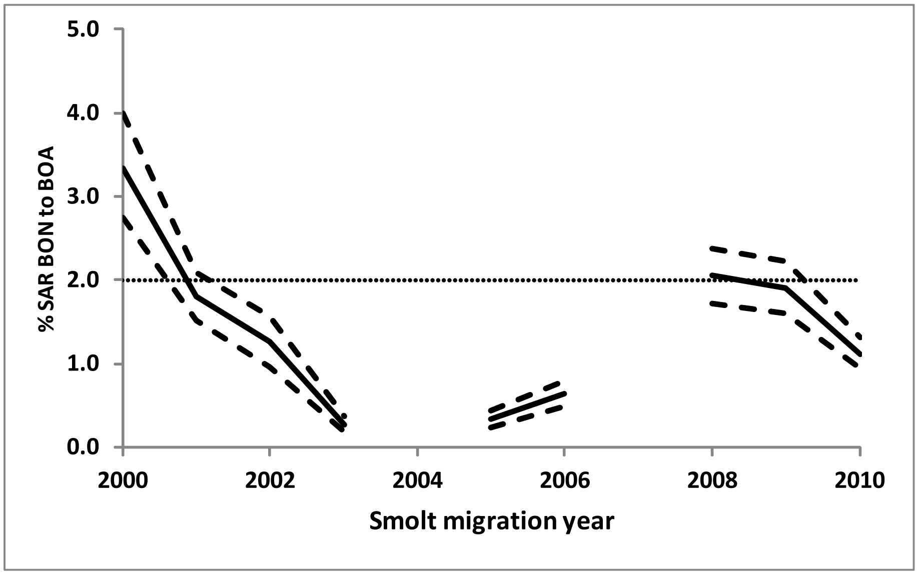


Figure 4.6. Bootstrapped SAR (including jacks) and upper and lower CI for wild spring Chinook from the John Day and Yakima rivers in the mid-Columbia region for migration years 2000-2010. Smolts are estimated at upper dam; adults are enumerated at BOA. Migration year 2010 is complete through 2-ocean returns only; no PIT tagged smolts were released in the Yakima River in 2010. The NPCC (2009) 2-6% SAR objective or the minimum 2% SAR 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 (Figure 4.7; Tables 4.24-4.25). BON-to-BOA SARs for Carson hatchery spring Chinook averaged (geometric mean) 1.07% during 2000-2010 (Table 4.24). MCN-BOA SARs for Cle Elum hatchery spring Chinook averaged 1.60% (Table 4.25). Estimated SARs for Warm Springs National Fish Hatchery spring Chinook 2007-2010 are presented in Table 4.26. 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 = 0.79) between populations during 2000-2010.

Carson Hatchery Chinook



Cle Elum Hatchery Chinook

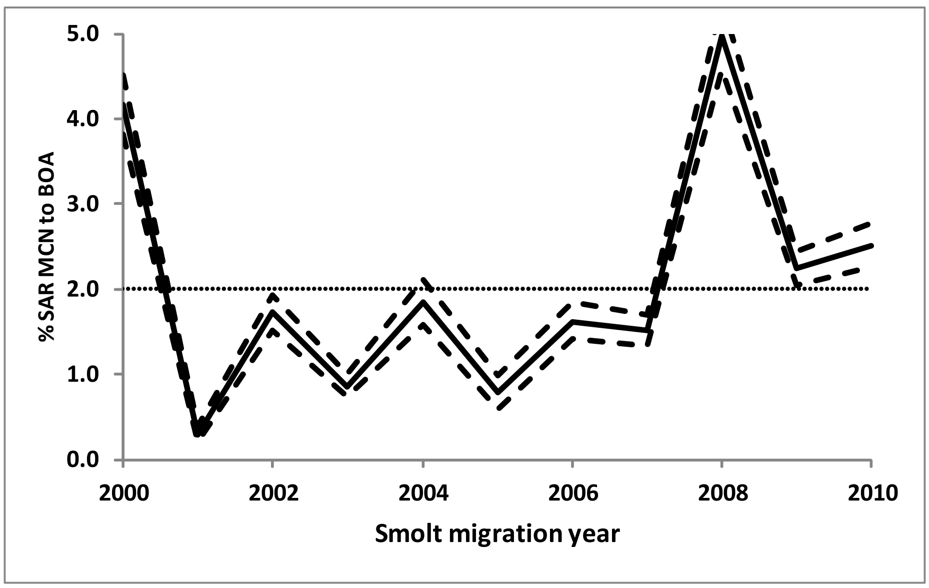


Figure 4.7. Bootstrapped SAR (including jacks) and upper and lower CI for hatchery spring Chinook in the mid-Columbia region for migration years 2000-2010. Smolts are estimated at upper dam; adults are enumerated at BOA. Migration year 2010 is complete through 2-ocean returns only. The NPCC (2009) 2-6% SAR objective or the minimum 2% SAR 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. We have the 2004-2009 PIT-tagged wild steelhead from John Day River summarized in Table 4.27. All six years of

JDA-BOA SAR estimates significantly exceeded the NPCC's minimum SAR objective of 2% (Figure 4.8). The PIT-tagged John Day River steelhead group represents an aggregate of five wild populations: the North Fork, Middle Fork, South Fork, upper mainstem, and lower mainstem John Day rivers. Fish in the lower mainstem John Day population from tributaries downstream of the ODFW juvenile seining site are not trapped and PIT tagged. Deschutes River wild steelhead SARs (BON-to-BOA) also significantly exceeded the NPCC's minimum SAR objective of 2% in the four years of study, 2006-2009 (Table 4.28; Figure 4.8). Yakima River wild steelhead SARs (MCN-to-BOA) significantly exceeded the NPCC's minimum SAR objective of 2% in all but one year (Table 4.29; Figure 4.8). 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, and correlated highly (average $r = 0.88$) with, wild steelhead SARs from the Snake River.

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.

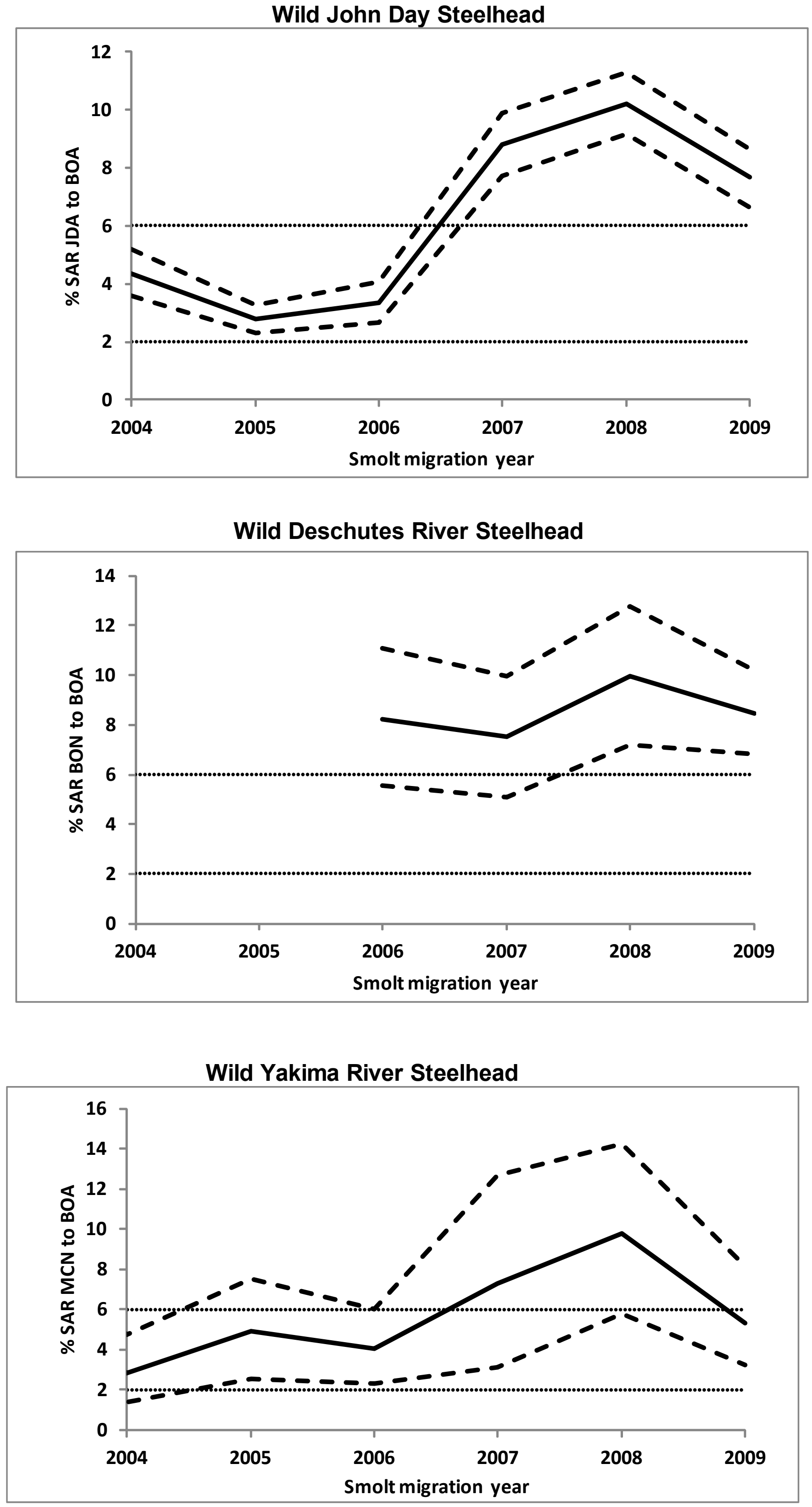


Figure 4.8. Bootstrapped SAR and upper and lower CI for wild steelhead from mid-Columbia region for migration years 2004-2009. Smolts are estimated at upper dam; adults are enumerated at BOA. The NPCC (2009) 2%-6% SAR objective or the minimum 2% SAR for listed wild populations is shown for reference.

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. 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. The CSS will explore incorporating Raymond's historic SAR estimates into a long-time series for upper Columbia spring Chinook and steelhead in future analyses.

An overarching goal of the CSS study is to establish long-term survival estimates over the full-life cycle of annual generations of salmon and steelhead from smolt to adult return and SARs for all other groups presented CSS reports are estimated from a smolt population at the uppermost dam encountered to an adult return at BOA or at the uppermost dam. However, the current lack of juvenile PIT tag detection capability in the Upper Columbia precludes this approach and therefore Upper Columbia SARs are presently estimated for most groups and migration years from MCN to BOA. 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) Public Utility District dams upstream of MCN.

The CSS has begun to estimate SARs of Upper Columbia wild spring Chinook and steelhead from populations upstream of Rocky Reach Dam (RRE), using smolt abundance estimates at RRE and adult counts at BOA for migration years 2008-2010. In addition, we have included time series of SARs from the SMP tagging at Rock Island Dam (RIS); these groups include wild/hatchery yearling (spring) Chinook; wild/hatchery subyearling (summer) Chinook, and wild/hatchery steelhead, migration years 2000-2010.

The estimated overall SARs (MCN to BOA, including jacks) for Upper Columbia River wild spring Chinook ranged from 0.5% to 3.3% during 2006-2010 (Tables 4.30 and 4.31; Figure 4.9); SARs significantly exceed 2% in 2008. The geometric mean SAR for Leavenworth hatchery spring Chinook was 0.58% during 2000-2010 (Table 4.32; Figure 4.9). The overall MCN-BOA SARs of Upper Columbia hatchery spring Chinook were highly correlated with wild and hatchery spring Chinook SARs from the mid-Columbia (average r = 0.79) and with wild and hatchery spring/summer Chinook SARs from the Snake River (average r = 0.83) during 2000-2010.

Overall SARs from RRE to BOA were also estimated in 2008 and 2010 for Upper Columbia River wild spring Chinook from the Entiat and Methow rivers (Table 4.33). Wild spring Chinook SARs based on smolts at RRE were only 51% (geometric mean of ratio) those based on smolts at MCN.

Overall SARs (MCN-BOA) for Upper Columbia River wild steelhead ranged from 1.9% to 6.7% during 2006-2009 (Table 4.34; Figure 4.10). SARs (MCN-BOA) for Upper Columbia River hatchery steelhead ranged from 0.9% to 5.8% during 2003-2008 (Table 4.35; Figure 4.10).

Overall SARs from RRE to BOA were also estimated in 2008 and 2009 for Upper Columbia River wild steelhead from the Entiat and Methow rivers (Table 4.36). This represents a subgroup of the wild steelhead aggregate reported in Table 4.33 (i.e., excludes Wenatchee River steelhead). Wild steelhead SARs based on smolts at RRE were only 61% (geometric mean of ratio) those based on smolts at MCN in 2008-2009.

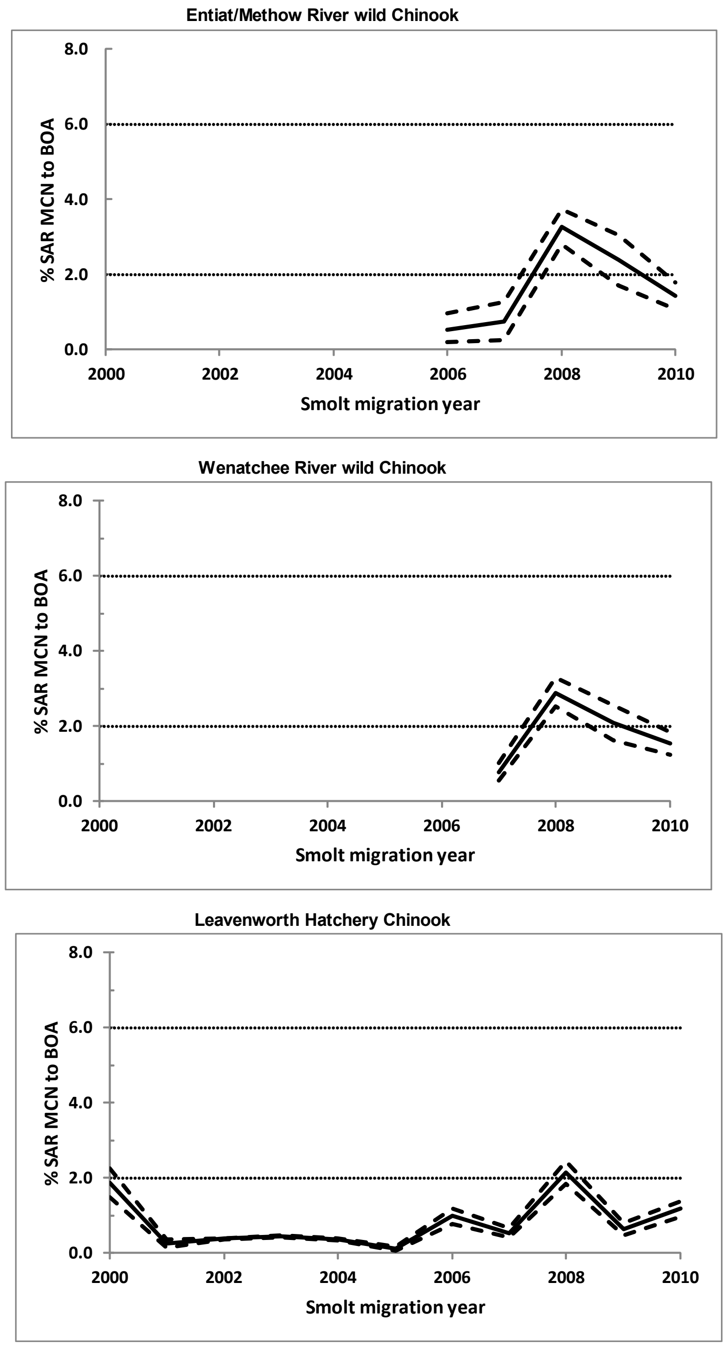
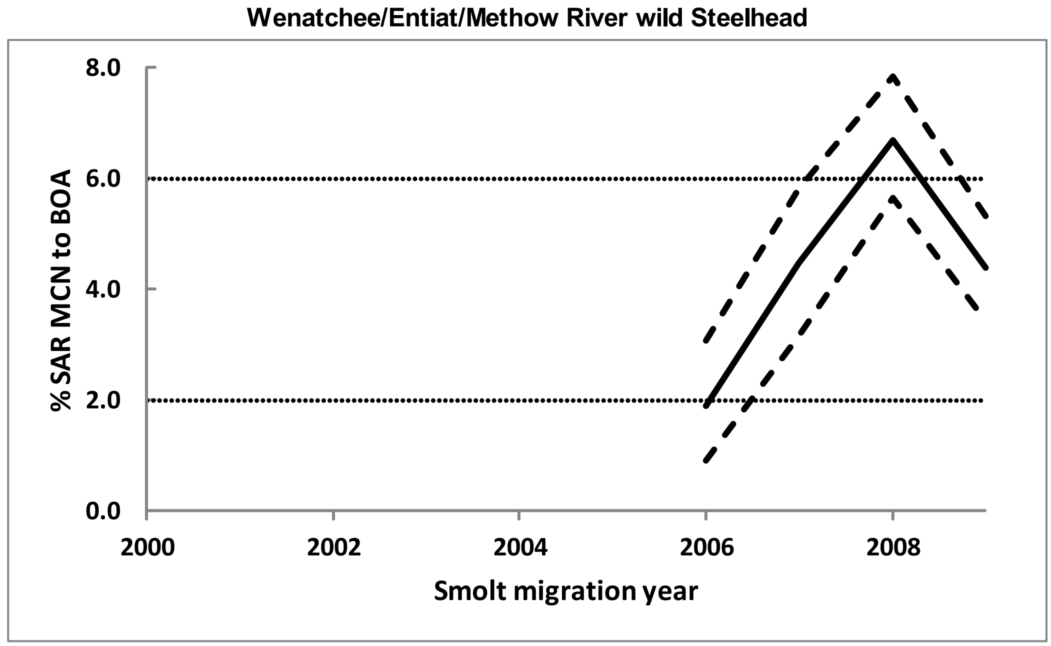


Figure 4.9. Bootstrapped SAR (MCN-to-BOA, including jacks) and upper and lower CI for Methow/Entiat River wild spring Chinook, Wenatchee River wild spring Chinook and Leavenworth hatchery spring Chinook from Upper Columbia region for migration years 2000-2010. Migration year 2010 is complete through 2-ocean returns only. The NPCC (2009) 2-6% SAR objective or minimum 2% SAR for listed wild populations is shown for reference.



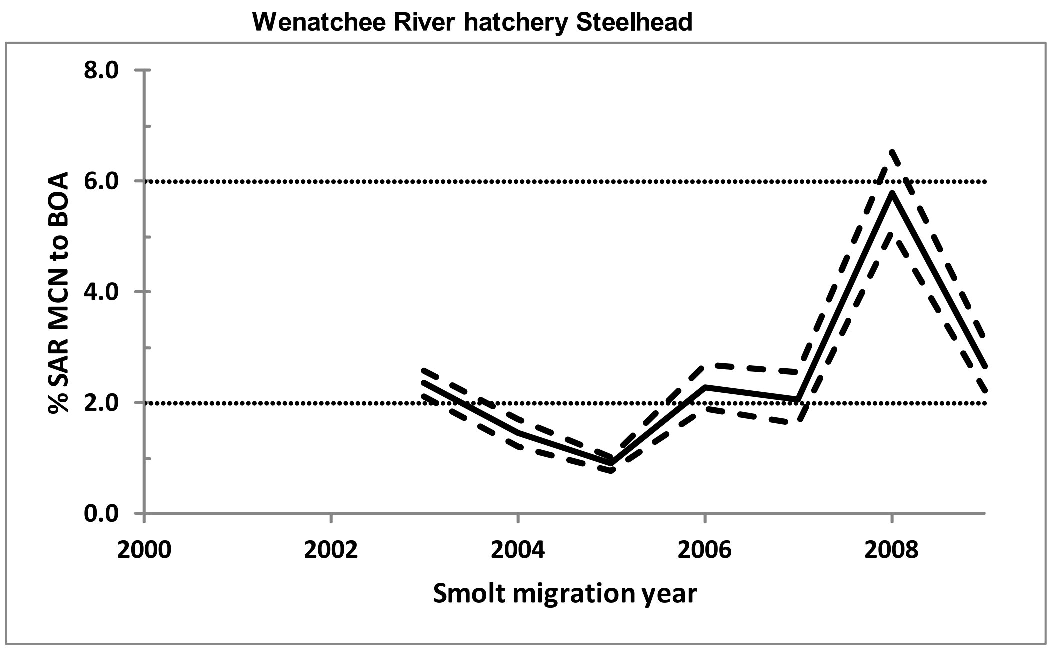


Figure 4.10. Bootstrapped SAR (MCN-to-BOA) and upper and lower CI for Methow/Entiat River wild steelhead and Wenatchee River hatchery steelhead from Upper Columbia region through the 2009 migration year. The hatchery steelhead group is a wild x wild cross released in the Wenatchee basin (reared at Chelan, East Bank, or Turtle Rock hatcheries depending on year). The NPCC (2009) 2-6% SAR objective for listed wild populations is shown for reference.

The missing component in the Upper Columbia SARs (upstream of McNary Dam in the Upper Columbia) is unavailable for most populations and migration years due to lack of smolt PIT tag detection at Upper Columbia mainstem dams. As described above, the CSS has begun to estimate SARs from Rocky Reach Dam for Entiat and Methow River wild spring Chinook and steelhead in recent years; SARs with smolt abundance estimated at RRE were about 50-60% those with smolt abundance estimated at MCN. The SMP estimates survival from Rock Island Dam (RIS; downstream of the Wenatchee basin) to McNary Dam for run-at-large hatchery and wild steelhead and Chinook captured, PIT-tagged, and released at RIS (FPC annual report 2010). Survival estimates through this 360 kilometer reach are estimated in 2-week periods across several migration years when sample size is available (Figure 4.11). The 2-week estimates are highly variable but consistently indicate that a large mortality occurs from RIS to MCN for the run-at-large spring Chinook (geometric mean survival = 0.57) and steelhead (geometric mean survival = 0.59). For the Wenatchee stocks, this implies that if it were possible to estimate SARs similarly to other CSS groups they would be, on average, 57% and 59% of that indicated by the MCN to BOA SAR. For example, for Wenatchee hatchery steelhead (Table 4.35) the geometric mean MCN to BOA SAR would change from 2.16% to 1.27%. SARs from smolts at RIS to adults at BOA are summarized in Tables 4.37 to 4.39 and Figure 4.12 for the SMP PIT tag groups of Upper Columbia wild and hatchery spring (yearling) Chinook, summer (subyearling) Chinook, and steelhead. The SARs RIS-to-BOA of the three Upper Columbia population groups were inter-correlated (average r = 0.63). The SARs of SMP groups are likely lower than for tributary-tagged wild groups 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, decade-long survival rate time series that is otherwise lacking in this region.

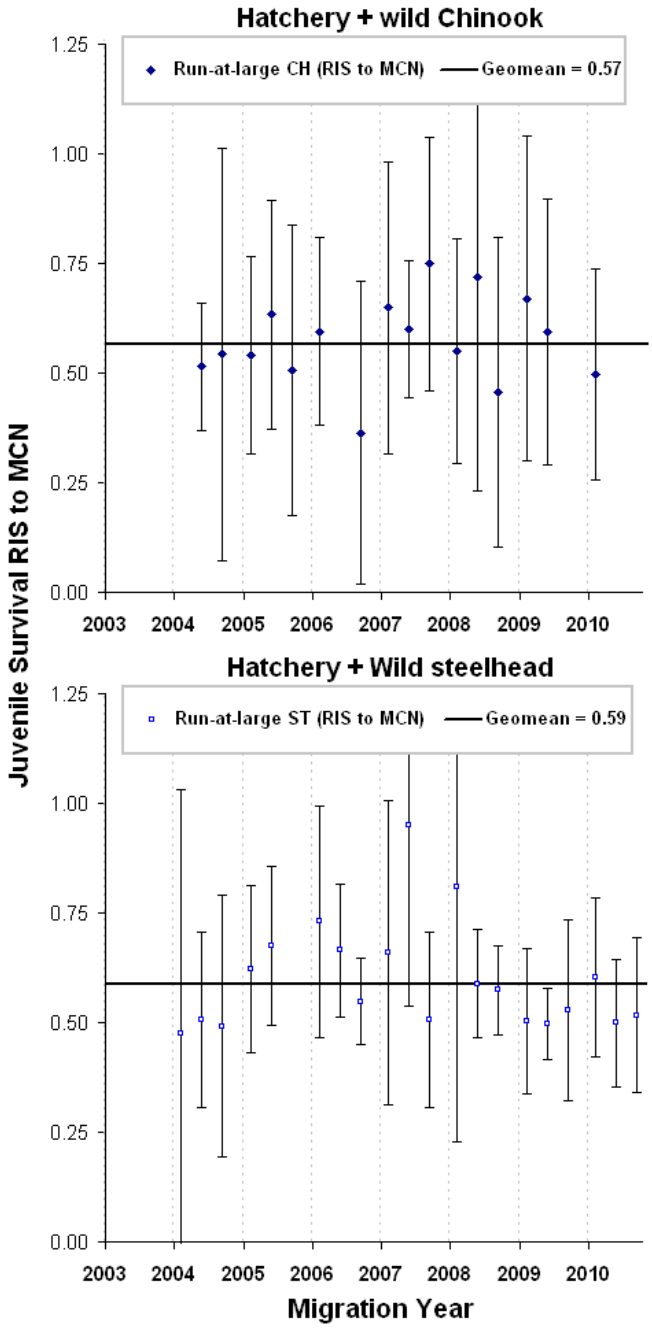


Figure 4.11. Juvenile survival from RIS to MCN for hatchery + wild yearling spring Chinook (top panel) and hatchery + wild steelhead (bottom panel). These two-week estimates are using CJS methods with smolts captured, PIT tagged, and released at RIS as part of the SMP project (FPC 2010 annual report). The confidence interval plotted is 95%.

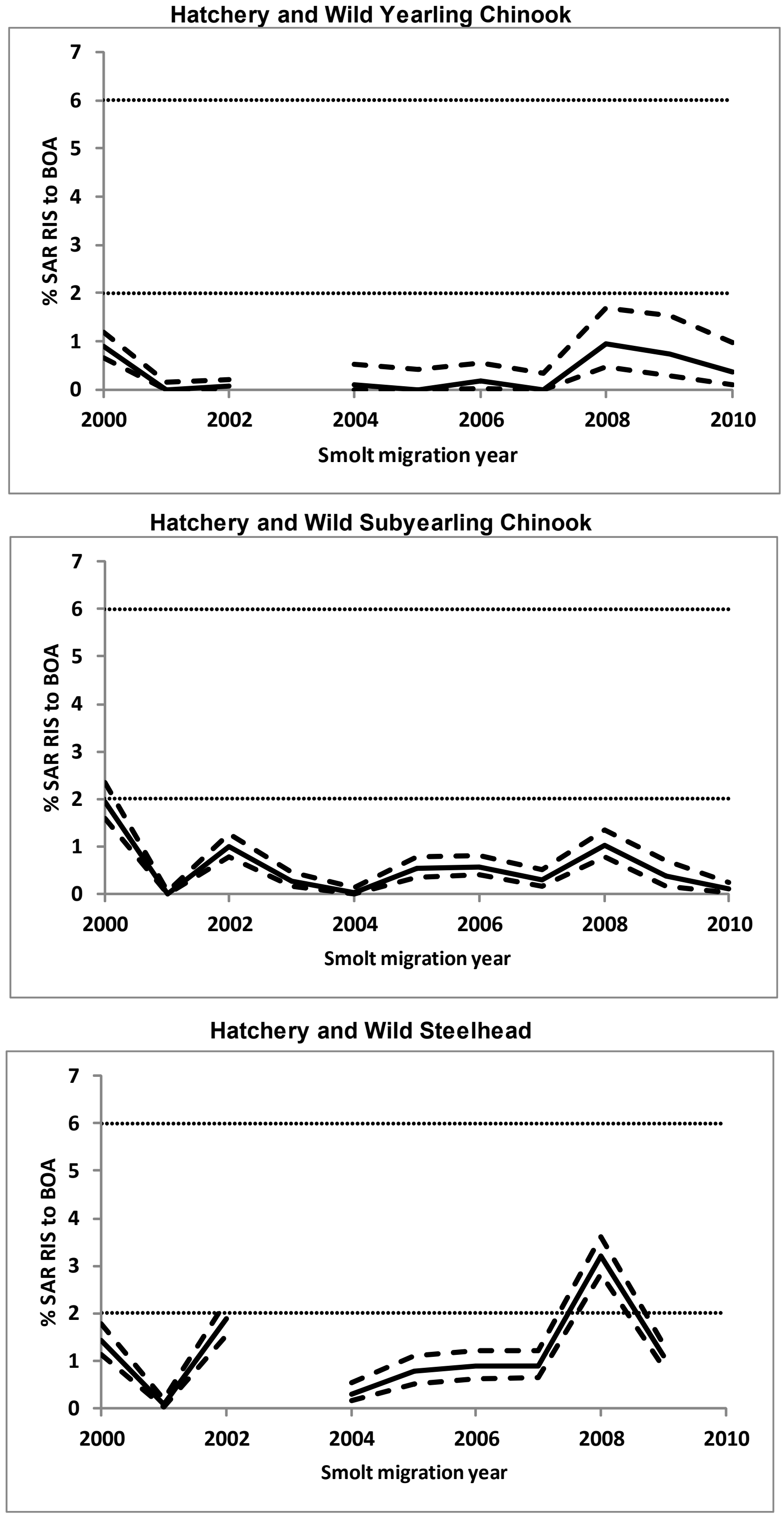


Figure 4.12. SAR (RIS-to-BOA) and upper and lower CI for Upper Columbia Wild and Hatchery Yearling Chinook (upper), Subyearling Chinook (middle) and steelhead (lower) tagged at Rock Island Dam for the Smolt Monitoring Program, 2000-2010. Smolts were tagged at upper dam; adults are enumerated at BOA. The NPCC (2009) 2%-6% SAR objective for listed wild populations is shown for reference.

Comparison of PIT-tag and Run Reconstruction SARs

The ISAB/ISRP (2008) 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 either 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 PIT-tagged, coded-wire-tagged, elastomer marked, and ad-clipped returned at a 25% lower rate than fish that were only coded-wire-tagged, elastomer marked, and ad-clipped. The Knudsen study illustrated the potential for PITtag effects, however, its applicability to other river reaches or populations of fish is unknown (Tuomikoski et al. 2009; DeHart 2009).

SARs based on IDFG run reconstruction (Kennedy et al. 2011; P. Kennedy, IDFG, pers. comm..) were 38% greater (geometric mean of ratio) than those based on PIT tags, during migration years 1996-2009 (Figure 4.13). The RR and PIT-tag SARs were highly correlated (0.95), and both time series indicated SARs were well short of the NPCC (2009) 2-6% SAR objectives across the majority of years.

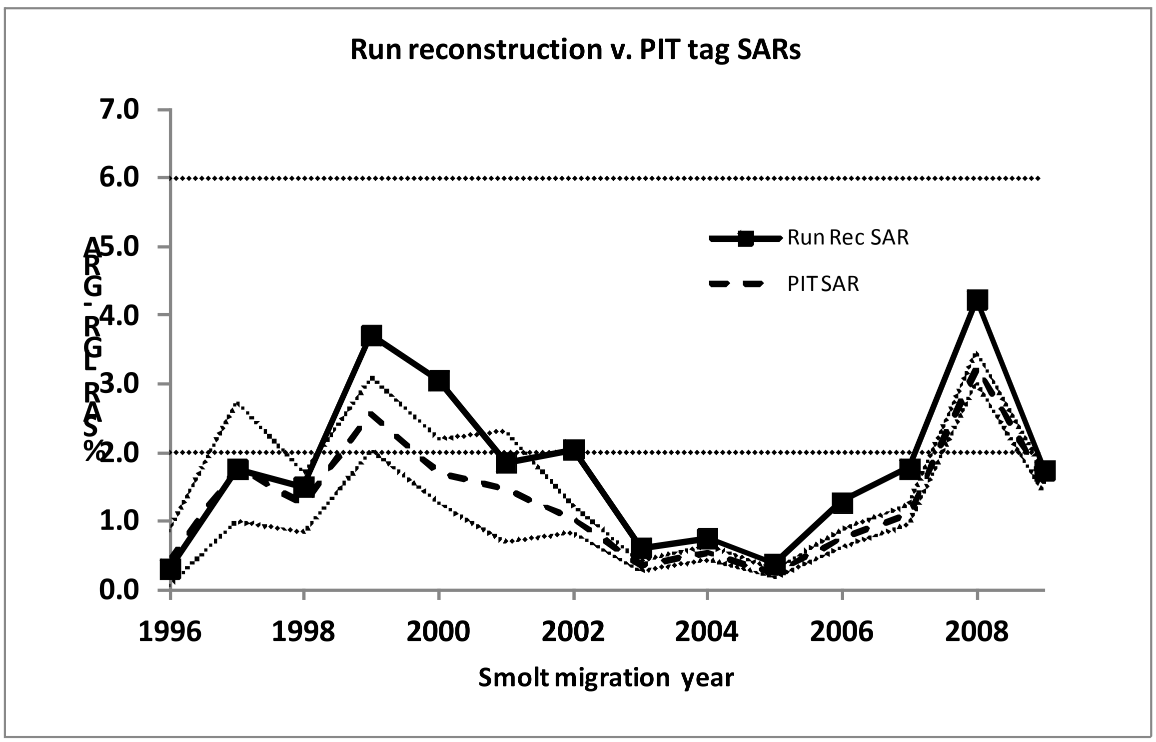


Figure 4.13. IDFG run reconstruction SARs (including jacks) compared to CSS PIT-tag SARs and 90% CI, Snake River wild spring/summer Chinook, migration years 1996-2009. NPCC (2009) 2-6% SAR objectives for listed wild populations are shown for reference.

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; 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.

The following factors could potentially bias RR SARs: 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.

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 1994-2009 ranged from 0.3% to 6.1% and the 6-year geometric mean was 1.9% (Table 4.40). These recent S.oa rates for spring/summer Chinook were more than five-fold lower than the geometric mean of 9.9% for the 1964-1969 period. Similarly, S.oa for wild steelhead declined more than 6-fold from a geometric mean of 17.5% during 1964-1969 to 2.6% during 1997-2009 (Table 4.41).

Estimated first year ocean survival rates, S.o1, for Snake River wild spring/summer Chinook during 1994-2009 ranged from 0.4% in 2005 to 8.2% in 2000 and the 16-year geometric mean was 2.6% (Table 4.40). Estimated S.o1 for wild steelhead during 1997-2008 ranged from 0.5% in 2004 to 9.7% in 2008 and the 13-yr geometric mean was 3.0% (Table 4.41). Over the same 13-yr period as shown for wild steelhead, the geometric mean of S.o1 was 2.7% for Snake River wild spring/summer Chinook. In contrast, the geometric mean of first year ocean survival during 1964-1969 was estimated to be 13.4% and 19.9% for Snake River spring/summer Chinook and steelhead, respectively (Petrosky and Schaller 2010).

There was a high degree of correlation during 1964-2009 between S.oa and S.o1 estimates, within species (0.999 for Chinook; 1.000 for steelhead) and between species (0.76 for both S.oa and S.o1). A possible advantage of the S.oa metric (over S.o1) is that it does not require any assumptions about annual ocean survival rates.

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 juvenile fish* transportation.

Discussion

In summary, it appears that neither Snake River wild spring/summer Chinook or wild steelhead populations are consistently meeting the NPCC 2-6% SAR objective. Geometric mean SARs (LGR-to-GRA) were 0.86% and 1.51% for PIT-tagged wild spring/summer Chinook and steelhead, respectively. 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, 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, in addition to providing valuable management information for the specific hatcheries and for 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. There were 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 1997-2008 are unknown, but may be related to the opportunistic nature of assembling aggregate hatchery steelhead groups from various monitoring programs prior to 2008. However, there appears to be a moderate correlation between wild spring/summer Chinook and wild steelhead SARs. More representative tagging for Snake River steelhead hatcheries began in coordination with LSRCP and IPC in migration year 2008. Future implementation of the CSS study 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.

The first juvenile migration year with sufficient numbers of PIT-tagged fish to estimate SARs for Snake River hatchery sockeye is 2009. The estimated sockeye SAR (LGR-GRA) for 2009 was 1.14% for Sawtooth hatchery-reared sockeye and 2.03% for Oxbow hatchery-reared sockeye. In 2010, all PIT-tagged sockeye were routed in-river, limiting our ability to estimate SARs for Snake River hatchery sockeye.

Mid-Columbia River wild spring Chinook populations, as represented by the John Day River and Yakima River aggregate groups, have experienced SARs generally within the range of the NPCC 2-6% SAR objective. The geometric mean SARs for John Day River and Yakima River wild spring Chinook were 4.3% and 2.7%, respectively, during 2000-2010. CSS has begun time series of wild steelhead SARs for the John Day River, Deschutes River and Yakima River, with all 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 2000-2010. 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 2000-2010. 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) Public Utility District dams upstream of MCN. The CSS has begun to estimate SARs of wild spring Chinook and steelhead from populations upstream of Rocky Reach Dam (RRE) for migration years 2008-2010. SARs from smolts at RRE were about 50-60% of those based on smolts at MCN for these populations and years.

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).

PIT tag SARs of Snake River wild spring/summer Chinook were highly correlated with IDFG RR SARs for the period 1996-2008, and SARs were well short of the NPCC 2-6% SAR objective from both time series. The RR SARs were about 38% 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 and being planned for other Columbia River hatcheries. Cooperative tagging efforts by the CSS, LSRCP and IPC, result in all Snake River spring/summer Chinook hatchery production releases now being PIT tagged at rates sufficient for in-season estimates of run size. Cassinelli et al. (2012) estimated that the window counts of hatchery Chinook (corrected for re-ascension and after-hours passage) ranged from 12% to 23% higher than the expanded PIT tag estimates in return years 2009-2011. Researchers also anticipate being able to estimate with relative precision returns of PIT-tagged and untagged McCall hatchery summer Chinook to the South Fork Salmon River (J. Cassinelli, IDFG, personal communication). The accounting would include estimates of adult survival from LGR to the South Fork Salmon River, Tribal and non-Tribal harvest within the subbasin and numbers of hatchery fish that drop out to spawn below the hatchery weir.

CSS studies have found that the SAR and first year ocean 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). Lower survival rates for spring/summer Chinook were associated with warmer ocean conditions, reduced upwelling in the spring, and with slower river velocity during the smolt migration or multiple passages through powerhouses at dams (Petrosky and Schaller 2010). Similarly, lower survival rates for steelhead were associated with warmer ocean conditions, reduced upwelling in the spring, and with 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) 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 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 in terms of improving the likelihood that Columbia River Basin salmon can survive varying ocean conditions (NPCC 2009). 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).

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) and Petrosky and Schaller (2010), have illuminated a promising direction of inquiry for upcoming CSS work. We plan to continue evaluation of the correlation of SARs among the regions. In addition, we plan to evaluate which environmental and river management variables best explain the variation in survival rates for the various life stages (e.g., SAR, S.oa, S.o1, and S.r) and by regional grouping. 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 and 2% minimum for recovery.
- 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.
- 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 NPPC SAR objectives.
- Hatchery (Carson and Cle Elum) and wild spring Chinook 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 upstream of MCN, most Upper Columbia SAR time series are presented as MCN-to-BOA, which overstates survival

within the migration corridor for these populations. The CSS has begun to estimate SARs from 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 PITtag 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 2009).

Supporting Tables

Table 4.1. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) wild spring/summer Chinook, 1994 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	90% LL	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 [B]	26,624	0.54	0.47	0.62	0.73	0.65	0.82
geometric mean		0.82			0.89		

[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 with 2-salt returns only through September 10, 2012.

Table 4.2. Overall LGR-to-BOA SARs for Snake River Basin (above LGR) wild spring/summer Chinook, 2000 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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 [B]	26,624	0.68	0.60	0.77	0.91	0.82	1.01
geometric mean		1.05			1.14		

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 with 2-salt returns only through September 10, 2012.

Table 4.3. Overall LGR-to-GRA SARs for Dworshak hatchery spring Chinook, 1997 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	90% LL	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	0.53	0.46	0.61	0.59	0.51	0.66
2010 [B]	32,204	0.45	0.38	0.51	0.78	0.70	0.86
geometric mean		0.48			0.56		

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 with 2-salt returns through September 10, 2012.

Table 4.4. Overall LGR-to-BOA SARs for Dworshak hatchery spring Chinook, 2000 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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	0.66	0.58	0.74	1.11	1.00	1.21
geometric mean		0.57			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 total tag release in years through 2005 and Group T tags beginning in 2006.

[B] Incomplete with 2-salt returns through September 10, 2012.

Table 4.5. Overall LGR-to-GRA SARs for Rapid River hatchery spring Chinook, 1997 to 2010. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR [A]	LGR-to-GRA without Jacks SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	LGR-to-GRA with Jacks SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 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 [B]	28,623	0.45	0.39	0.52	0.75	0.67	0.84
geometric mean		0.74			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 with 2-salt returns through September 10, 2012.

Table 4.6. Overall LGR-to-BOA SARs for Rapid River hatchery spring Chinook, 2000 to 2010. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR [A]	LGR-to-BOA without Jacks SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	LGR-to-BOA with Jacks SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 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 [B]	28,623	0.71	0.62	0.80	1.09	0.97	1.20
geometric mean		0.81			0.96		

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 with 2-salt returns through September 10, 2012.

Table 4.7. Overall LGR-to-GRA SARs for Catherine Creek hatchery spring Chinook, 2001 to 2010. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR [A]	LGR-to-GRA without Jacks SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	LGR-to-GRA with Jacks SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
1997	--	--	--	--	--	--	--
1998	--	--	--	--	--	--	--
1999	--	--	--	--	--	--	--
2000	--	--	--	--	--	--	--
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 [B]	6,329	0.84	0.66	1.04	1.50	1.23	1.78
geometric mean		0.58			0.78		

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 with 2-salt returns through September 10, 2012.

Table 4.8. Overall LGR-to-BOA SARs for Catherine Creek hatchery spring Chinook, 2001 to 2010. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving LGR [A]	LGR-to-BOA without Jacks SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	LGR-to-BOA with Jacks SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2000	--	--	--	--	--	--	--
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 [B]	6,329	1.14	0.90	1.39	1.90	1.60	2.24
geometric mean		0.78			1.00		

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 with 2-salt returns through September 10, 2012.

Table 4.9. Overall LGR-to-GRA SARs for McCall hatchery summer Chinook, 1997 to 2010. 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	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 [B]	20,552	0.53	0.45	0.61	1.00	0.87	1.12
geometric mean		1.07			1.44		

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 with 2-salt returns through September 10, 2012.

Table 4.10. Overall LGR-to-BOA SARs for McCall hatchery summer Chinook, 2000 to 2010. 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
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 [B]	20,552	0.66	0.56	0.75	1.25	1.11	1.38
geometric mean		1.11			1.49		

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 with 2-salt returns through September 10, 2012.

Table 4.11. Overall LGR-to-GRA SARs for Imnaha hatchery summer Chinook, 1997 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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 [B]	9,907	0.75	0.61	0.91	1.42	1.21	1.66
geometric mean		0.84			1.37		

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 with 2-salt returns through September 10, 2012.

Table 4.12. Overall LGR-to-BOA SARs for Imnaha hatchery summer Chinook, 2000 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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 [B]	9,907	0.73	0.59	0.88	1.76	1.53	2.02
geometric mean		0.98			1.55		

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 with 2-salt returns through September 10, 2012.

Table 4.13. Overall LGR-to-GRA SARs for Clearwater hatchery spring Chinook, 2006 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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 [B]	37,579	0.47	0.41	0.53	0.69	0.62	0.77
geometric mean		0.56			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 total tag release in years through 2005 and Group T tags beginning in 2006.

[B] Incomplete with 2-salt returns through September 10, 2012.

Table 4.14. Overall LGR-to-BOA SARs for Clearwater hatchery spring Chinook, 2006 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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 [B]	37,579	0.64	0.57	0.71	0.91	0.83	1.00
geometric mean		0.81			1.01		

[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 2005 and Group T tags beginning in 2006.

[B] Incomplete with 2-salt returns through September 10, 2012.

Table 4.15. Overall LGR-to-GRA SARs for Sawtooth hatchery spring Chinook, 2007 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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 [B]	6,631	0.42	0.30	0.56	0.75	0.59	0.94
geometric mean		0.57			0.95		

[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 with 2-salt returns through September 10, 2012.

Table 4.16. Overall LGR-to-BOA SARs for Sawtooth hatchery spring Chinook, 2007 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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 [B]	6,631	0.51	0.37	0.67	0.98	0.78	1.19
geometric mean		0.66			1.11		

[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 with 2-salt returns through September 10, 2012.

Table 4.17. Overall LGR-to-GRA SARs for Pahsimeroi hatchery summer Chinook, 2008 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	90% LL	90% UL
2008	5,963	1.27	1.02	1.52	2.13	1.82	2.47
2009	6,892	0.55	0.40	0.70	0.73	0.57	0.89
2010 [B]	5,729	0.09	0.03	0.16	0.19	0.10	0.30
geometric mean		0.39			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 with 2-salt returns through September 10, 2012.

Table 4.18. Overall LGR-to-BOA SARs for Pahsimeroi hatchery summer Chinook, 2008 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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 [B]	5,729	0.10	0.04	0.18	0.23	0.13	0.33
geometric mean		0.54			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 with 2-salt returns through September 10, 2012.

Table 4.19. Overall LGR-to-GRA and LGR-to-BOA SARs for Snake River Basin (above LGR) Wild Steelhead, 1997 to 2009.

Juvenile migration year	Smolts arriving LGR [A]	LGR-to-GRA			LGR-to-BOA		
		SAR	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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	2.44	2.14	2.77	3.56	3.17	3.98
geometric mean (97-09)		1.57		geomean	2.44		

[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.

Table 4.20. Overall LGR-to-GRA and LGR-to-BOA SARs for Snake River Basin (above LGR) Hatchery Steelhead, 1997 to 2009.

Juvenile migration year	Subbasin and run-type	Smolts arriving LGR [A]	LGR-to-GRA			LGR-to-BOA		
			SAR	Non-parametric CI		SAR	Non-parametric CI	
			Estimate	90% LL	90% UL	Estimate	90% LL	90% UL
1997	all	24,710	0.39	0.23	0.57	--	--	--
1998	all	23,507	0.56	0.31	0.85	--	--	--
1999	all	27,193	0.92	0.59	1.28	--	--	--
2000	all	24,565	1.89	1.16	2.68	2.28	1.46	3.08
2001	all	20,877	0.92	0.24	1.74	1.38	0.52	2.31
2002	all	20,681	0.95	0.40	1.72	0.98	0.29	1.71
2003	all	21,400	1.46	1.24	1.68	1.82	1.57	2.08
2004	all	17,082	2.08	1.14	3.19	2.28	1.24	3.45
2005	all	19,640	1.83	1.17	2.55	2.95	2.07	3.87
2006	all	13,473	1.96	1.32	2.62	2.71	1.98	3.52
2007	all	21,828	1.64	1.37	1.92	2.34	2.00	2.66
2008	GRN-A	16,858	4.54	4.23	4.85	6.75	6.37	7.15
2008	IMN-A	12,468	4.50	4.15	4.83	6.70	6.26	7.12
2008 [B]	SAL-A	19,133	4.78	4.51	5.07	6.45	6.13	6.78
2008	SAL-B	16,673	0.83	0.71	0.95	1.28	1.14	1.43
2008	CLW-B	24,718	1.46	1.33	1.58	2.17	2.01	2.33
2008	all	89,884	3.09	3.00	3.19	--	--	--
2009	GRN-A	15,279	1.62	1.44	1.79	2.45	2.23	2.68
2009	IMN-A	11,286	1.72	1.50	1.91	2.63	2.38	2.89
2009	SAL-A	29,321	1.91	1.78	2.04	2.52	2.37	2.67
2009	HCD-A	4,536	3.04	2.63	3.47	4.76	4.23	5.28
2009	SAL-B	15,706	0.74	0.63	0.85	1.12	0.99	1.26
2009	CLW-B	28,455	1.03	0.93	1.13	1.48	1.35	1.60
2009	all	103,947	1.49	1.43	1.55	--	--	--
geometric mean (97-09)			1.29	geomean (00-07)		1.98		

[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 2008.

[B] Excludes 1,200 released from Niagra Springs due to low number and exclusive return to river at transportation sites.

Table 4.21. Overall LGR-to-GRA and LGR-to-BOA SARs for Snake River Sawtooth (SAWT) and Oxbow (OXBH) hatchery Sockeye, 2009 to 2010.

Hatchery-Juvenile migration year	Smolts arriving LGR	LGR-to-GRA[A]			LGR-to-BOA[A]		
		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[B]	17,224	1.15	1.02	1.29	1.81	1.65	1.98
SAWT-2010[C]	8,071	--	--	--	1.34	0.38	3.14
OXBH-2009[B]	2,214	2.03	1.52	2.56	2.98	2.30	3.72
OXBH-2010[D]	2,524	--	--	--	--	--	--

[A] Adult returns through September 10, 2012. May still be incomplete returns.

[B] 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 .

[C] All PIT tagged sockeye were routed in-river. There were very few incidentally transported PIT-tagged fish, therefore, estimate of overall SAR LGR-to-GRA was not possible.

[D] All PIT tagged sockeye were routed in-river. Additionally, this group has a much lower sample size (less than 25% of Sawtooth release). Therefore, the overall SAR was not estimable.

Table 4.22. Overall JDA-to-BOA SARs for John Day River Basin Wild spring Chinook, 2000 to 2010. 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	2,799	3.14	2.43	3.85	3.32	2.57	4.04
2005	3,817	1.86	1.51	2.22	2.07	1.71	2.47
2006	2,232	2.06	1.52	2.56	2.15	1.61	2.65
2007	2,726	4.33	3.65	5.00	5.06	4.33	5.76
2008	2,980	5.47	4.72	6.27	6.21	5.40	7.03
2009	3,072	7.10	6.17	8.06	7.45	6.45	8.41
2010[B]	3,068	3.13	2.56	3.73	4.43	3.74	5.11
geometric mean		3.86			4.25		

[A] Estimated population of tagged study fish alive to JDA tailrace (includes 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 to augment the NOAA Trawl detections below BON.

[B] Incomplete with 2-salt returns only through September 10, 2012

Table 4.23. Overall MCN-to-BOA SARs for Yakima River Basin Wild spring Chinook, 2000 to 2010. SARs are calculated with and without jacks. No PIT-tagged smolts released in 2010.

Juvenile migration year	Smolts arriving MCN [A]	MCN-to-BOA without Jacks			MCN-to-BOA with Jacks		
		SAR	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	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	2.80	2.30	1.78	2.84
2003	2,143	2.47	1.97	3.06	2.89	2.32	3.55
2004	1,297	3.70	2.83	4.57	3.78	2.90	4.66
2005	519	1.35	0.56	2.31	1.35	0.56	2.31
2006	565	1.59	0.72	2.57	1.77	0.85	2.79
2007	362	1.93	0.87	3.30	1.93	0.87	3.30
2008	509	6.87	4.88	8.90	9.23	7.01	11.74
2009	987	4.96	3.82	6.14	5.57	4.35	6.87
2010	0	--			--		
geometric mean		2.81			3.11		

[A] Estimated population of tagged study fish alive to MCN tailrace (includes 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 to augment the NOAA Trawl detections below BON.

[B] Incomplete with 2-salt returns only through September 10, 2012

Table 4.24. Overall BON-to-BOA SARs for Carson Hatchery spring Chinook, 2000 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI			SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	90% LL	90% UL		Estimate	90% LL	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 [C]	---	---	---	---	---	---	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 [C]	---	---	---	---	---	---	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 [B]	11,155	0.97	0.80	1.15	1.11	0.94	1.31	14,947	0.72	0.72	0.95
geometric mean		1.02			1.07				0.78		

[A] Estimated population of tagged study fish alive to BON tailrace (includes 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 to augment the NOAA Trawl detections below BON.

[B] Incomplete with 2-salt returns only through September 10, 2012

[C] Not calculated; release to BON survival estiimate > 1.0.

Table 4.25. Overall MCN-to-BOA SARs for Cle Elum Hatchery spring Chinook, 2000 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	90% LL	90% UL
2000	13,794	3.81	3.47	4.14	4.17	3.82	4.52
2001	9,228	0.28	0.19	0.37	0.29	0.20	0.39
2002	11,728	1.37	1.19	1.55	1.73	1.51	1.93
2003	11,962	0.59	0.49	0.71	0.86	0.73	1.01
2004	7,982	1.54	1.30	1.78	1.85	1.59	2.12
2005	5,784	0.66	0.49	0.84	0.78	0.59	0.98
2006	10,141	1.25	1.07	1.44	1.62	1.42	1.84
2007	12,675	1.01	0.87	1.16	1.51	1.33	1.69
2008	11,837	3.12	2.81	3.42	4.98	4.58	5.37
2009	15,727	1.78	1.60	1.96	2.24	2.04	2.44
2010[B]	12,490	1.49	1.30	1.68	2.51	2.27	2.77
geometric mean		1.22			1.60		

[A] Estimated population of tagged study fish alive to MCN tailrace (includes fish detected at the dam and those estimated to pass undetected).

[B] Incomplete with 2-salt returns only through September 10, 2012

Table 4.26. Overall BON-to-BOA SARs for Warm Springs hatchery spring Chinook (Deschutes River), 2007 to 2010. 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	Non-parametric CI		SAR	Non-parametric CI			SAR	Non-parametric CI	
		Estimate	90% LL	90% UL	Estimate	90% LL	90% UL		Estimate	90% LL	90% UL
2007[B]	--	--	--	--	--	--	--	19,698	0.30	0.30	0.44
2008[B]	--	--	--	--	--	--	--	19,936	0.84	0.73	0.94
2009[B]	--	--	--	--	--	--	--	19,924	0.65	0.56	0.74
2010[C]	8,444	0.36	0.24	0.46	0.62	0.47	0.78	14,907	0.20	0.14	0.26
geometric mean		0.36			0.62				0.43		

[A] Estimated population of tagged study fish alive to BON tailrace (includes 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 to augment the NOAA Trawl detections below BON.

[B] Chinook smolts released in fall and spring and form two different cohorts. Cannot distinguish between fall and spring PIT tag releases. Estimating juvenile population at BON not possible.

[C] Incomplete with 2-salt returns only through September 10, 2012

Table 4.27. Overall JDA-to-BOA SARs for John Day River Basin wild steelhead, 2004-2009.

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
geometric mean		5.51		

[A] Estimated population of tagged study fish alive to JDA tailrace (includes 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 to augment the NOAA Trawl detections below BON.

Table 4.28. Overall BON-to-BOA SARs for Deschutes River Basin (Trout Creek) wild steelhead, 2006-2009.

Juvenile migration year	Smolts arriving BOA [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
geometric mean		8.50		

[A] Estimated population of tagged study fish alive to BON tailrace (includes 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 to augment the NOAA Trawl detections below BON.

Table 4.29. Overall MCN-to-BOA SARs for Yakima River Basin wild steelhead, 2002-2009.

Juvenile migration year	Smolts arriving MCN [A]	MCN-to-BOA		
		SAR Estimate	Non-parametric CI	
			90% LL	90% UL
2002	357	8.12	5.13	11.33
2003	293	7.85	5.02	11.08
2004	384	2.86	1.39	4.76
2005	263	4.94	2.56	7.52
2006	397	4.03	2.32	6.03
2007	219	7.30	3.12	12.67
2008	215	9.79	5.77	14.24
2009	375	5.33	3.25	8.18
geometric mean		5.86		

[A] Estimated population of tagged study fish alive to MCN tailrace (includes 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 to augment the NOAA Trawl detections below BON.

Table 4.30. Overall MCN-to-BOA SARs for Upper Columbia Wild spring Chinook (Wenatchee River), 2007 to 2010.

Juvenile migration year	Smolts arriving MCA[A]	MCN-to-BOA (without jacks)[B] SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	MCN-to-BOA (with jacks)[B] 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[C]	4,837	1.20	0.94	1.47	1.53	1.24	1.85
geometric mean		1.49			1.62		

[A] Estimated population of tagged study fish alive to MCN tailrace (includes fish detected at the dam and those estimated to pass undetected).

[B] CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary to augment the NOAA Trawl detections below BON.

[C] 2010 returns incomplete, 2-salts only through September 10, 2012

Table 4.31. Overall MCN-to-BOA SARs for Upper Columbia Wild spring Chinook (Entiat and Methow Rivers), 2006 to 2010.

Juvenile migration year	Smolts arriving MCA[A]	MCN-to-BOA (without jacks)[B] SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	MCN-to-BOA (with jacks)[B] SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006[C]	927	0.43	0.11	0.81	0.54	0.2	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[D]	3,205	1.31	0.96	1.65	1.44	1.07	1.78
geometric mean		1.22			1.35		

[A] Estimated population of tagged study fish alive to MCN tailrace (includes fish detected at the dam and those estimated to pass undetected).

[B] CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary to augment the NOAA Trawl detections below BON.

[C] 2006 is Entiat River only

[D] 2010 returns incomplete, 2-salts only through September 10, 2012

Table 4.32. Overall MCN-to-BOA SARs for Leavenworth Hatchery spring Chinook (Wenatchee River), 2007 to 2010. SARs are calculated with and without jacks.

Juvenile migration year	Smolts arriving MCA [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
2000	4,360	1.83	1.45	2.21	1.86	1.47	2.24
2001	3,808	0.24	0.13	0.37	0.24	0.13	0.37
2002	178,609	0.36	0.34	0.39	0.38	0.35	0.40
2003	153,594	0.43	0.40	0.45	0.45	0.42	0.48
2004	104,754	0.34	0.31	0.37	0.35	0.32	0.38
2005	7,880	0.09	0.04	0.15	0.11	0.05	0.18
2006	8,183	0.89	0.72	1.09	0.98	0.78	1.19
2007	8,882	0.46	0.34	0.59	0.53	0.41	0.65
2008	9,118	1.91	1.65	2.18	2.13	1.85	2.44
2009	7,152	0.57	0.43	0.72	0.63	0.48	0.79
2010 [B]	9,838	0.75	0.61	0.90	1.17	0.97	1.37
geometric mean		0.52			0.58		

[A] Estimated population of tagged study fish alive to MCN tailrace (includes fish detected at the dam and those estimated to pass undetected).

[B] Incomplete with 2-salt returns only through September 10, 2012

Table 4.33. Overall RRE-to-BOA SARs for Upper Columbia Wild Chinook (Entiat and Methow Rivers), 2008 to 2010.

Juvenile migration year	RRE-to-BOA (without jacks)[B]			RRE-to-BOA (with jacks)[B]		
	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]	1.55	1.17	1.94	1.72	1.30	2.16
2009[D]	--	--	--	--	--	--
2010[E]	0.80	0.59	1.00	0.88	0.66	1.08
geometric mean	1.11			1.23		

[A] The Entiat/Methow wild Chinook aggregate 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 PIT-tags detected on bird colonies in the Columbia River estuary to augment the NOAA Trawl detections below BON.

[C] Uses recaptures at Rocky Reach Dam

[D] Too few recaptures to calculate SARs

[E] Uses new juvenile detector and recaptures at Rocky Reach Dam. 2010 returns incomplete, 2-salts only through September 10, 2012

Table 4.34. Overall MCN-to-BOA SARs for Upper Columbia Wild Steelhead (Wenatchee, Entiat and Methow Rivers), 2006 to 2009.

Juvenile migration year	Smolts arriving MCA[A]	MCN-to-BOA[B]		
		SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2006[C]	472	1.91	0.90	3.08
2007	896	4.46	3.16	5.81
2008	2,260	6.68	5.66	7.84
2009	1,621	4.38	3.44	5.32
geometric mean		3.97		

[A] Estimated population of tagged study fish alive to MCN tailrace (includes fish detected at the dam and those estimated to pass undetected).

[B] CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and returning adults to augment the NOAA Trawl detections below BON.

[C] 2006 is Entiat River only, all other years are Entiat, Methow, and Wenatchee Rivers combined

Table 4.35. Overall MCN-to-BOA SARs for Upper Columbia Hatchery Steelhead released into the Wenatchee Basin (Eastbank, Turtle Rock, and Chelan hatcheries), 2003 to 2009.

Juvenile migration year	Smolts arriving MCA[A]	MCN-to-BOA[B]		
		SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 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
geometric mean		2.16		

[A] Estimated population of tagged study fish alive to MCN tailrace (includes fish detected at the dam and those estimated to pass undetected).

[B] CJS estimation of S1 uses PIT-tags detected on bird colonies in the Columbia River estuary and returning adults to augment the NOAA Trawl detections below BON.

Table 4.36. Overall RRE-to-BOA SARs for Upper Columbia Wild Steelhead (Entiat and Methow Rivers), 2008 to 2009.

Juvenile migration year	RRE-to-BOA[B] SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2008	4.77	3.31	6.47
2009	2.30	1.57	3.17
geometric mean	3.31		

[A] The Entiat/Methow wild steelhead aggregateis 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 to augment the NOAA Trawl detections below BON.

[C] Uses recaptures at Rocky Reach Dam

Table 4.37 Overall RIS-to-BOA SARs for Upper Columbia Wild and Hatchery Yearling Chinook tagged at Rock Island Dam, 2000 to 2010.

Juvenile migration year	Smolts tagged at RIS[A]	RIS-to-BOA (without jacks) SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL	RIS-to-BOA (with jacks) SAR Estimate	Non-parametric CI 90% LL	Non-parametric CI 90% UL
2000	3989	0.90	0.67	1.19	0.90	0.67	1.19
2001	1837	0.00	0.00	0.16	0.00	0.00	0.16
2002	3987	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	1127	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	0.38	0.10	0.97	0.38	0.10	0.97
geometric mean		--			--		
arithmetic mean		0.28			0.33		

[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.

[B] No Data in 2003 due to bypass inoperable during spring outmigration

Table 4.38 Overall RIS-to-BOA SARs for Upper Columbia Wild and Hatchery Sub-yearling Chinook tagged at Rock Island Dam, 2000 to 2010.

Juvenile migration year	Smolts tagged at RIS[A]	RIS-to-BOA (without jacks) SAR Estimate	RIS-to-BOA (without jacks) Non-parametric CI 90% LL	RIS-to-BOA (without jacks) Non-parametric CI 90% UL	RIS-to-BOA (with jacks) SAR Estimate	RIS-to-BOA (with jacks) Non-parametric CI 90% LL	RIS-to-BOA (with jacks) Non-parametric CI 90% UL
2000	4073	1.94	1.60	2.33	2.01	1.66	2.41
2001	4484	0.00	0.00	0.07	0.00	0.00	0.07
2002	4800	1.00	0.78	1.27	1.06	0.83	1.34
2003	4338	0.28	0.16	0.45	0.28	0.16	0.45
2004	3183	0.03	0.00	0.15	0.03	0.00	0.15
2005	3547	0.54	0.35	0.79	0.59	0.40	0.85
2006	4208	0.57	0.39	0.80	0.62	0.43	0.86
2007	3596	0.31	0.17	0.51	0.36	0.21	0.57
2008	3678	1.03	0.77	1.35	1.06	0.80	1.38
2009	1889	0.37	0.17	0.69	0.37	0.17	0.69
2010	3625	0.11	0.04	0.25	0.14	0.05	0.29
geometric mean		--			--		
arithmetic mean		0.56			0.59		

[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.

Table 4.39 Overall RIS-to-BOA SARs for Upper Columbia Wild and Hatchery steelhead tagged at Rock Island Dam, 2000 to 2010.

Juvenile migration year	Smolts tagged at RIS[A]	RIS-to-BOA SAR Estimate	RIS-to-BOA Non-parametric CI 90% LL	RIS-to-BOA Non-parametric CI 90% UL
2000	3946	1.42	1.12	1.77
2001	4027	0.07	0.02	0.19
2002	3996	1.88	1.54	2.27
2003[B]	--	--	--	--
2004	2627	0.30	0.15	0.55
2005	2850	0.77	0.52	1.10
2006	3181	0.88	0.63	1.20
2007	3551	0.90	0.66	1.21
2008	6052	3.21	2.84	3.60
2009	5304	1.09	0.87	1.36
geometric mean		0.80		
arithmetic mean		1.17		

[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.

[B] No Data in 2003 due to bypass inoperable during spring outmigration

Table 4.40. Estimation of ocean survival rates, S.oa, and first year ocean survival rates, S.o1, for Snake River wild spring/summer Chinook, migration years 1964-2009. Estimates for 1964-1993 based on Petrosky and Schaller (2010); estimates for 1994-2009 based on CSS parameter estimates for SAR, in-river survival, proportion transported and D. Survival rates from 1985 through 1992 are unavailable.

Migration year	In-river survival (SR)	Proportion transported (pT)	D	System survival	SAR (lgr-lgr)	SAR (lgr - Col. R. mouth)	S.oa(lgr)	S.oa(col)	S.o1
1964	0.46	0.00	0.53	0.46	0.022	0.038	0.049	0.082	0.113
1965	0.46	0.00	0.53	0.46	0.026	0.039	0.056	0.084	0.114
1966	0.46	0.00	0.53	0.46	0.021	0.035	0.046	0.076	0.104
1967	0.47	0.00	0.53	0.47	0.035	0.065	0.074	0.139	0.183
1968	0.45	0.00	0.53	0.45	0.020	0.036	0.043	0.080	0.106
1969	0.34	0.00	0.53	0.34	0.024	0.055	0.072	0.161	0.224
1970	0.17	0.00	0.53	0.17	0.014	0.028	0.080	0.163	0.222
1971	0.20	0.03	0.53	0.21	0.011	0.020	0.053	0.093	0.124
1972	0.09	0.07	0.53	0.12	0.008	0.012	0.063	0.100	0.142
1973	0.03	0.07	2.16	0.18	0.004	0.005	0.020	0.028	0.039
1974	0.28	0.00	0.53	0.28	0.009	0.012	0.032	0.043	0.061
1975	0.19	0.10	0.53	0.22	0.026	0.034	0.117	0.151	0.217
1976	0.10	0.14	0.53	0.16	0.003	0.004	0.019	0.026	0.035
1977	0.01	0.56	2.16	1.19	0.005	0.008	0.005	0.007	0.010
1978	0.23	0.48	0.53	0.37	0.009	0.014	0.025	0.038	0.053
1979	0.19	0.48	0.53	0.35	0.007	0.010	0.019	0.029	0.040
1980	0.15	0.55	0.53	0.36	0.005	0.008	0.015	0.022	0.032
1981	0.15	0.44	0.53	0.31	0.006	0.008	0.020	0.027	0.037
1982	0.25	0.26	0.53	0.32	0.013	0.015	0.041	0.048	0.066
1983	0.23	0.25	0.53	0.30	0.010	0.011	0.032	0.036	0.051
1984	0.29	0.43	0.53	0.39	0.009	0.011	0.023	0.027	0.038
1985		0.58							
1986		0.51							
1987		0.62							
1988		0.62							
1989		0.57							
1990		0.62							
1991		0.67							
1992		0.58							
1993	0.34	0.89	0.53	0.50	0.003	0.004	0.005	0.007	0.011
1994	0.20	0.86	0.36	0.33	0.004	0.006	0.014	0.018	0.025
1995	0.41	0.81	0.42	0.41	0.004	0.005	0.009	0.012	0.016
1996	0.44	0.71	0.92	0.77	0.004	0.006	0.005	0.008	0.011
1997	0.51	0.57	0.40	0.44	0.018	0.027	0.041	0.061	0.078
1998	0.61	0.82	0.55	0.55	0.013	0.018	0.024	0.032	0.042
1999	0.59	0.86	0.72	0.69	0.025	0.029	0.036	0.042	0.055
2000	0.48	0.71	0.32	0.36	0.017	0.021	0.048	0.058	0.082
2001	0.23	0.99	2.16	2.10	0.013	0.016	0.006	0.008	0.010
2002	0.61	0.71	0.44	0.48	0.010	0.012	0.021	0.026	0.033
2003	0.60	0.69	0.68	0.65	0.004	0.004	0.005	0.007	0.009
2004	0.40	0.93	0.45	0.44	0.005	0.006	0.012	0.014	0.019
2005	0.48	0.93	1.07	1.01	0.002	0.003	0.002	0.003	0.004
2006	0.57	0.66	0.47	0.50	0.008	0.009	0.015	0.019	0.024
2007	0.60	0.21	0.80	0.64	0.011	0.013	0.017	0.020	0.026
2008	0.66	0.46	0.82	0.73	0.032	0.043	0.045	0.059	0.076
2009	0.56	0.42	0.65	0.59	0.016	0.021	0.027	0.036	0.047
				Geomean					
				1960s	0.024	0.043	0.056	0.099	0.134
				1970s	0.008	0.012	0.031	0.047	0.065
				1980s	0.008	0.010	0.025	0.031	0.043
				1990s	0.007	0.010	0.014	0.019	0.026
				2000s	0.009	0.011	0.014	0.017	0.023

Table 4.41. Estimation of ocean survival rates, S.oa, and first year ocean survival rates, S.o1, for Snake River wild steelhead, migration years 1964-2009. Estimates for 1964-1993 based on Petrosky and Schaller (2010); estimates for 1997-2009 based on CSS parameter estimates for SAR, in-river survival, proportion transported and D. Survival rates from 1985 through 1992 are unavailable.

Migration year	In-river survival (SR)	Proportion transported (pT)	D	System survival	SAR (lgr-lgr)	SAR (lgr - Col. R. mouth)	S.oa(lgr)	S.oa(col)	S.o1
1964	0.56	0.00	1.03	0.56	0.038	0.082	0.068	0.146	0.166
1965	0.56	0.00	1.03	0.56	0.035	0.074	0.062	0.132	0.150
1966	0.56	0.00	1.03	0.56	0.039	0.083	0.069	0.148	0.169
1967	0.32	0.00	1.03	0.32	0.039	0.077	0.122	0.239	0.272
1968	0.43	0.00	1.03	0.43	0.032	0.058	0.075	0.136	0.155
1969	0.20	0.00	1.03	0.20	0.035	0.062	0.175	0.312	0.354
1970	0.24	0.00	1.03	0.24	0.024	0.044	0.101	0.184	0.209
1971	0.17	0.03	1.03	0.20	0.021	0.040	0.107	0.202	0.230
1972	0.09	0.10	1.03	0.18	0.014	0.025	0.078	0.133	0.152
1973	0.01	0.05	1.03	0.06	0.006	0.009	0.097	0.145	0.165
1974	0.08	0.00	1.03	0.08	0.013	0.018	0.158	0.227	0.258
1975	0.27	0.19	1.03	0.41	0.018	0.027	0.043	0.066	0.075
1976	0.13	0.15	1.03	0.27	0.016	0.026	0.059	0.098	0.111
1977	0.01	0.72	1.03	0.74	0.009	0.013	0.012	0.018	0.020
1978	0.08	0.73	1.03	0.76	0.030	0.043	0.039	0.056	0.064
1979	0.02	0.74	1.03	0.76	0.031	0.044	0.041	0.058	0.066
1980	0.03	0.90	1.03	0.91	0.025	0.035	0.027	0.038	0.044
1981	0.12	0.81	1.03	0.84	0.011	0.016	0.013	0.018	0.021
1982	0.21	0.57	1.03	0.67	0.033	0.052	0.049	0.077	0.088
1983	0.19	0.72	1.03	0.78	0.025	0.044	0.032	0.056	0.064
1984	0.25	0.72	1.03	0.80	0.035	0.060	0.043	0.075	0.084
1985		0.99			0.029	0.050			
1986		0.98			0.026	0.049			
1987		0.96			0.033	0.060			
1988		0.94			0.019	0.032			
1989		0.87			0.010	0.016			
1990		0.93			0.023	0.037			
1991		0.99			0.015	0.024			
1992		0.99			0.010	0.016			
1993	0.29	0.93	1.03	0.96	0.011	0.016	0.011	0.016	0.019
1994	0.38	0.91	1.03	0.96	0.012	0.018	0.013	0.019	0.021
1995	0.53	0.92	1.03	0.97	0.014	0.021	0.014	0.021	0.024
1996	0.50	0.80	1.03	0.91	0.016	0.023	0.017	0.026	0.030
1997	0.52	0.72	1.18	0.98	0.012	0.017	0.013	0.017	0.020
1998	0.54	0.89	0.11	0.15	0.003	0.004	0.021	0.028	0.030
1999	0.45	0.87	1.07	0.97	0.028	0.039	0.031	0.040	0.047
2000	0.30	0.85	0.50	0.46	0.027	0.036	0.061	0.077	0.087
2001	0.04	0.99	1.46	1.42	0.025	0.033	0.018	0.023	0.028
2002	0.52	0.68	2.24	1.65	0.021	0.029	0.014	0.018	0.020
2003	0.37	0.72	1.75	1.34	0.016	0.022	0.013	0.016	0.019
2004	0.18	0.97	2.69	2.57	0.009	0.012	0.004	0.005	0.005
2005	0.27	0.93	1.30	1.20	0.008	0.011	0.007	0.009	0.011
2006	0.58	0.65	0.52	0.53	0.011	0.020	0.021	0.037	0.042
2007	0.38	0.40	1.20	0.70	0.026	0.034	0.037	0.049	0.055
2008	0.49	0.41	0.60	0.53	0.032	0.045	0.061	0.085	0.097
2009	0.70	0.45	0.95	0.80	0.024	0.037	0.030	0.046	0.053
				Geomean					
				1960s	0.036	0.072	0.088	0.175	0.199
				1970s	0.016	0.026	0.060	0.095	0.108
				1980s	0.023	0.038	0.030	0.047	0.053
				1990s	0.013	0.019	0.016	0.023	0.026
				2000s	0.018	0.025	0.019	0.026	0.030

Chapter 5

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 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 US 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 US Army Corps of Engineers on collaborative analyses which include methods consistent with the CSS. This 2012 report is the second 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.

The inclusion of fall Chinook in the Comparative Survival Study 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 has 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.

To apply the CSS approach to fall Chinook we develop methods for excluding those groups of fish that showed high potential for holding over. Holdovers are juvenile fish that do not actively migrate through the hydro-system during the summer or fall after emergence, or in the year released, and instead pass after the PIT-tag detection systems have shutdown for winter at the dams, or during the following spring. Holdover detections are removed from juvenile survival estimates in the CSS methodology due to potential bias those detections would introduce into reach survivals (Berggren et. al. 2005). And, fish passing during the winter shutdown are not represented in estimates of survival and detection probability and therefore may introduce bias into SARs, particularly for the C_0 group, which relies on estimated survival to Lower Granite Dam as well as detection probabilities at downstream dams.

Results of modeling predicted holdover probability were presented in the 2011 CSS Annual Report (Tuomikoski et al 2011). Those models were used to predict which groups of fish, or individual fish within PIT-tagged release groups, would be most likely to holdover based on modeling. The models were run using all marked fish in a given year—combining fish from all release groups in the case of hatchery fish and combining wild with surrogate releases. The models fit quite well for the years modeled. The modeling correctly identified those release groups most likely to holdover. However, using the predictions to isolate and remove individual marked fish from particular release groups based on predicted holdover probability proved unsuccessful. Therefore, only release groups with low holdover proportions (or no holdovers) were used in SAR estimation.

A simulation was developed that identified the potential bias to SAR estimates that could be expected based on the holdover proportions observed for individual release groups. The results of the simulations suggest that very little bias was evident for fish with low holdover proportions. The simulations also showed that the CSS methodology is likely inappropriate to apply to groups with high holdover rates such as the surrogate and wild fall Chinook released in recent years in the Clearwater River. Further refinement of the simulation tools we developed will be necessary to determine a threshold for holdover rates that signifies too much bias to SARs. However, the simulations did suggest that for most groups bias was very small. For those groups with no holdovers detected and no or few late season migrants, there was no indication that any bias would be introduced into SAR estimates (from holdovers) so that simulations were not necessary.

Based on our simulations and holdover probability predictions, CSS identified groups of fish suitable for SAR estimation using the CSS methodology. The final section of this chapter reports the results of SAR estimates both overall and for study groups of fish for the out-migration years 2006 to 2009.

Removing Holdovers from SAR estimation using Predicted Holdover Detection Probability

As described in the 2011 CSS Annual Report we predicted holdover detection probability using release date and length at release when available for subyearling Chinook salmon releases for each year from 2001 to 2009. Each fish within a year was then assigned a predicted holdover detection probability based on modeling. The next step was to sort individual PIT-tagged fish into those more likely to holdover, and those less likely to holdover based on those predictions. The purpose was to identify individuals or groups that were most likely to holdover and remove them from consideration in SAR analysis to remove concerns about bias due to holdovers. Based on the analyses described in the following sections it was not feasible to remove individual fish from release groups since predicted holdover probabilities were very similar for individual fish within release groups. Instead, the predicted holdover detection probabilities could only be used to identify release groups with high holdover detection probabilities. The analysis did highlight the importance of release date and fish size at release for determining holdover probability. The following section describes the methods that use holdover detection probability as a decision tool to identify and remove holdovers from SAR analysis. The results are presented for 2009 only for brevity, but results were similar for the years 2006 to 2008 as well.

Methods

Based on length at release and date of release individual PIT-tagged subyearling Chinook were assigned holdover detection probabilities (Tuomikoski et. al. 2011). Based on a frequency histogram of predicted holdover detection probability, we chose a threshold holdover detection probability that seemed to best divide fish into those more likely to holdover versus those likely to migrate as subyearlings. This threshold was used to assign observed fish into two classifications. Those fish that were above the threshold were classified as "positive" or likely to be detected as a holdover and those fish below the threshold were classified "negative" not likely to holdover. To assess the validity of the threshold we determined the number of fish that were correctly classified based on detections in the hydro-system. Those fish that were detected at Lower Granite Dam prior to August 1 were considered subyearling migrants (not likely to holdover within the hydro-system and be detected as holdovers later). Those fish detected as a yearling at any dam in the hydro-system were part of the holdover detection group. We did not consider fish that had no detection since whether classification was successful for those fish could not be determined. Late season migrants (after August 1 at Lower Granite Dam) were considered ambiguous in terms of the holdover likelihood and were not used to identify these thresholds.

The initial two classifications were further defined into four categories. Fish assigned to the high holdover class and detected as holdovers were assigned at "TP" or true positive group. Those fish that were assigned to the high holdover or "positive" class but were detected passing Lower Granite Dam as subyearlings were assigned to the "FP" or false positive group. Fish detected as holdovers with predicted holdover probability below the threshold were assigned to the "FN" or false negative category, while subyearling migrants correctly assigned to the "negative" class—fish with holdover detection probability below the threshold, were assigned to the "TN" or true negative category.

To assess predictive performance, or how well we correctly classified fish into "TP" and "TN" categories, we used the normalized mutual information coefficient (Rost and Sander 1993, Rost et. al. 1994). When outcomes are binary, as in this classification for holdover predictions, then the normalized information coefficient (*IC*) is defined as the mutual information coefficient (*I*) divided by the entropy (H). According to (Baldi et. al. 2000) the mutual information coefficient is calculated as

$$
\begin{aligned}
I(D,M) = &-\frac{TP}{N}\log\frac{TP}{N}-\frac{TN}{N}\log\frac{TN}{N}-\frac{FP}{N}\log\frac{FP}{N}-\frac{FN}{N}\log\frac{FN}{N} \\
&-\frac{TP}{N}\log\left[\frac{TP+FP}{N}\frac{TP+FN}{N}\right] \\
&-\frac{FN}{N}\log\left[\frac{TP+FN}{N}\frac{TN+FN}{N}\right] \\
&-\frac{FP}{N}\log\left[\frac{TP+FP}{N}\frac{TN+FP}{N}\right] \\
&-\frac{TN}{N}\log\left[\frac{TN+FN}{N}\frac{TN+FP}{N}\right],
\end{aligned}
$$

where, D is the data set and M was the model predicting the data. Entropy (H) is calculated as

$$
H(D,M) = -\frac{TP+FN}{N}\log\left[\frac{TP+FN}{N}\right]-\frac{TN+FP}{N}\log\left[\frac{TN+FP}{N}\right].
$$

The normalized *IC* is calculated as

$$
IC(D,M) = \frac{I(D,M)}{H(D,M} .
$$

The normalized mutual information coefficient (*IC*) was shown to be a robust method for simultaneously accounting for all four data classifications (TN, TP, FN, FP) to determine model prediction accuracy given the data (Baldi et. al. 2000). The *IC* ranges between zero and one with zero indicating perfectly random and one indicating perfect prediction.

Results

The results of the analysis using observations from the 2009 out-migration showed that a threshold detection probability could be used to successfully distinguish those fish likely to holdover from those not likely to holdover Table 5.1. When all release groups were included in the analysis and a threshold holdover detection probability of 0.006 was applied, the normalized mutual information criteria (IC) was 0.84 indicating a relatively good ability to predict which fish would holdover in that year. Based on our analysis using the threshold <0.006 (fish with a holdover detection probability less than 0.006 were likely subyearling migrants) nearly 100% of subyearling migrants were correctly classified, while about 78% of holdovers would have been excluded successfully. However, using this global approach, all holdovers for certain release groups would be retained based on the criteria of 0.006. For example, the Snake River surrogate releases had 91 holdover detections and none of these were assigned a holdover probability greater than 0.004. Thus none of these fish were categorized in the positive class or as likely to holdover based on the criteria.

We sought to find the maximum threshold for Snake River surrogate releases only, and found it to be nearer 0.001. But in that case the IC was only 0.002 indicating very little ability to separate the subyearlings from yearling migrants. When other individual release groups were assessed this way, maximizing the IC for each release, the IC values were most often near 0, ranging from 0.002 to 0.123.

Table 5.1. Results for 2009 subyearling Chinook of applying a threshold holdover detection probability to separate fish likely to holdover from those likely to migrate as subyearlings using the normalized mutual information criteria (IC).

Release Group	IC(D,M)	Threshold HO detection probability	Comments
All release groups	0.8403	< 0.006	
Big Canyon Creek Surrogates	0.123	< 0.016	No FN or TN at <0.006 threshold
Snake River Surrogates	0.002	< 0.001	No FP or TP at <0.006 threshold
Clearwater Wild	0.0044	< 0.006	Maximum IC was 0.078 at <0.032
Snake River Wild	0.009	< 0.006	
Cedar Flats Acclimation Facility	NA	< 0.006	No FP or TP at <0.006 threshold

However, separation of holdovers was only possible when the method was applied to individual fish in ***all*** release groups for the migration year and thresholds tended to identify entire release groups as having high holdover probability and not individuals within those groups as we had first envisioned when developing this approach. Within PIT-tagged release groups such as Big Canyon Creek surrogates, length and date of release was not as variable as that observed among groups for an entire migration year and predictions based on those variables worked best to identify entire groups as apposed to individual fish with high holdover probability. Results from other years were similar and are not shown for the sake of brevity.

In summary, we originally proposed using these predictions based on length and release dates to remove individual fish from within PIT-tag release groups. However, after analyzing the patterns in holdover detection probabilities, it was clear that the prediction capabilities were not sensitive enough to identify individuals within release groups. Instead, the predictions and decision criteria were better employed identifying PIT-tagged groups with high holdover probability. We focused SAR estimation on those groups that overall had few or no holdovers, and as such had low holdover detection probabilities.

Simulation to quantify potential holdover bias.

There was concern that tag groups containing large number of holdover detections or undetected migrants passing LGR during winter might lead to biased SARs. The presence of winter migrants would cause an underestimate of C_0 juvenile population using CJS survival estimates inherent in the SAR estimates and survival estimates in the CSS method. Since holdover fish could not be easily removed from release groups for SAR estimation using predicted holdover probability, it was important to evaluate the total bias that could occur in SAR estimates if any holdover fish were present in the release groups used. Simulations were developed to determine the potential amount of bias to CJS derived SAR estimates that might be expected from including various numbers of holdover fish in the SAR estimation.

The observed PIT-tagged holdover fish were used in simulations to determine the possible size of the juvenile holdover population that might have been present but undetected based on their late season migration timing. Simulations with detection data, and migration timing information were used to calculate the amount of bias possible in PIT-tag subyearling fall Chinook release groups.

The focus of the simulations was to translate detected holdovers into a simulation of total holdover bias (in terms of the juvenile starting population as LGR) that might be expected. (It should be noted that not all holdovers bias SARs. Holdovers that were detected as subyearlings within the hydro-system would have very little effect on SAR estimation since their Lower Granite passage would have been accounted for in CJS survival estimates.) Holdover detections (i.e. detections as yearlings) were removed from juvenile detection histories for CJS estimates, so that those holdover detected fish were not represented in juvenile survival estimates and would not bias estimates of survival. The simulations focused on identifying those holdovers that could have caused bias because they passed LGR into the hydro-system after PIT-tag detector shut down in the late fall, or passed LGR the following spring after the bypass and detection systems restarted.

Methods

Using simulated data we projected the total juvenile fish population passing LGR that would not have been included in the C_0 population estimate using the CSS methodology. This consisted of fish that would have passed after the PIT-tag detection system shutdown at Lower Granite Dam, which typically occurred in mid-December. Fish passage at LGR during the winter was considered the key component to determining holdover bias since most PIT-tag detectors shut-down for winter, including the LGR detector, therefore, very little information was available to determine winter passage timing or magnitude.

To estimate the magnitude of the population that passed during the time when PIT tag detectors were not functional, detections of holdover fish the following spring at Bonneville Dam were used to simulate the total population of fish that may have passed. PIT-tagged fish that had not been previously detected as subyearlings anywhere upstream were used in this analysis. These detected fish were then expanded by an estimate of detection probability at Bonneville Dam to get a Bonneville holdover population. (Spring detections of holdover fish at the trawl detector in the Columbia River estuary were used to estimate detection probability at Bonneville Dam.) In order to use this Bonneville holdover population to estimate the bias to the LGR-to-GRA C_0 SAR, the Bonneville population was expanded to a LGR equivalent juvenile population using a range of three different survival rates of 0.25, 0.5 and 0.75. The average survival rate of non-holdover subyearling migrants was 0.74. Therefore, based on the non-holdover survival rate this range of estimates was used to simulate what was thought to be a likely range of survivals for fish migrating through the hydro-system, since overwinter migration survival could not be adequately estimated using single release capture-recapture CJS methods.

Bonneville Dam was also shutdown for a period during the winter; for example, the BON detection system was shutdown December 21 in 2009 and restarted February 18 in 2010. Because of the shutdown, some fish could have passed LGR after shutdown December 5, 2009 and subsequently passed Bonneville Dam prior restart 76 days later. In order to account for this possible unmonitored passage, winter passage at Lower Granite Dam was simulated to determine what portion of the holdover fish might have passed the entire reach (LGR to BON) during periods when the PIT-tag system was not monitoring due to winter shutdown.

To simulate unmonitored winter passage, late season passage numbers at Lower Granite Dam were estimated using a method similar to Sanford and Smith (2002) and is described in a white paper available at on the Fish Passage Center web page at: (http://www.fpc.org/smolt/juvenile_popindex/35-08.pdf). That methodology allowed daily detection probabilities at Lower Granite Dam to be predicted based on flow and spill at the project. Then daily PIT-tag detections were expanded to daily PIT-tag populations for a more accurate assessment of the magnitude of PIT-tag subyearling Chinook passage during late season. The average daily passage of PIT-tagged fish the month prior to shutdown (November 5 to December 5) was used in the simulation as the daily number of fish passing Lower Granite Dam during PIT-tag system shutdown. For the simulation the daily winter passage numbers were assumed to remain constant, at the average, even though winter passage likely slows down considerably based on detection data from Ice Harbor Dam (where monitoring is nearly continuous in the winter in some years). However, the higher passage numbers were chosen in order to be conservative since using this passage would more likely identify higher potential bias in simulations of juvenile PIT-tag populations than if passage numbers were assumed to decline in the January to March period.

In order to determine how far downstream these winter fish would migrate prior to restart of the detector at Bonneville Dam, fish migration rates (travel distance per day) of fish detected at Ice Harbor Dam in November and December were used to simulate travel time of fish that passed Lower Granite after shutdown during the winter. Daily numbers of fish simulated to pass LGR were randomly assigned migration rates from observed fish. The number of these simulated fish that passed Bonneville Dam (461 km downstream) based on LGR passage date and migration rate were determined for each simulation. The simulated passage was repeated 1,000 times. The average simulated winter passage proportion of PIT-tagged fish was then added to the estimated spring passage population at Bonneville Dam to account for potential unmonitored passage at Bonneville Dam. The total simulated bias (i.e. undercount of holdover fish) N_{bias} to the LGR juvenile starting population was calculated;

$$N_{Bias} = (HO_u * (HO_{bon} / p_{bon}) + (HO_{bon} / p_{bon})) / S_{r01}$$

Where

HO_u = Unmonitored winter passage proportion (expressed as a proportion of all holdover passage, times the probability of passing LGR to BON prior to BON restart).

HO_{bon} = holdovers detected at Bonneville Dam (not observed at or past LGR as subs)

p_{bon} = Bonneville detection probability was the proportion of all holdover trawl detects also seen at BON (PIT-tags seen at BON & TWX)/(all TWX detects)).

S_{r01} range of survival values applied to holdovers surviving to and detected at BON dam to get a LGR equivalent juvenile population range. Here we used values from 0.25 to 0.75 for simulation.

For the simulation, all PIT-tag groups within a single migration year were combined for deriving both migration rates as well as Bonneville detection probabilities. This was done because there were relatively low numbers of holdover detections and for some release groups there were no holdover detects or only a few detections. Groups with few detections, were evaluated using simulations derived from all available tags to provide some measure of potential bias that might be expected to C_0 SARs assuming similar behavior was occurring in all late season/holdover migrants.

In order to determine the potential bias to SAR estimates based on the simulated LGR equivalent holdover populations, the LGR equivalent juvenile population was added to the CJS derived juvenile population estimates. The resulting SAR estimate was used to compare to the CSS SAR calculated without the LGR equivalent juvenile population added to the CJS derived juvenile population estimate. This was used to determine the potential bias that could be expected to occur given the simulated passage assumptions. The percent bias was calculated as

$$c0SAR_{Bias} = (c0SAR_{css} - c0SAR_{sim}) / c0SAR_{css} * 100 .$$

Results

The simulation method used likely overestimated the LGR holdover population N_{bias} for two reasons. First, all holdover fish with no prior detections were included in the Bonneville population estimate for holdovers. This would have included some fish that entered the hydro-system undetected at LGR (and other dams potentially) as subyearlings and completed passage to Bonneville Dam undetected as yearlings. Those fish would have been part of the C_0 population at LGR originally. This was a done to be conservative and because there was no way to separate those fish from holdovers that either passed LGR after shutdown undetected or passed the entire hydro-system undetected as yearlings. Second, the distribution of winter passage was assumed to be of similar magnitude to late season passage at LGR. As mentioned earlier this was likely an overestimate. As a result of these assumptions the resulting bias calculations presented in this section represent a likely maximum possible bias to SAR estimates forC_0.

For the release groups for which SARs are reported in the final section of this chapter, the simulated relative bias in the C_0 SAR was projected to be 1% or less of the initial SAR derived using CSS methods (see tables 5.2 to 5.5). Many of the SAR estimates were quite low so that even a projected 1% bias in the SAR estimate represented a minute change to the SAR. For example, included in the results for 2008 simulations (Table 5.4) was the projected bias to the C_0 SAR for Snake River wild subyearling Chinook. For that SAR the estimated bias ranged from 0.36% to 1.07% (based on different assumed survival rates--S_r). The original C_0 SAR for that group, based on an estimated C_0 population of 2,104 juvenile fish at LGR and 19 adults, was 0.90%. Based on simulation the bias adjusted C_0 SAR was projected to be between 0.89% and 0.90%. Given the low SAR the projected maximum simulated bias was only 0.01% reduction representing a 1% relative change.

In some cases, for groups with high holdover rates and higher SARs, bias was likely much higher based on simulation results. Groups with high projected bias based on simulation or simply high holdover proportions were not included in the SAR estimates reported in the final section of this chapter since estimates were not deemed reliable. For example, in 2009 the Big Canyon Creek release of surrogate subyearling fall Chinook reared at Dworshak Hatchery, had projected bias to the C_0 SAR ranging from 81% to 91%. In that case, the initial C_0 SAR using the CSS method was 20.7%. This SAR was obviously biased but included here for illustration purposes only. The SAR was based on an estimated 766 C_0 juvenile population at LGR and 159 adults that returned to LGR. Based on simulation, we projected an additional 3,200 to 9,500 juvenile fish passed after LGR shutdown in December, resulting in a greatly reduced C_0 SAR to the range of 1.5% to 4%. Based on the CSS methods, the transport SAR for this group was 2.0% and the C_1 SAR was 1.8% so that the range of C_0 SARs from the simulation was more realistic by comparison. However, as stated previously, due to the large number of holdovers and the high potential for bias in this group, SAR estimates were considered unreliable and were not included in this report

For migration year 2006 simulated bias was calculated for several release groups (Table 5.2). The range of bias simulated to occur in the release groups ranged from 0.02% to 0.26% for groups that were included in SAR analyses reported in this chapter. The highest bias (3.9% to 10.8%) was calculated for the Big Canyon Creek release of fish reared at Dworshak Hatchery (a surrogate release group). That group was included in simulation results for illustration purposes. Due to a high holdover rate and the potential bias to SARs that release group was not included in SAR estimations. Based on the simulations for that group, between 359 and 1,076 juvenile fish were projected passing LGR after the bypass shutdown in December.

Table 5.2 Results of simulation for 2006 subyearling fall Chinook determining possible holdover bias to SAR estimation by release group (jacks included). Additional juvenile population due to holdovers are shown (Lower Granite Equivalents) that were simulated to have been unsampled at Lower Granite Dam due to winter shutdown or yearling migration and the resulting percent bias to SAR estimate.

Release Site, Tag Site, (PIT-tag coord-id)	HO detects BON	BON detect prob	Unmonitored Bon Passage	LGR Pop Equiv using various Sr			Projected Bias to C_0 SAR
				0.25	0.5	0.75	
Big Canyon Creek, Lyons Ferry Hatchery, (DMM)	1	0.32	0-1	13	7	4	0.02%-0.06%
Couger Creek, Lyons Ferry Hatchery, (DMM)	2	0.32	0-1	26	13	9	0.09%-0.26%
Hells Canyon Dam, Umatilla Hatchery, (DMM)	0	NA	NA	NA	NA	NA	NA
Pittsburgh Landing, Umatilla Hatchery, (DMM)	0	NA	NA	NA	NA	NA	NA
Snake River, Dworshak Hatchery, (DMM)	4	0.32	1-2	17	26	52	0.03%-0.07%
Snake River, Lyons Ferry Hatchery, (DMM)	1	0.32	0-1	13	7	4	0.05%-0.14%
Big Canyon Creek, Dworshak Hatchery, (DMM)[a]	82	0.32	17-51	1076	538	359	3.9%-10.8%

[a] This release was included to illustrate simulation results for a group with high holdover detections. The release group SARs were not included in this Chapter due to likely high bias to C_0 group SAR.

For migration year 2007 simulated bias was calculated for two release groups (Table 5.3). The range of bias simulated to occur in those release groups ranged from 0% to 4.8%. The highest bias was calculated for the wild subyearling Chinook release in the Snake River. Due to the bias indicated by simulations as well as low sample size the SAR was considered unreliable and not reported for the wild subyearling release for 2007. No simulations were done for Captain Johns Rapid, Pittsburg Landing because no C_0 adults returned so that the SAR remained at 0 for any juvenile population size. For the Hells Canyon Dam release group there were no holdover fish detected at Bonneville Dam and no late season migrants indicating no potential for undetected winter passage so that no holdover simulation was necessary. Due to low return rates of adults and low release numbers SARs were considered unreliable for estimation of SARs by study category and were not included in the report despite the lack of bias indicated based on simulations. Transportation study marking was curtailed in 2007 resulting in low sample sizes for most release groups.

Table 5.3 Results of simulation for 2007 subyearling fall Chinook determining possible holdover bias to SAR estimation by release group (jacks included). Additional juvenile population due to holdovers are shown (Lower Granite Equivalents) that were simulated to have been unsampled at Lower Granite Dam due to winter shutdown or yearling migration and the resulting percent bias to SAR estimate.

Release Site, Tag Site, (PIT-tag coord-id)	HO detects BON	BON detect prob	Unmonitored Bon Passage	LGR Pop Equiv using various Sr			Projected Bias to C_0 SAR
				0.25	0.5	0.75	
Big Canyon Creek, Big Canyon Creek, (BDA)	1	0.32	0-1	13	7	4	0.17%-0.51%
Captain Johns Rapid, Captain Johns Rapid (BDA)	1	0	NA	NA	NA	NA	NA
Pittsburgh Landing, Pittsburgh Landing, (BDA)	0	NA	NA	NA	NA	NA	NA
Hells Canyon Dam, Oxbow Hatchery, (BDL)	0	NA	NA	NA	NA	NA	NA
Snake River, Wild, (WPC)	11	0.32	3-10	148	74	49	1.7%-4.8%

Relatively few holdover fish were detected from migration year 2008 release groups that were used in SAR analyses. Only two release groups from migration year 2008 had holdovers detected at Bonneville Dam so that simulations were possible; the wild subyearlings marked in the Snake River had two Bonneville detects and the Snake River surrogate release of fish reared at Dworshak Hatchery had 24 detections (Table 5.4). Simulated bias to those groups was low—ranging from 0.12% to a maximum of 1.0%. As described previously that maximum 1.0% relative bias meant a change in SAR from 0.90% down to 0.89%. That small amount of bias was not deemed large enough to affect analyses or to remove it from considerations in comparisons to transport SARs or to affect the overall SAR.

Table 5.4 Results of simulation for 2008 subyearling fall Chinook determining possible holdover bias to SAR estimation by release group (jacks included). Additional juvenile population due to holdovers are shown (Lower Granite Equivalents) that were simulated to have been unsampled at Lower Granite Dam due to winter shutdown or yearling migration and the resulting percent bias to SAR estimate.

Release Site, Tag Site, (PIT-tag coord-id)	HO detects BON	BON detect prob	Unmonitored Bon Passage	LGR Pop Equiv using various Sr			Projected Bias to C_0 SAR
				0.25	0.5	0.75	
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Captain Johns Rapid, Lyons Ferry Hatchery (BDA)	0	NA	NA	NA	NA	NA	NA
Grande Ronde River, Irrigon Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Snake River, Dworshak Hatchery, (DMM)	24	0.37	4-12	273	136	91	0.12%-0.36%
Snake River, Lyons Ferry Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Snake River, Umatilla Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Snake River, Wild, (WPC)	2	0.37	0-1	23	11	8	0.36%-1.0%

Migration year 2009 simulations were reported for three release groups (Table 5.5). Most release groups used in SAR analysis had no holdover detections at Bonneville Dam indicating very low bias to SARS were likely due to holdovers. Relatively few holdover fish were detected in 2009 release groups that were used in SAR analyses. The highest calculated bias in release groups for which SARs were reported was to the Snake River surrogate releases of fish reared at Dworshak Hatchery; for that group relative bias was projected to range from 0.26% to 0.79%. The projected increase to LGR juvenile population due to holdover passage was between 136 and 409; which was small considering the LGR starting population for the C_0 group was estimated at over 51,000. The SAR for the Snake River surrogate release was estimated at 0.156% and accounting for holdover bias from the simulation meant the SAR was reduced to 0.154%. Based on the simulations there appeared to be no significant bias to SARs for the groups of fish used in CSS SAR estimations.

Table 5.5 Results of simulation for 2009 subyearling fall Chinook determining possible holdover bias to SAR estimation by release group (jacks included). Additional juvenile population due to holdovers are shown (Lower Granite Equivalents) that were simulated to have been unsampled at Lower Granite Dam due to winter shutdown or yearling migration and the resulting percent bias to SAR estimate.

Release Site, Tag Site, (PIT-tag coord-id)	HO detects BON	BON detect prob	Unmonitored Bon Passage	LGR Pop Equiv using various Sr			Projected Bias to C_0 SAR
				0.25	0.5	0.75	
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	2	0.28	1-2	30	15	10	0.18%-0.53%
Captain Johns Rapid, Lyons Ferry Hatchery (BDA)	0	NA	NA	NA	NA	NA	NA
Grande Ronde River, Irrigon Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Snake River, Dworshak Hatchery, (DMM)	27	0.28	10-29	409	204	136	0.26%-0.79%
Snake River, Lyons Ferry Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Snake River, Oxbow Hatchery, (BDL)	0	NA	NA	NA	NA	NA	NA
Snake River, Umatilla Hatchery, (BDA)	0	NA	NA	NA	NA	NA	NA
Snake River, Wild, (WPC)	1	0.28	0-1	15	8	5	0.30%-0.90%

SAR estimation

Similar to spring/summer Chinook, sockeye and steelhead SARs presented in chapter 4 and Appendix A, SARs are presented in the following section for subyearling fall Chinook PIT-tagged fish and released at various locations above Lower Granite Dam. The same methodologies were used in estimating SARs for fall Chinook that were described for other species in this and previous CSS reports (see appendix A). Adult return data used in SAR estimation were updated through the end of 2011, so that returns through 5-salt are complete for 2006 migration year; 4-salt adults for 2007; 3-salt adults for 2008; and 2-salt adults for 2009.

Through the holdover prediction process described above, we identified those groups with low holdover detection probability. We used that information as well as holdover detection rates at Bonneville Dam to select groups appropriate for SAR estimation using the CSS methods. We used simulation to assure that the likely bias to SARs for these groups was low. 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.

Patterns in Annual Overall SARs

Overall SARs for Snake River subyearling fall have been quite low in the years we have analyzed. 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 (Table 5.6 and 5.7). SARs for migration year 2008 tended to be higher than those for 2006 and 2007 despite the fact that 4-salt and 5-salt fish have not yet returned (Table 5.8).

The highest SAR (including jacks) among release groups in migration year 2006, was 0.90 for juvenile fish reared at Lyons Ferry Hatchery and released at Big Canyon Creek acclimation facility (Table 5.6). For migration year 2007, overall SARs including jacks, was highest at 0.36 for fish reared at Oxbow Hatchery and released below Hells Canyon Dam (Table 5.7). All other SARs with jacks were 0.05% or lower for migration year 2007 and included zero in the lower 90% confidence interval.

Table 5.6. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) Hatchery origin PIT-tagged subyearling fall Chinook, 2006 (with 90% confidence intervals). SARs are calculated with and without jacks.

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, (DMM)	32,105	0.56 (0.49 - 0.63)	0.90 (0.82 - 0.98)
Couger Creek, Lyons Ferry Hatchery, (DMM)	11,143	0.21 (0.14 - 0.29)	0.31 (0.22 - 0.40)
Hells Canyon Dam, Umatilla Hatchery, (DMM)	11,930	0.21 (0.14 - 0.28)	0.31 (0.23 - 0.40)
Pittsburgh Landing, Umatilla Hatchery, (DMM)	14,894	0.12 (0.07 - 0.17)	0.24 (0.17 - 0.31)
Snake River, Dworshak Hatchery, (DMM)	63,844	0.25 (0.22 - 0.28)	0.36 (0.32 - 0.40)
Snake River, Lyons Ferry Hatchery, (DMM)	11,083	0.29 (0.20 - 0.38)	0.42 (0.32 - 0.53)

Table 5.7. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) Hatchery origin PIT-tagged subyearling fall Chinook, 2007 (with 90% confidence intervals). SARs are calculated with and without jacks.

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, Big Canyon Creek, (BDA)	3,935	0.05 (0.00 - 0.12)	0.05 (0.00 - 0.12)
Captain Johns Rapid, Captain Johns Rapid (BDA)	4,453	0.01 (0.00 - 0.01)	0.01 (0.00 - 0.01)
Pittsburgh Landing, Pittsburgh Landing, (BDA)	2,689	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Hells Canyon Dam, Oxbow Hatchery, (BDL)	12,915	0.30 (0.07 - 0.57)	0.36 (0.13 - 0.63)

More release groups and release sites were available in 2008 compared to 2007 for SAR estimation. SARs for 2008 hatchery release groups were over 1.0% for most groups (when jacks were included), and one estimate, for fish reared at Umatilla Hatchery and released in the Snake River below Hells Canyon Dam was over 2.0%.

Table 5.8. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) Hatchery origin PIT-tagged subyearling fall Chinook, 2008 (with 90% confidence intervals). SARs are calculated with and without jacks.

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)	12,280	0.84 (0.70 - 0.99)	1.64 (1.43 - 1.83)
Captain Johns Rapid, Lyons Ferry Hatchery (BDA)	15,205	0.53 (0.44 - 0.63)	1.05 (0.91 - 1.19)
Grande Ronde River, Irrigon Hatchery, (BDA)	7,987	0.21 (0.12 - 0.31)	0.54 (0.40 - 0.69)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	11,464	0.77 (0.63 - 0.91)	1.63 (1.43 - 1.83)
Snake River, Dworshak Hatchery, (DMM)	62,103	0.44 (0.39 - 0.48)	0.89 (0.83 - 0.95)
Snake River, Lyons Ferry Hatchery, (BDA)	5,693	0.60 (0.42 - 0.78)	1.07 (0.83 - 1.30)
Snake River, Umatilla Hatchery, (BDA)	12,201	0.91 (0.77 - 1.06)	2.12 (1.90 - 2.35)

SARs for 2009 hatchery release groups were much lower than 2008. Only up to 3-salt adults were available for these SAR estimates so it remains to be seen how well these groups will perform compared to other recent years.

Table 5.9. Overall LGR-to-GRA SARs for Snake River Basin (above LGR) Hatchery origin PIT-tagged subyearling fall Chinook, 2009 (with 90% confidence intervals). SARs are calculated with and without jacks.

Release Site, Tag Site, (PIT-tag coord-id)	Smolts arriving LGR[A]	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)	5,239	0.04 (0.00 - 0.09)	0.11 (0.04 - 0.20)
Captain Johns Rapid, Lyons Ferry Hatchery (BDA)	5,889	0.00 (0.00 - 0.00)	0.19 (0.10 - 0.29)
Grande Ronde River, Irrigon Hatchery, (BDA)	8,795	0.11 (0.06 - 0.18)	0.19 (0.12 - 0.26)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	4,786	0.17 (0.08 - 0.27)	0.29 (0.17 - 0.44)
Snake River, Dworshak Hatchery, (DMM)	42,538	0.10 (0.08 - 0.13)	0.18 (0.15 - 0.22)
Snake River, Lyons Ferry Hatchery, (BDA)	5,078	0.18 (0.08 - 0.28)	0.35 (0.22 - 0.50)
Snake River, Oxbow Hatchery, (BDL)	4,569	0.09 (0.02 - 0.17)	0.31 (0.18 - 0.45)
Snake River, Umatilla Hatchery, (BDA)	15,156	0.05 (0.02 - 0.08)	0.14 (0.09 - 0.19)

Finally, overall SARS for wild Snake River subyearling Chinook were low similar to what was observed for hatchery origin fish (Table 5.10). The pattern among years was similar to hatchery fish with the overall SAR for 2008 being the highest even without 2012 and 2013 returns. The 2007 SAR was not reported due to the low number of adult returns (six total adult returns) which made the estimate unreliable and in part due to the low sample size of PIT-tag releases for this group. However, based on return rates from hatchery origin fish in this year, it is likely the wild SAR would have been very near to zero as well.

Table 5.10. Overall LGR-to-GRA SARs for Snake River wild-origin PIT-tagged subyearling fall Chinook, 2006 to 2009 (with 90% confidence intervals). SARs are calculated with and without jacks.

Migration Year	Smolts arriving LGR[A]	SAR without Jacks (Non-parametric CI 90% LL - 90% UL)	SAR with Jacks (Non-parametric CI 90% LL - 90% UL)
2006	363	0.28 (0.00 - 0.85)	0.28 (0.00 - 0.84)
2008	3,590	0.33 (0.00 - 0.96)	0.99 (0.30 - 2.02)
2009	499	0.40 (0.00 - 0.90)	0.60 (0.16 - 1.22)

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 2006 to 2009. 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. And while the C_1 SARs were 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.

In 2006 hatchery SARs by study category showed the highest SAR of 0.66% for the C_0 group from the Big Canyon Creek release of subyearling Chinook marked at Lyons Ferry Hatchery (Table 5.11). That C_0 SAR was significantly higher than the transport SAR of 0.37 based on non-overlapping confidence intervals. In all other cases the confidence intervals overlapped when comparing the T_x and C_0 groups in 2006 migration year hatchery release groups.

Table 5.11 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 2006 (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, (DMM)	0.37 (0.30 - 0.45)	0.66 (0.57 - 0.75)	0.56 (0.44 - 0.69)
Couger Creek, Lyons Ferry Hatchery, (DMM)	0.31 (0.17 - 0.46)	0.11 (0.00 - 0.17)	0.05 (0.00 - 0.15)
Hells Canyon Dam, Umatilla Hatchery, (DMM)	0.22 (0.13 - 0.32)	0.20 (0.12 - 0.29)	0.16 (0.04 - 0.30)
Pittsburgh Landing, Umatilla Hatchery, (DMM)	0.08 (0.03 - 0.12)	0.15 (0.09 - 0.23)	0.18 (0.08 - 0.28)
Snake River, Dworshak Hatchery, (DMM)	0.27 (0.22 - 0.32)	0.21 (0.18 - 0.24)	0.24 (0.19 - 0.29)
Snake River, Lyons Ferry Hatchery, (DMM)	0.37 (0.22 - 0.53)	0.33 (0.24 - 0.45)	0.39 (0.20 - 0.64)

Results for 2007 were not available due to low sample sizes of releases and very low adult return rates. Transportation study marking was curtailed in 2007 when low production numbers made it impossible to mark adequate fish for study goals.

Results for the 2008 migration year are presented below but adult returns will not be considered complete until 2013 when any 5-salt adults would have returned. With that in mind, SAR for 2008 were relatively low compared to spring migrants reported in Appendix A with the highest SAR again for the Big Canyon Creek release, but in this case the transport SAR of 1.09 was significantly higher than that of the C_0 SAR of 0.62 based on non-overlapping 90% confidence intervals. The transport SAR for Snake River releases of surrogates was also significantly higher than that of the C_0 release.

Table 5.12 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 2008 (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)	1.09 (0.85 - 1.36)	0.62 (0.51 - 0.74)	0.66 (0.50 - 0.86)
Captain Johns Rapid, Lyons Ferry Hatchery (BDA)	0.54 (0.39 - 0.69)	0.52 (0.43 - 0.62)	0.49 (0.37 - 0.63)
Grande Ronde River, Irrigon Hatchery, (BDA)	0.28 (0.13 - 0.45)	0.20 (0.13 - 0.28)	0.23 (0.08 - 0.40)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	0.91 (0.70 - 1.14)	0.72 (0.59 - 0.86)	0.66 (0.51 - 0.82)
Snake River, Dworshak Hatchery, (DMM)	0.60 (0.52 - 0.69)	0.35 (0.31 - 0.38)	0.35 (0.28 - 0.42)
Snake River, Lyons Ferry Hatchery, (BDA)	0.86 (0.53 - 1.21)	0.57 (0.41 - 0.75)	0.06 (0.00 - 0.17)
Snake River, Umatilla Hatchery, (BDA)	1.06 (0.84 - 1.30)	0.88 (0.74 - 1.03)	0.69 (0.53 - 0.87)

For migration year 2009 only 2-salt adults were included, so that SARs could change significantly with additional adult returns between 2012 and 2014. Based on returns to date, the SARs were all quite low, with the transport SAR of 0.26% for Snake River releases from Lyons Ferry Hatchery marked fish having the highest return. That release study group SAR was not significantly different than the C_0 SAR of 0.14 and generally the point estimates for transport groups were below those for C_0 in-river fish. In most cases the in-river C_0 SAR was not significantly higher than transport SAR except in the case of the Big Canyon Creek release of Lyons Ferry Hatchery marks, where the C_0 SAR was 0.12% compared to 0.00% for transported fish. Again, these estimates only include 2 years of adult returns where returns for at least 2 additional years are likely

Table 5.13 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 2009 (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)	0.00 (0.00 - 0.00)	0.12 (0.05 - 0.21)	0.10 (0.03 - 0.20)
Captain Johns Rapid, Lyons Ferry Hatchery (BDA)	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Grande Ronde River, Irrigon Hatchery, (BDA)	0.09 (0.03 - 0.18)	0.14 (0.08 - 0.20)	0.17 (0.06 - 0.30)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	0.08 (0.00 - 0.17)	0.13 (0.05 - 0.23)	0.13 (0.03 - 0.23)
Snake River, Dworshak Hatchery, (DMM)	0.15 (0.10 - 0.21)	0.16 (0.13 - 0.18)	0.20 (0.15 - 0.27)
Snake River, Lyons Ferry Hatchery, (BDA)	0.26 (0.09 - 0.44)	0.14 (0.05 - 0.24)	0.14 (0.00 - 0.28)
Snake River, Oxbow Hatchery, (BDL)	0.08 (0.00 - 0.19)	0.08 (0.00 - 0.16)	0.16 (0.06 - 0.28)
Snake River, Umatilla Hatchery, (BDA)	0.07 (0.03 - 0.13)	0.03 (0.01 - 0.05)	0.05 (0.02 - 0.10)

SAR estimates by study category for wild subyearling fall Chinook were only available for three of four years and only for the Snake River release groups (Table 5.14). Marking of Snake River wild fish was too low in 2007 and adult returns were too few to allow SAR estimation for that group. Clearwater wild groups exhibited relatively high holdover rates and SARs were not estimated due to potential holdover bias associated with those holdovers and releases were too likely too small to estimate SARs. For the Snake River wild release groups the 2006 C_0 SAR was higher than the transport SAR, but not significantly due to overlapping confidence intervals. Confidence intervals were wide for the transport groups in all years and included zero so no comparisons were significantly different. For wild fish transport SARs were higher than C_0 SARs in 2008 and 2009, but again it was not a significant difference. In addition, returns from the 2009 migration year include only six adults so data should be viewed as very preliminary until 3- to 5-salt adults return.

The confidence intervals on the wild mark groups tended to be much wider than those of the hatchery groups due largely to relatively low numbers of wild fish marked each year relative to hatchery releases. The estimates of smolts arriving at Lower Granite Dam shown in Table 5.10 showed populations in each year less than 500 fish in 2006 and 2009. In contrast hatchery groups had estimated LGR populations between 4,000 fish to over 60,000. More adult returns are anticipated for the 2008 and 2009 returns which may change SAR estimates for the wild groups.

Table 5.14 Estimated LGR-to-GRA SAR (%) by study category without jacks for PIT-tagged wild subyearling Chinook marked and released in the Snake River by USFWS from 2006 to 2009 (with 90% confidence intervals).

Migration Year	SAR(T_x) %	SAR(C_0) %	SAR(C_1) %
2006	0.56 (0.00 - 1.73)	0.96 (0.34 - 1.69)	0.53 (0.00 - 1.29)
2008	1.50 (0.00 - 3.48)	0.90 (0.56 - 1.27)	0.78 (0.37 - 1.25)
2009[a]	0.91 (0.00 - 2.03)	0.18 (0.00 - 0.37)	0.13 (0.00 - 0.37)

[a] Total of 6 adults for all three categories combined in 2009 so that SARs are not reliable.

Estimates of TIR and D

The estimates of transport-inriver SAR ratios are reported below using methods described in chapter 4. For the 2006 migration year, TIRS were significantly different from one for two groups, indicating a difference from equality for the two study groups. For the Big Canyon Creek release the TIR was 0.57 indicating for that group that in-river SAR for C_0 was higher than for transported fish (Table 5.15). In contrast the Couger Creek release had a TIR of 2.81. Other release groups had non-significant differences in TIR with the ratio varying above and below one.

Table 5.15 Estimated Transport-InRiver-Ratios (TIR) in LGR-to-GRA SAR (%) without jacks for PIT-tagged hatchery subyearling Chinook by release site, tag site and coordinator ID from 2006 (with 90% confidence intervals). TIRs significantly different than one are bolded.

Release Site, Tag Site, (PIT-tag coord-id)	TIR	D
Big Canyon Creek, Lyons Ferry Hatchery, (DMM)	**0.57 (0.44 - 0.71)**	0.50 (0.34 - 0.80)
Couger Creek, Lyons Ferry Hatchery, (DMM)	**2.81 (1.33 - 5.79)**	1.28 (0.58 - 2.80)
Hells Canyon Dam, Umatilla Hatchery, (DMM)	1.08 (0.60 - 2.00)	0.73 (0.39 - 1.43)
Pittsburgh Landing, Umatilla Hatchery, (DMM)	0.49 (0.19 - 1.02)	0.27 (0.10 - 0.58)
Snake River, Dworshak Hatchery, (DMM)	1.26 (0.99 - 1.59)	0.67 (0.48 - 1.02)
Snake River, Lyons Ferry Hatchery, (DMM)	1.12 (0.64 - 1.82)	0.61 (0.35 - 1.01)

The estimates of transport-inriver SAR ratios for migration year 2008 were significantly different from one for two groups, indicating a difference from equality for the two study groups (Table 5.16). For the Big Canyon Creek release the TIR was 1.74 and for Snake River surrogate releases the TIR was 1.75 indicating that for both groups transport SARs were significantly higher than for C_0 groups (Table 5.16). For all other release groups the TIR ratios were not significantly different from one indicating no significant difference between transport and C_0 SARs. It should be pointed out that these ratios are preliminary since additional adult returns are expected for this migration year in 2012 and 2013.

Table 5.16 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 2008 (with 90% confidence intervals). TIRs significantly different than one are bolded.

Release Site, Tag Site, (PIT-tag coord-id)	TIR	D
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	**1.74 (1.26 - 2.30)**	1.00 (0.60 - 2.12)
Captain Johns Rapid, Lyons Ferry Hatchery (BDA)	1.03 (0.73 - 1.42)	0.55 (0.33 - 1.02)
Grande Ronde River, Irrigon Hatchery, (BDA)	1.37 (0.60 - 2.50)	0.60 (0.25 - 1.11)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	1.26 (0.93 - 1.72)	0.46 (0.29 - 0.77)
Snake River, Dworshak Hatchery, (DMM)	**1.75 (1.47 - 2.05)**	0.85 (0.65 - 1.12)
Snake River, Lyons Ferry Hatchery, (BDA)	1.51 (0.91 - 2.39)	0.71 (0.40 - 1.20)
Snake River, Umatilla Hatchery, (BDA)	1.21 (0.92 - 1.57)	0.75 (0.55 - 1.00)

The estimates of transport-inriver SAR ratios for migration year 2009 were not significantly different from one for any groups for which the data could be estimated (Table 5.17). The data are very preliminary with only a single year of adult returns included in the analysis.

Table 5.17 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 2009 (with 90% confidence intervals). TIRs significantly different than one are bolded.

Release Site, Tag Site, (PIT-tag coord-id)	TIR	D
Big Canyon Creek, Lyons Ferry Hatchery, (BDA)	NA	NA
Captain Johns Rapid, Lyons Ferry Hatchery (BDA)	NA	NA
Grande Ronde River, Irrigon Hatchery, (BDA)	0.63 (0.12 - 1.51)	0.29 (0.05 - 0.76)
Pittsburgh Landing, Lyons Ferry Hatchery, (BDA)	0.61 (0.00 - 1.99)	0.41 (0.00 - 1.42)
Snake River, Dworshak Hatchery, (DMM)	1.15 (0.67 - 1.85)	0.50 (0.29 - 0.79)
Snake River, Lyons Ferry Hatchery, (BDA)	1.81 (0.61 - 5.44)	0.94 (0.31 - 2.83)
Snake River, Oxbow Hatchery, (BDL)	NA	NA
Snake River, Umatilla Hatchery, (BDA)	NA	NA

The estimate of TIR for migration year 2006 was not significantly different from one for the wild subyearling Chinook released into the Snake River (TIR = 0.59, 90% CI 0.00 – 2.52). The estimate of D is 0.31 (90% CI 0.00 – 1.36). Data for 2008 and 2009 were not deemed reliable due to low adult returns and were not reported. With additional adult returns in out years it may be possible to provide more data on the wild fish TIRs. However, based on low sample sizes, it may be difficult to detect a significant difference between study groups.

Conclusions

The method CSS developed for differentially identifying subyearling fall Chinook holdover probability worked well on a population level but did not work well for identifying individual fish within release groups. Because of that inability to identify individual fish within release groups the method was not used as originally intended. Instead, overall holdover detection probability was only helpful in identifying groups of fish with high likelihood for holdovers.

The method for identifying holdover probability did indicate that release date and length at release were important for determining the likelihood of holding over. The results of that analysis showed that subyearling Chinook that were released late in the season, such as Clearwater River wild marks, or at smaller size, such as surrogate releases, had a higher likelihood of holding over. Those data were useful in helping to identify which release groups should be excluded from SAR estimation using the CSS methodology.

Simulations indicated that holdovers could bias SARs when high numbers of holdovers were detected in the hydro-system. Those holdover detections, as well as high numbers of late season migrants passing Lower Granite Dam, were indicative of likely bias to the juvenile population estimate for C_0 SARs based on our simulations. Groups with high bias due to holdovers--based on simulations--were excluded from SAR analysis.

Simulations of groups included in SAR analysis in this report indicated that bias was very low in the groups of fish that were included in this report. Further work may be necessary to more precisely identify bias if it is to be used to modify estimated SARs. At this point the simulations appear useful to identify groups with relatively high likelihood of bias as distinct from those with very little bias, but no attempt was made to use simulations to identify a threshold level of bias that would be unacceptable.

Overall Smolt-to-adult-return rates for Snake River subyearling fall Chinook were very low in the 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. While adults are still to return for migration years 2008 and 2009 SARs for those years were relatively low as well.

By study group, SARs were also quite low and based on TIRs there appears to be no benefit to transport evident in the 2006 returns. Returns for more recent years are not complete but there appeared to be a significant benefit for some transport groups 2008 while in 2009 the pattern of little or no transport benefit appears similar to 2006.

Chapter 6
Patterns in age at maturity for PIT-tagged spring/summer Chinook salmon and sockeye

The spring/summer Chinook salmon in the Columbia River basin that have been PIT-tagged through the CSS and other tagging projects provide important information on survival, migration timing and other demographic parameters. The purpose of this chapter is to update information on the age at maturity for returning adults that have been PIT-tagged. Age at maturity data are useful as a basis for sibling models to generate pre-season forecasts of adult salmon returns (Haeseker et al. 2008) and as a monitoring tool for identifying changes in age composition over time. As a monitoring tool, these data can inform management questions on hatchery practices and the influence of environmental factors. In the case of the former, it has been shown that age at maturity in salmon can be influenced by hatchery mating practices (Hankin et al. 1993, Heath et al. 1994) as well as hatchery rearing and growth conditions (Thorpe 1991, Heath et al. 1994, Shearer et al. 2006). In the case of the later, temporal changes in age at maturity have also been associated with environmental factors that appear to operate during ocean residence (Pyper et al. 1999, Holt and Peterman 2004). The continued monitoring of age at maturity may have the potential to separate the effects of hatchery practices versus ocean environmental conditions and ultimately improve biological understanding and management of these populations.

There are several advantages to using PIT-tags for developing age structure data.. First, the detection systems in adult dam ladders provide both a high sampling rate (effectively 100%) and a consistent sampling environment for collecting age at maturity data. PIT-tags also allow for individual identification and for determining stock origin, which can be useful partitioning sources of variation among the mixed-stock populations that comprise the overall returns to the Columbia River Basin.

In this chapter, we update age at maturity datasets and analyses of patterns of variation in age at maturity for hatchery and wild Chinook. The goal was to answer the research question, do all stocks share similar age at maturity over time, or are there differences between stocks? Additionally, because little information is available on the age structure of sockeye in the Snake River Basin, we summarized age at maturity for Snake River hatchery sockeye.

Methods

Potential methods for enumerating mini-jacks

Adult fish counts are available from several Corps of Engineer and Public Utility projects throughout the Columbia Basin. However, because the goals of each counting program are varied, there are several issues with the use of these counts to enumerate mini-jacks (FPC 2009b). Specifically some of these are: (i) there is variable fish passage during non-counting hours that varies by project, species, day, and time of year; (ii) there is a potential bias in visual size determination across projects; and (iii) the amount of adult fallback varies across time and projects. Also, to our knowledge, only dams in the Middle and Upper Columbia specifically target mini-jacks which would exclude all Snake River stocks.

The utilization of PIT-tags to monitor mini-jack returns introduces different challenges. During their outmigration, spring and summer Chinook juveniles sometimes enter adult ladders and are recorded as an adult observation in the PTAGIS database. The dataset housed at the Fish Passage Center currently includes only first and last detections within the adult ladder. Separating juvenile outmigrants in the ladder and true mini-jack returns requires all of the coil data from the PTAGIS database to establish a direction of movement within the adult ladder (i.e. upstream or downstream) in order to separate the juvenile outmigrants from true mini-jacks. Potential candidates for the mini-jack category can be chosen but using these candidates in any calculations would bias the mini-jack contribution higher than it actually was and confound any results. For these reasons, mini-jacks counts are not included in this update of the adult age data.

Age at maturity

Presented here are summaries of age at maturity for sixteen stocks of spring/summer Chinook salmon that were PIT tagged in the Snake River, Lower Columbia, and Upper Columbia river basins for juvenile migration years 2000-2009 (Table 6.1). In order to make comparisons across stocks using a similar endpoint, all stocks were aged at the Bonneville Dam adult ladders (BOA) using PIT tag data through July 11, 2012 for Chinook and July 31, 2012 for sockeye. These sixteen Chinook stocks are comprised of five wild stocks (Snake, John Day, Yakima, Wenatchee, and Entiat/Methow rivers) and eleven hatchery stocks (Catherine Creek acclimation pond, Clearwater, Dworshak, Imnaha acclimation pond, McCall, Pahsimeroi, Sawtooth, Rapid River, Carson, Cle Elum, and Leavenworth). The Entiat/Methow river wild stocks are presented as one combined stock because of the small sample size and to present data that are aligned with overall SARs presented elsewhere in this report. Chinook adult returns consisted of age-3, age-4 and age-5 fish. Age-3 fish are predominantly male and are termed jacks. The mean age at maturity and the proportion of the adults that were age-3 ("jack proportion") are provided for each Chinook stock by juvenile outmigration year. The age at maturity for Snake River sockeye presented here is a first for these reports and includes PIT-tagged Sawtooth and Oxbow hatchery releases from the Snake River Basin (Table 6.2).

The data and analyses for Chinook in this chapter follow last year's report (Tuomikoski et al, 2011, Chapter 7) where jacks, 1-salts, and 2-salts are presented as age-3, age-4, and age-5, respectively. This year's analyses include six additional Chinook stocks when addressing the question of whether there were any common patterns in variation of age at maturity across stocks or migration year. Specifically, we conducted an analysis of variance (ANOVA) to address the question of whether there were any common patterns of variation in age at maturity across stock, years, or both. A significant stock effect would indicate that mean age at maturity varies by stock. A significant year effect would indicate that some common factor is influencing age at maturity across stocks. To examine whether stock or year effects influence the probability of returning as a jack, we conducted a logistic regression analysis. The dependent variable in the logistic model was coded as ‘1’ if the adult was a jack and a zero otherwise. For Snake River hatchery sockeye, the adult returns were summarized by age for the two years of PIT tag data currently available.

Table 6.1. Total numbers of adults aged at BOA for each of the sixteen Chinook stocks presented in this chapter.

Stock	Race	n	years
Snake wild	spring/summer	3,477	2000-2009
Catherine Creek	spring	793	2000-2009
Clearwater	spring	1,258	2006-2009
Dworshak	spring	2,561	2000-2009
Rapid River	spring	3,895	2000-2009
Sawtooth	spring	234	2007-2009
McCall	summer	4,877	2000-2009
Imnaha	summer	2,516	2000-2009
Pahsimeroi	summer	275	2008-2009
John Day wild	spring	1,259	2000-2009
Carson	spring	1,625	2000-2009
Cle Elum	spring	2,399	2000-2009
Yakima wild	spring	489	2000-2009
Leavenworth	spring	2,194	2000-2009
Wenatchee wild	spring	258	2007-2009
Entiat/Methow wild aggregate	spring	210	2006-2009

Table 6.2. Total numbers of adults aged at BOA for two Snake River hatchery sockeye stocks presented in this chapter.

Stock	n	years
Sawtooth	433	2009-2010
Oxbow	83	2009-2010

Results

Some general characteristics of the sixteen Chinook stocks are apparent when summarized together. An example of the returns from the the 2009 outmigration year is shown in Figure 6.1. The age structure of Chinook stocks, hatchery or wild, within the Columbia and Snake River basins, when organized by their juvenile outmigration year, are typically dominated by the age-4 cohort of adults. A larger proportion of age-5 adults is present in the Snake River basin wild Chinook as compared with their hatchery counterparts. McCall, and Imnaha, two summer Chinook stocks within the Snake River basin, have a relatively high number of jacks along with Sawtooth, a spring Chinook stock.

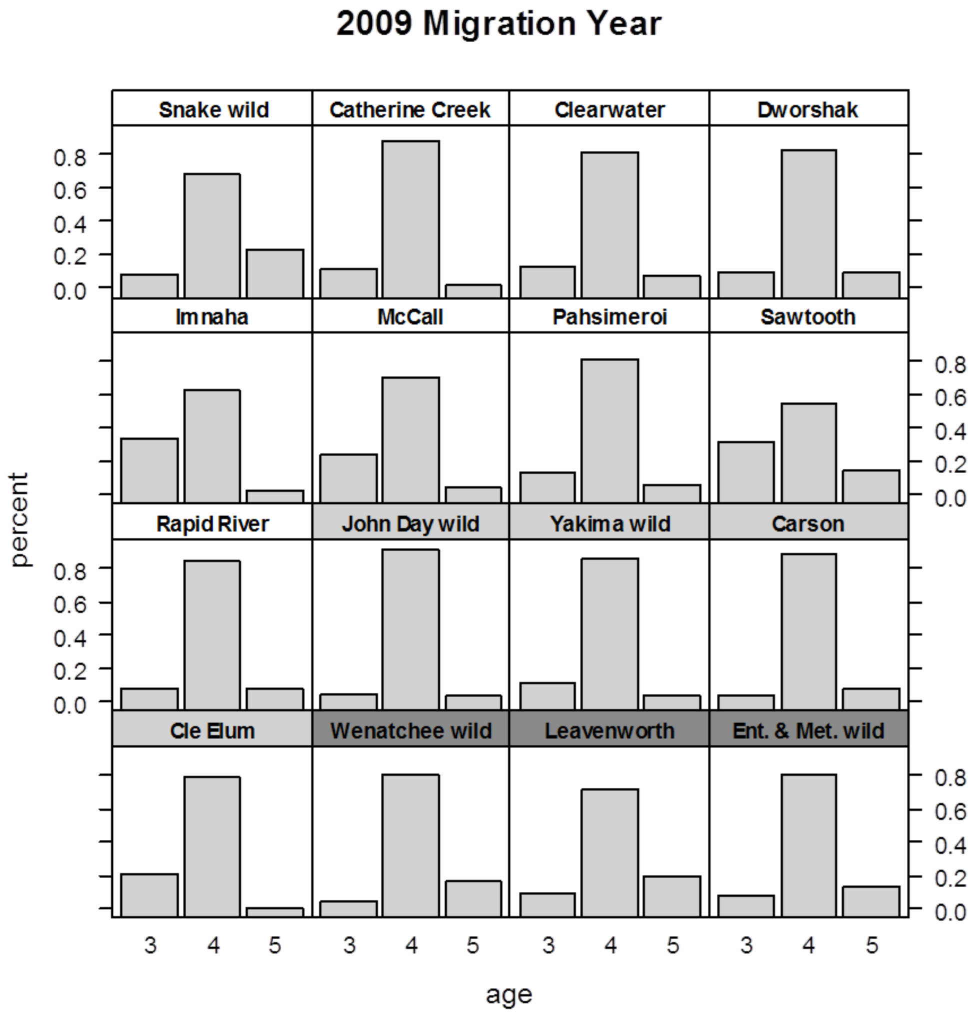


Figure 6.1. The age structure by percentage from the 2009 outmigration for wild and hatchery (sp/su) Chinook from the Snake River (titles not shaded), Middle Columbia River (lightly shaded titles), and Upper Columbia River (darkly shaded titles). Adults are aged by BOA detection from 2010-2012.

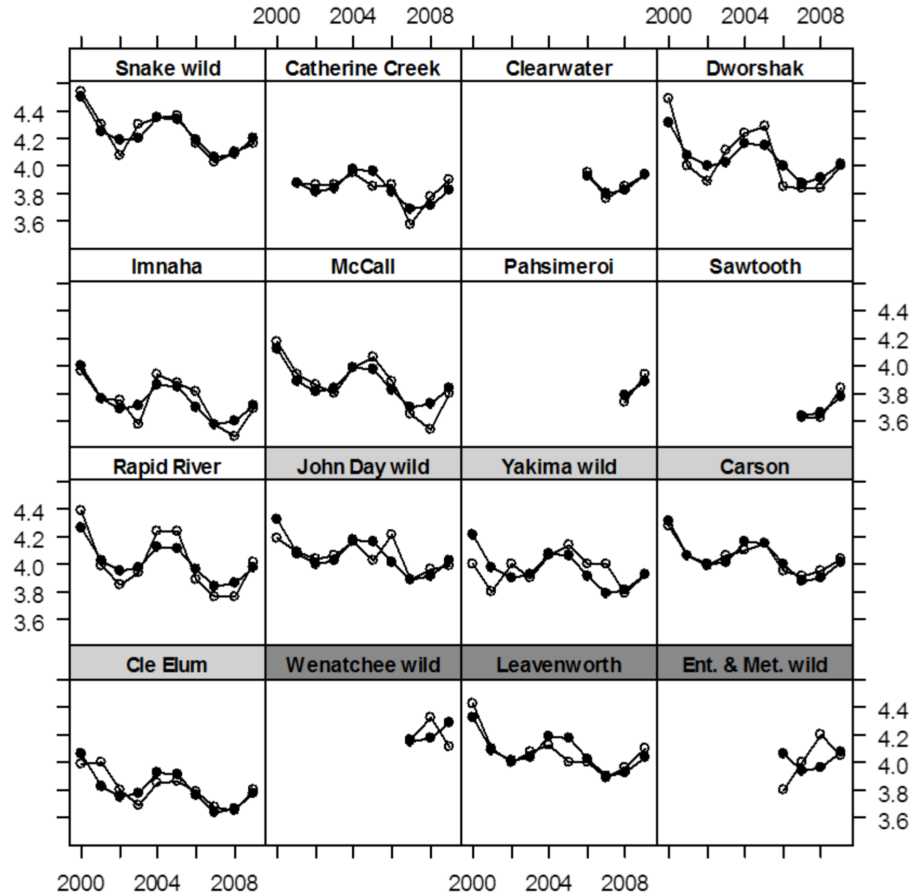


Figure 6.2. Observed mean ages (open circles) for wild and hatchery (sp/su) Chinook from the Snake River (titles not shaded), Middle Columbia River (lightly shaded titles), and Upper Columbia River (darkly shaded titles). Adults are aged by BOA detection from 2001-2012. Factor level means from ANOVA model are plotted as filled circles.

Table 6.3. ANOVA results for mean age at maturity model with stock and year effects.

Source of variation	Sum Sq	Df	F value	Pr(>F)
Stock	2.5649	15	18.599	< 2.2e-16
Year	1.62621	9	19.653	< 2.2e-16
Residuals	0.91938	100		

Results from the ANOVA, with six additional stocks as compared with last year's report, again identified that significant patterns of variation were accounted for by stock and year (Table 6.3). Stock and year effects accounted for 50% and 32% of the overall variation in mean age at maturity indicating that there is substantial variability among different stocks as well as a common factor influencing age at maturity across the Columbia River Basin Chinook salmon included here. The high degree of temporal variation shared among stocks is well illustrated in Figure 6.2. For example, stocks that outmigrated in 2000 had relatively high age's at maturity, whereas 2007 and 2008 had relatively low age's at maturity. Further, nearly every stock experienced an increase in age at maturity for 2004 and 2009 (Figure 6.2).

Along with these temporal effects, each stock's average effect on age at maturity is shown in Figure 6.3. Most wild stocks had a relatively high age at maturity when averaged across years (Figure 6.3). Among the youngest stocks were Sawtooth, Imnaha, and Pahsimeroi, although few years data are available for Sawtooth and Pahsimeroi. After accounting for stock effects and year effects in the ANOVA model, 18% of the overall variability was not explained by these two factors.

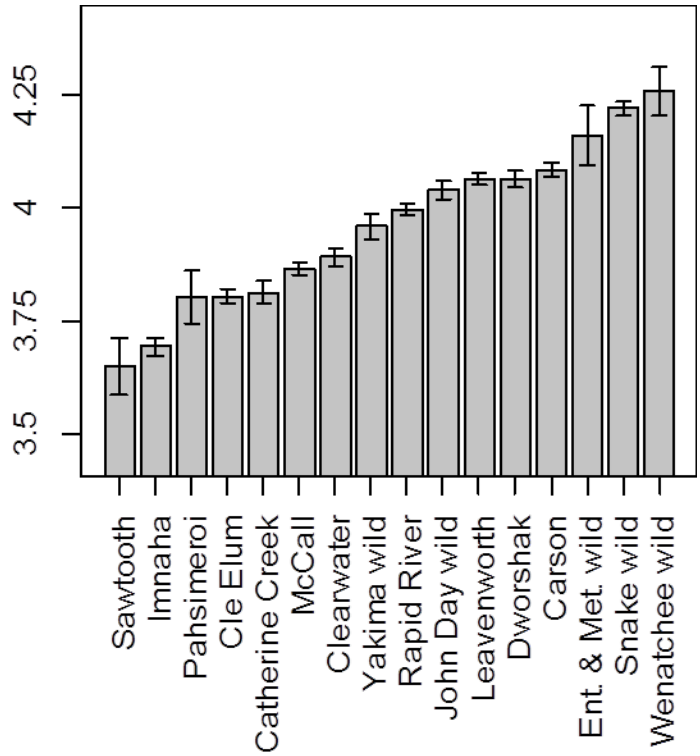


Figure 6.3. Factor level means of age at maturity for sixteen Chinook stocks (Methow and Entiat are combined). Error bars are 95% confidence intervals.

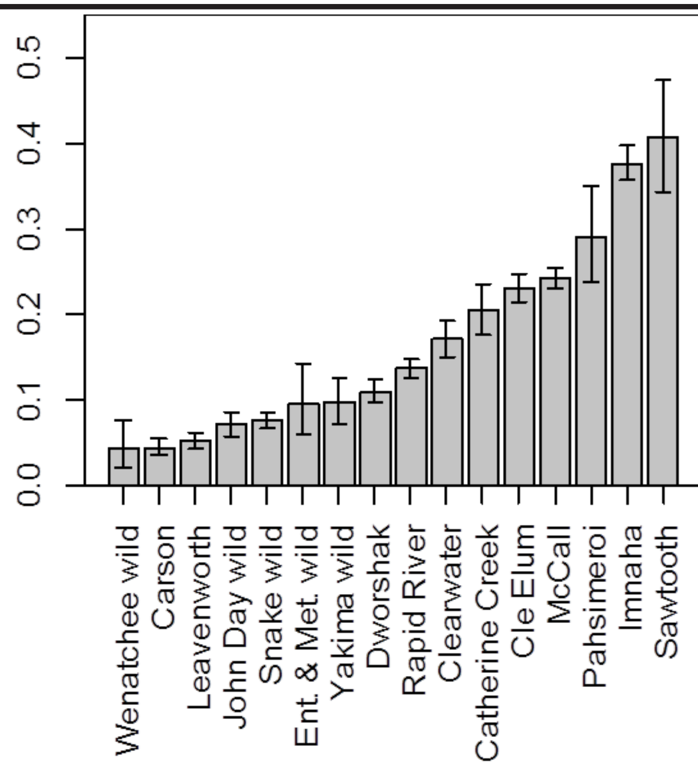


Figure 6.4. Mean jack proportions across years with 95% confidence intervals.

The logistic regression results on the jack proportions identified significant stock and year effects as well. The stocks showed a wide range in their average jack proportions (Figure 6.4). Pahisimeroi, Sawtooth, and Imnaha had the highest average jack proportion (Figure 6.4) which is aligned with their relatively young age structure (Figure 6.3). Those stocks with relatively low jack proportions included Wenatchee wild, Carson, and Leavenworth. With the exception of Carson hatchery, wild stocks had lower jack proportions than their hatchery counterparts (Figure 6.4). In addition to these stock effects, there is evidence that a common factor is influencing jack proportions across the Columbia River Basin Chinook stocks that were examined (Figure 6.5). For example, all stocks that outmigrated in 2000 tended to have lower-than-average jack proportions, while all stocks that outmigrated in 2007 and 2008 tended to have higher-than-average jack proportions. Concurrent with the increase in mean age at maturity for 2004 and 2009 (Figure 6.2), most stocks had a lower jack proportion in 2004 and 2009 (Figure 6.5). The jack proportions by year were consistently the highest for the Imnaha hatchery stock. The four highest occurrences of jack percentage included Imnaha in 2003, 2007, and 2008 and McCall in 2008 (Figure 6.5). The jack percentages in these cases ranged from 45% to 55% implying that, assuming an equal proportion of males and females, nearly all hatchery males returned as age-3 jacks in those years.

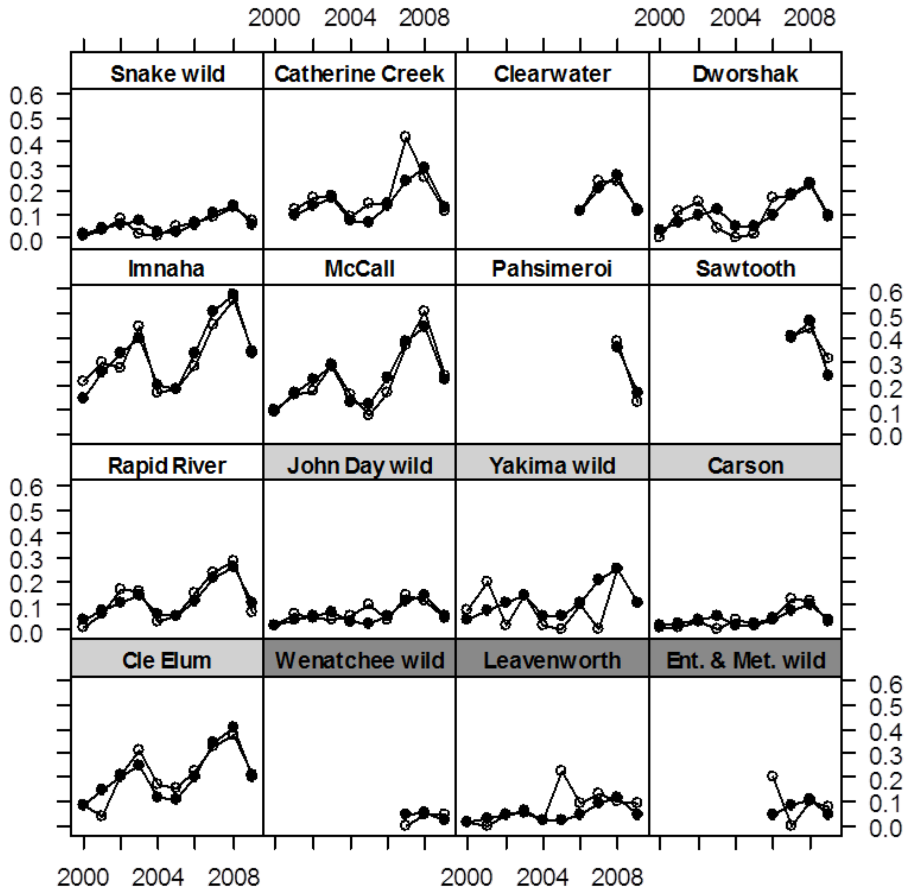


Figure 6.5. Observed jack proportions (open circles) for wild and hatchery (sp/su) Chinook from the Snake River (titles not shaded), Middle Columbia River (lightly shaded titles), and Upper Columbia River (darkly shaded titles). Adults are aged by BOA detection from 2001-2012. Fitted logistic regression estimates are plotted as filled circles.

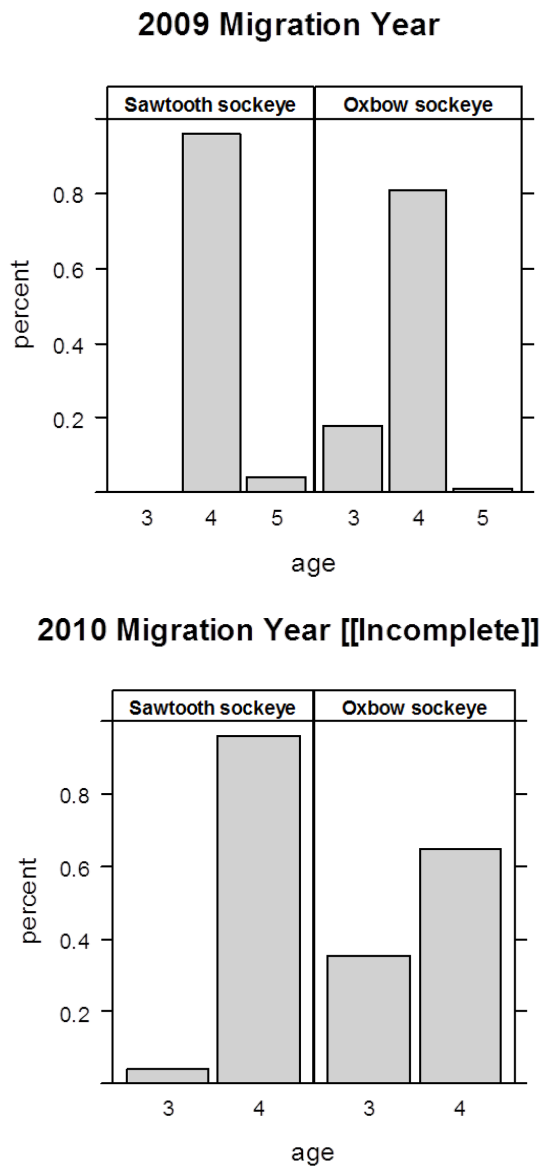


Figure 6.6. The age structure by percentage for Snake River hatchery sockeye from Sawtooth and Oxbow. The left panel shows the 2009 outmigration. The right panel displays the 2010 outmigration which is currently incomplete.

Snake River sockeye were aged similarly to Chinook at Bonneville dam for one nearly complete return (2009 outmigration) and one incomplete return (2010 outmigration). Just as for Chinook, sockeye returns from the 2009 outmigration consisted mostly of age-4 adults. Although currently incomplete, the 2010 outmigration of Sockeye are potentially following a similar pattern. For both outmigration years, Oxbow hatchery had many more age-3 adults than did Sawtooth hatchery; there were zero age-3's from the Sawtooth in 2009 (Figure 6.6). Correspondingly, the mean age at maturity for the 2009 outmigrants was 4.0 for Sawtooth Hatchery and 3.83 for Oxbow Hatchery.

Discussion

Age at maturity is an important factor with regards to salmon population dynamics and demography, as well as for management of salmon populations. For example, sibling relationships are commonly used to generate pre-season forecasts of salmon abundance (Haeseker et al. 2008). The results of this chapter build on last year's report. The 2011 CSS report found that there was no strong association between age at maturation with either outmigration experience (transport vs. in-river) or SAR. With seven additional stocks used here, the result of significant differences between stocks in their age at maturity was strengthened and suggests that using a common sibling model across all stocks may not perform well. Some stocks have high proportions of jacks while other stocks have very few jacks (Figure 6.3). Variation in stock-specific adult returns, combined with variation in stock-specific age composition will tend to confound sibling relationships and the pre-season forecasts that are based on those relationships. One alternative may be to develop stock-specific sibling relationships that account for these differences in age-composition between stocks.

The identification of significant, across-stock variation in age at maturity and jack proportions by outmigration year indicates that there is some factor or factors that are influencing age at maturity across Columbia River Basin stocks. Pyper et al. (1999) and Holt and Peterman (2004) similarly found regional covariation in age at maturity for sockeye salmon, but this study appears to be the first to identify regional covariation in age at maturity for Chinook salmon. It is interesting to note that the between-stock correlations observed in this study of Chinook salmon are generally stronger than those observed for sockeye salmon in Pyper et al. (1999). If this factor can be identified, then there is additional opportunity to improve forecasting by accounting for this variation in sibling relationships. For example, if it were known that a higher proportion of jacks were expected from a particular outmigration year, then the predicted return of age-4 adults could be adjusted accordingly. The results shown here for hatchery Sockeye are the first of age at maturity for Sockeye in the Snake River basin with PIT tags to our knowledge. The continuation of this time series will provide valuable information that has potential in forecasting and monitoring of this resource.

Conclusions

- This update of the age at maturity datasets for wild and hatchery Chinook (seven additional groups) strengthened the findings that both stock and year factors influence both the age at maturity for Chinook and the jack percentage of Chinook.
- The highest jack percentages for Chinook occurred in 2003, 2007, and 2008 from Imnaha and 2008 from McCall and ranged from 45% to 55%. This implies that, assuming a 50/50 sex ratio, nearly all adult males returned as age-3 (jacks) in these cases.
- The summary of current PIT tag data shows that Oxbow hatchery sockeye adult returns include a much higher component of age-3 (1-salt) adults and therefore a lower age at maturity than their Sawtooth hatchery counterparts. Both sockeye stocks appear to consist mostly of age-4 adults.

Glossary of Terms

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.
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.
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.
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.
CHH	Hatchery Chinook salmon

CHW	Wild Chinook salmon
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.
CRITFC	Columbia River Inter-Tribal Fish Commission
CSS	Comparative Survival Study
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CTWSRO	Confederated Tribes of the Warm Springs Reservation of Oregon
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.
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.
FCRPS	Federal Columbia River Power System

FGE	Proportion of the living fish passing the powerhouse that were detected in the smolt collection system.
FPC	Fish Passage Center
FTT	Fish Travel Time. The number of days a fish spends migrating through the reservoirs and past dams or through defined reaches.
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.
GRA	Lower Granite Dam adult fish ladder
Holdover (HO)	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 shutdown for winter at the dams, or during the following spring.
IDFG	Idaho Department of Fish and Game
IHR	Ice Harbor Dam
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
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
LMN	Lower Monumental Dam
LSRCP	Lower Snake River Compensation Plan
MCA	McNary Dam adult fish ladder
MCN	McNary Dam
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.
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
NPT	Nez Perce Tribe
ODFW	Oregon Department Fish and Wildlife
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.
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.

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.
PRD	Priest Rapids Dam
PTAGIS	PIT-tag Information System. Regional depository and clearing house for the Columbia Basin PIT-tag release and detection information.
RIS	Rock Island Dam
RRE	Rocky Reach Dam
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 irregardless of their route of passage.
SBT	Shoshone-Bannock Tribes
SMP	Smolt Monitoring Program
S.o1	Survival during the first year of ocean life.
S.oa	Marine survival rates from the stage smolts enter the estuary to adult return.
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.
STH	Hatchery summer steelhead
STW	Wild summer steelhead
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.
TWX	Trawling operation by NMFS in the lower Columbia River in the vicinity of Jones Beach that detects PIT-tagged fish.
USACE	U.S. Army Corp of Engineers
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
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.

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Appendix A

Survivals (S_R), SAR, TIR, and *D* for Snake River Hatchery and Wild Spring/Summer Chinook Salmon, Steelhead, and Sockeye

This appendix presents juvenile in-river survival from LGR tailrace to BON tailrace (termed S_R) for PIT-tagged Snake River wild and hatchery spring/summer Chinook and steelhead smolts analyzed in the CSS. In previous years, these juvenile survival data were presented in Chapter 2. In addition, this appendix presents smolt-to-adult survival rate estimates (SAR) for the PIT-tagged spring/summer Chinook and summer steelhead smolts analyzed in the CSS. In previous years reports, the SARs, TIR, and *D* data were presented in Chapter 4. As with the 2011 CSS Annual Report, this year's report continues to include estimates of juvenile survival (S_R) and smolt-to-adult survival (SAR) for PIT-tagged Snake River sockeye smolts released into the Salmon River since 2009. 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 (1994-2011), hatchery spring/summer Chinook (1997-2011), wild and hatchery steelhead (1997-2011), and hatchery sockeye (2009-2011). SARs, TIR, and *D* are estimated for PIT-tagged wild spring/summer Chinook (1994-2010), hatchery spring/summer Chinook (1997-2010), wild and hatchery steelhead (1997-2009), and hatchery sockeye (2009-2010). 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 Website (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 Website. The data on the juvenile migrant reach survival rates (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 only available from the FPC Website. These two series of data have become voluminous and difficult to present in report appendices, but are easily accessible from the FPC website in download formats amenable to analyses by interested users. Data are accessed from the FPC website homepage as follows:

(i) Click on "SURVIVAL DATA," then "JUVENILES" to access:
  a. "CSS Reach Survival Data" – provides survival rate estimates for individual reaches.
  b. "CSS S_R, TIR, and D" – provides estimate S_R for LGR-to-BON reach survival rate.
  c. "CSS Number of Fish by Site" – provides PIT-tag numbers by release site for juvenile data above and smolt-to-adult data below.

(ii) Click on "SURVIVAL DATA," then "SMOLT-TO-ADULT" to access:
  a. "CSS returning adults age composition query" – provides number of returning adults for PIT-tagged fish by juvenile year, release, and age.
  b. "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.

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

d. "CSS SR, TIR, and D" – provides estimated TIR and *D* 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 rates 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 Cormack-Jolly-Seber (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%. A reach survival estimate was considered unreliable when its point estimate exceeded 100% or its coefficient of variation exceeded 25%. For the plots that included point estimates and confidence intervals, when an estimate did not meet these two criteria, the sample size was considered too small and the estimate was not presented.

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, 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 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 only include 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.

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 following text box, the formula for estimating the number of juvenile fish in Category T_0 is:

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

Symbol Definitions:
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

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

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

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, and unknown disposition fish)
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_0 = Sum of site-specific removals at dams below LMN of fish not detected previously at a Snake River Dam estimated in LGR-equivalents. Pre-2003 uses fixed expansion rate of 50% survival rate for all removals below LMN. Beginning with migration year 2003, d0 contains site-specific removals below that have been expanded by their corresponding estimated survival rate from LGR.
$d_{5.0}$ = removals of C_0 type fish at MCN
$d_{6.0}$ = removals of C_0 type fish at JDA
$d_{7.0}$ = removals of C_0 type fish at BON

d_1 = Sum of site-specific removals at dams below LMN of fish previously detected at a Snake River Dam estimated in LGR-equivalents. Pre-2003 uses fixed expansion rate of 50% survival rate for all removals below LMN. Beginning with migration year 2003, d1 contains site-specific removals below that have been expanded by their corresponding estimated survival rate from LGR.
$d_{5.1}$ = removals of C_1 type fish at MCN
$d_{6.1}$ = removals of C_1 type fish at JDA
$d_{7.1}$ = removals of C_1 type fish at BON

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 rate (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 text box, the formula for estimating the number of juvenile fish in Category C_0 is:

$$C_0 = R * S_1 - \left(m_{12} + \frac{m_{13}}{S_2} + \frac{m_{14}}{S_2 * S_3} \right) - d_0 \qquad \text{[A.2]}$$

where, for migration years 1994-2002,

$$d_0 = \left(\frac{(d_{5.0} + d_{6.0} + d_{7.0})}{0.5} \right)$$

and beginning in 2003,

$$d_0 = \left(\frac{d_{5.0}}{S_2 * S_3 * S_4} + \frac{d_{6.0}}{S_2 * S_3 * S_4 * S_5} + \frac{d_{7.0}}{S_2 * S_3 * S_4 * S_5 * S_6} \right).$$

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 regards to possible effects on subsequent survival of passing through Snake River dam bypass/collection systems (see Chapter 7), and in investigating non-transport operations. Using symbols defined in the text box, the formula for estimating the number of juvenile fish in Category C_1 is:

$$C_1 = \left(m_{12} - d_2 \right) + \left(\frac{(m_{13} - d_3)}{S_2} \right) + \left(\frac{(m_{14} - d_4)}{S_2 * S_3} \right) - d_1 \qquad \text{[A.3]}$$

where, for migration years 1994-2002,

$$d_1 = \left(\frac{(d_{5.1} + d_{6.1} + d_{7.1})}{0.5} \right)$$

and, beginning in 2003,

$$d_1 = \left(\frac{d_{5.1}}{S_2 * S_3 * S_4} + \frac{d_{6.1}}{S_2 * S_3 * S_4 * S_5} + \frac{d_{7.1}}{S_2 * S_3 * S_4 * S_5 * S_6} \right).$$

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 in CSS 10-yr 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 C). 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 2006-2011 were consistently higher than many previous years (see Figure 1.4).

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 chapter, 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 through-out 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) only exist over a particular temporal window of the smolt outmigration. 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. The schematic in Figure A.1 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.

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

$$T_{X}\_t = X_{12} + X_{1A2} / S_2 + X_{1AA2} / (S_2{*}S_3) \qquad [A.4]$$

where A = 0 if undetected and 1 if detected at a dam prior to the transportation site.

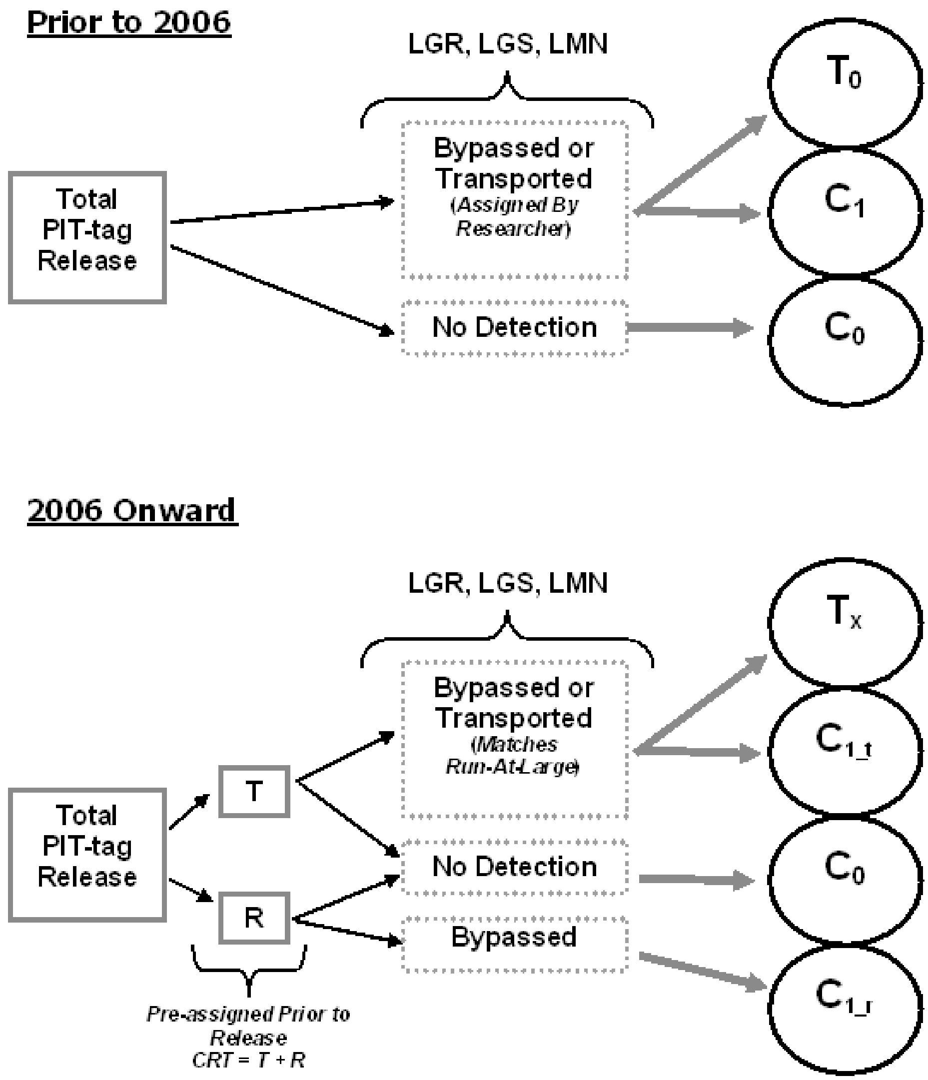


Figure A.1 Schematic depicting how the differently marked cohorts are used to translate into SARs for all years of the CSS relative to the passage of PIT-tagged smolts at the three Snake River collection/ transportation dams (LGR, LGS, and LMN). The upper flow chart covers years prior to pre-assignments 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 except for hatchery steelhead which began in 2008.

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 rates 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 parameters m_{12}, m_{13}, and m_{14} is sensitive to the estimated reach survival rates being used. Reach survival rates 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 rates 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 rates 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 D 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, we use the following expectation formulas. For estimating the expected C_0 smolt numbers $E[C_0]$_t and $E[C_0]$_crt, where known removal d_0 is a constant, the equation is:

$$E[C_0] = R_1 \bullet S_1 \bullet (1-P_2) \bullet (1-P_3) \bullet (1-P_4) - d_0 \qquad [A.5]$$

where

$$d_0 = \left(\frac{d_{5.0}}{S_2 * S_3 * S_4} + \frac{d_{6.0}}{S_2 * S_3 * S_4 * S_5} + \frac{d_{7.0}}{S_2 * S_3 * S_4 * S_5 * S_6} \right)$$

For estimating the expected C_1 smolt numbers $E(C_1)$_t and $E(C_1)$_r, where known removals d_1, d_2, d_3, and d_4 are constants, the equation is obtained by re-arranging terms in Equation A.3,

$$C_1 = [m_{12} + m_{13}/S_2 + m_{14}/(S_2 \bullet S_3)] - [d_2 + d_3/S_2 + d_4/(S_2 \bullet S_3) + d_1]$$

where

$$d_1 = \left(\frac{d_{5.1}}{S_2 * S_3 * S_4} + \frac{d_{6.1}}{S_2 * S_3 * S_4 * S_5} + \frac{d_{7.1}}{S_2 * S_3 * S_4 * S_5 * S_6} \right)$$

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

$$E[m_{12}] = R_1 \bullet S_1 \bullet P_2$$
$$E[m_{13}] = R_1 \bullet S_1 \bullet [(1-P_2) \bullet S_2 \bullet P_3]$$
$$E[m_{14}] = R_1 \bullet S_1 \bullet [(1-P_2) \bullet S_2 \bullet (1-P_3) \bullet S_3 \bullet P_4]$$

to yield:

$$E[C_1] = R_1 \bullet S_1 \bullet [P_2 + (1-P_2) \bullet P_3 + (1-P_2) \bullet (1-P_3) \bullet P_4] - [(d_2 + d_3/S_2 + d_4/(S_2 \bullet S_3) + d_1] \quad [A.6]$$

Special considerations for migration year 2010

In some cases, the closed form estimators of the CJS model performed poorly during outmigration 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 during 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 underestimate 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 that 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 C1 SAR used equation A.3 instead of A.6 because of remarkably low detection probabilities at LMN that were probably a result of the noted bias. To reflect the experience of the run at large, Group T fish were used in the C1 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 outmigration 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:

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

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

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

For migration years 2006 and later, the adult counts (i.e., AT_{LGR}, AT_{LGS}, AT_{LMN}) include both first-time detected and previously detected fish. The abbreviated capture histories for the smolt outmigration 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:

$$SAR(T_X\_t) = \{AT_{LGR}\_t + AT_{LGS}\_t + AT_{LMN}\_t\} / T_X\_t \qquad [A.10]$$

Using the total release, the formula for $SAR(C_0\_crt)$ is:

$$SAR(C_0\_crt) = \{AC_0\_crt\} / C_0\_crt \qquad [A.11]$$

Using the pre-assigned fish in Group T, the equations for $SAR[EC_1\_t]$ is:

$$SAR[EC_1\_t] = \{AC_1\_t\} / E[C_1\_t] \qquad [A.12]$$

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 (α=0.10) test of H_0 TIR = 1 versus H_A TIR $\neq$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 outmigrants is *D*. *D* is the ratio of SARs of transported smolts (SAR(T_0)) to in-river outmigrants (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:

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

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:

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

where S_R is the estimated in-river survival from LGR tailrace to BON tailrace and S_T is the assumed direct transportation survival rate (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 hydro system 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 rate 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 rate 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 rate for the fish once they were placed into the transportation vehicle (truck or barge). The S_T estimate for years prior to 2006 is:

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

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:

$$S_T = (0.98)[(X_{12}+X_{1A2}+ X_{1AA2})/(X_{12}+X_{1A2}/S_2+ X_{1AA2}/(S_2 \bullet S_3)] \quad [A.17]$$

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 (α=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 Chinook, wild and hatchery steelhead, and hatchery sockeye.

Wild and hatchery Chinook

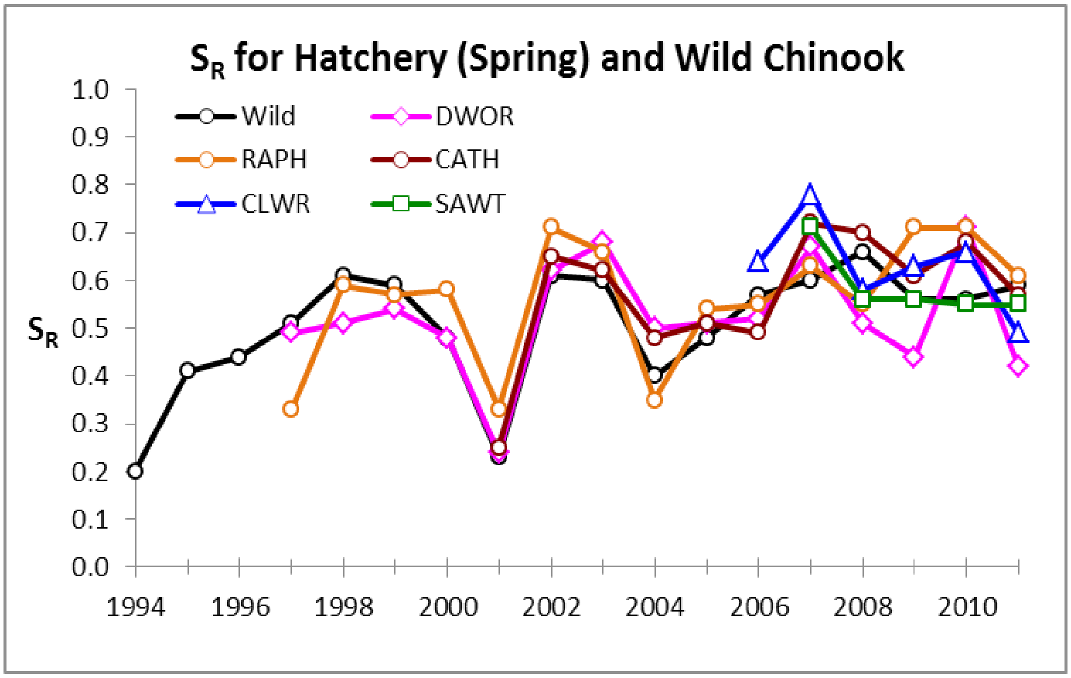


Figure A.2 Trend in in-river survival (S_R) for PIT-tagged Snake River wild spring/summer Chinook and hatchery spring Chinook in migration years 1994 to 2011. Data are from Tables A.1 and A.2.

Table A.1 Estimated in-river survival LGR to BON (S_R) of PIT-tagged wild Chinook and hatchery spring Chinook from Rapid River Hatchery, Dworshak NFH, and Catherine Creek AP for migration years 1994 through 2011 (with 90% confidence intervals). Migration years 2006 and later use reach survival rate 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[1] (0.33 - 0.82)	0.33[3] (0.24 - 0.45)	0.49[3] (0.31 - 0.80)	
1998	0.61 (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 - 0.62)	0.71 (0.65 - 0.79)	0.71 (0.65 - 0.78)	0.68 (0.56 - 0.95)
2011	0.59[1] (0.55 - 0.66)	0.61[2] (0.53 - 0.71)	0.42 (0.31 - 0.59)	0.57[2] (0.42 - 0.77)
Geomean	**0.51**	**0.56**	**0.54**	**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 rate 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 wild Chinook and hatchery spring Chinook from Clearwater Hatchery and Sawtooth Hatcheryfor migration years 1994 through 2011 (with 90% confidence intervals). Migration years 2006 and later use reach survival rate estimates of combined T and R groups.

Migration Year	Aggregate Wild Chinook	Clearwater Hatchery	Sawtooth 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[1] (0.33 - 0.82)		
1998	0.61 (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 (0.54 - 0.75)	
2007	0.60[1] (0.57 - 0.63)	0.78 (0.74 - 0.83)	0.71 (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 - 0.72)	0.55 (0.44 - 0.70)
2011	0.59[1] (0.55 - 0.66)	0.49 (0.40 - 0.64)	0.55[1] (0.41 - 0.78)
Geomean	**0.51**	**0.62**	**0.58**
2001	0.23 (0.20 - 0.27)		

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

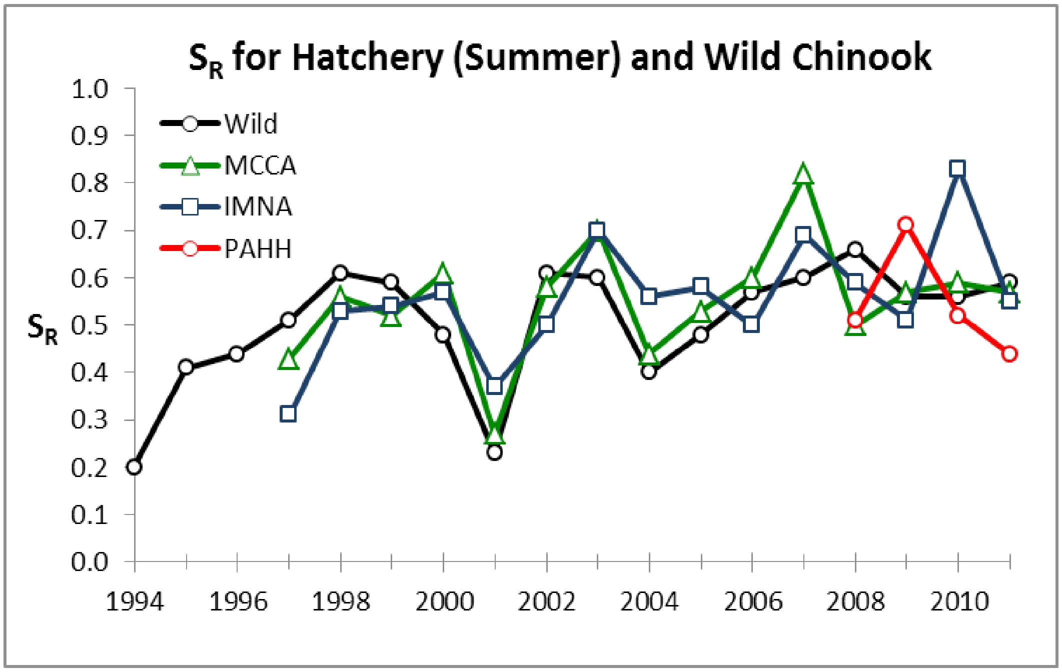


Figure A.3 Trend in in-river survival (S_R) for PIT-tagged Snake River wild spring/summer Chinook and hatchery summer Chinook in migration years 1994 to 2011. Data for wild Chinook are from Table A.1 and hatchery summer Chinook are from Table A.3.

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 2011 (with 90% confidence intervals). Migration years 2006 and later use reach survival rate estimates of combined T and R groups.

Migration Year	McCall Hatchery	Imnaha AP	Pahsimeroi Hatchery	Clearwater Hatchery
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 (0.52 - 0.66)	0.83 (0.70 - 1.02)	0.52 (0.38 - 0.76)	
2011	0.57[2] (0.50 - 0.66)	0.55[1] (0.45 - 0.71)	0.44[1] (0.38 - 0.52)	0.62[1] (0.53 - 0.74)
Geomean	**0.57**	**0.56**	**0.54**	
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 rate expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

Wild and hatchery Steelhead

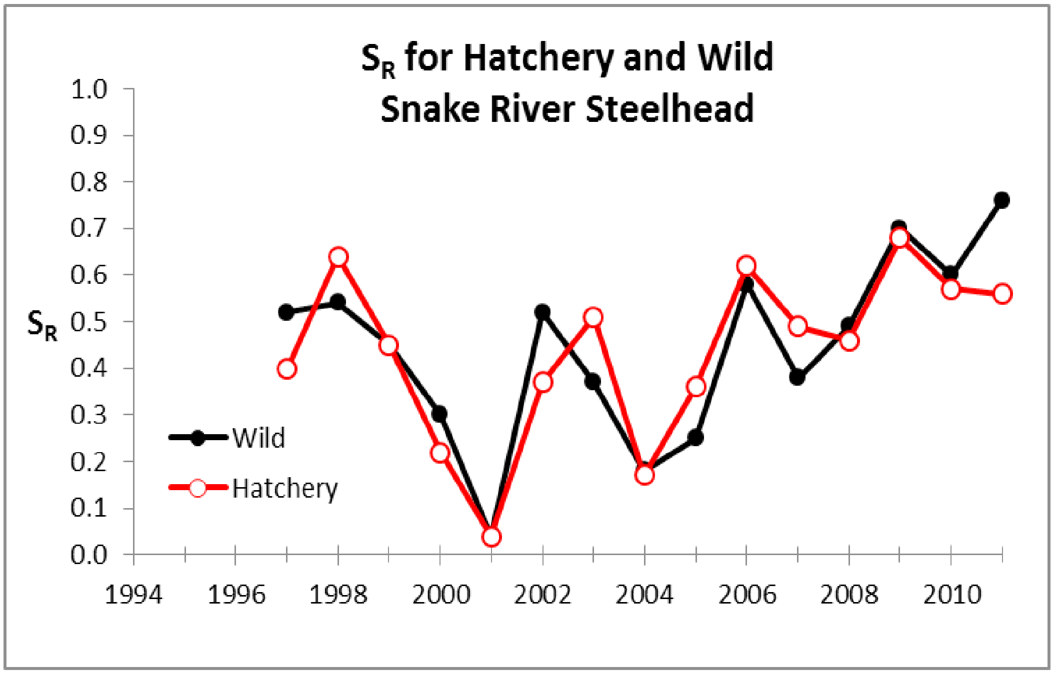


Figure A.4 Trend in in-river survival (S_R) for PIT-tagged Snake River aggregate wild and hatchery steelhead in migration years 1997 to 2011. Data are from Table A.4.

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 2011 (with 90% confidence intervals). Migration years 2006 and later use reach survival rate 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 (0.44 - 0.49)
2009	0.70[1] (0.59 - 0.85)	0.68 (0.63 - 0.72)
2010	0.60 (0.51 - 0.71)	0.57 (0.54 - 0.59)
2011	0.76[2] (0.62 - 0.96)	0.56[2] (0.54 - 0.59)
Geomean	**0.44**	**0.44**
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 rate expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).

Table A.5 Estimated in-river survival LGR to BON (S_R) of PIT-tagged hatchery A-Run steelhead for migration years 2008 through 2011 (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
2008	0.50[2] (0.41 - 0.60)	0.43[2] (0.35 - 0.54)	0.50[2] (0.44 - 0.57)	
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] (0.58 - 0.90)
2010	0.62 (0.57 - 0.69)	0.57 (0.51 - 0.66)	0.53[2] (0.48 - 0.59)	0.72 (0.58 – 0.95)
2011	0.67[2] (0.60 - 0.77)	0.57[2] (0.47 - 0.72)	0.70[2] (0.63 - 0.79)	0.60[2] (0.51 - 0.73)
Geomean	**0.61**	**0.56**	**0.60**	**0.68**

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

Table A.6 Estimated in-river survival LGR to BON (S_R) of PIT-tagged hatchery B-Run steelhead for migration years 2008 through 2011 (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
2008	0.47[2] (0.44 - 0.51)	0.42[2] (0.37 - 0.49)
2009	0.61 (0.55 - 0.68)	0.70 (0.58 - 0.87)
2010	0.52 (0.49 - 0.56)	0.46 (0.40 - 0.54)
2011	0.48[2] (0.46 - 0.50)	0.55[2] (0.43 - 0.72)
Geomean	**0.52**	**0.52**

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

Hatchery Sockeye

Table A.7 Estimated in-river survival LGR to BON (S_R) of PIT-tagged hatchery sockeye from Sawtooth Hatchery for migration years 2009 through 2011 (with 90% confidence intervals). All reach survival estimates are of combined T and R groups.

Migration Year	Sawtooth Hatchery
2009	0.64 (0.52 - 0.83)
2010	0.53 (0.41 - 0.73)
2011	0.44[1] (0.35 - 0.56)
Geomean	**0.53**

[1 to 3] Number of reaches with a constant "per mile" survival rate expansion applied (1 = 25% expansion JDA to BON; 2 = 51% expansion MCN to BON; 3 = 77% expansion LMN to BON).
Due to small sample sizes, S_R for the Oxbow Hatchery sockeye cannot be estimated for migration years 2009-2011.

Estimates of SAR by Study Category

Presented here are the LGR-to-GRA SAR estimates 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 Chinook

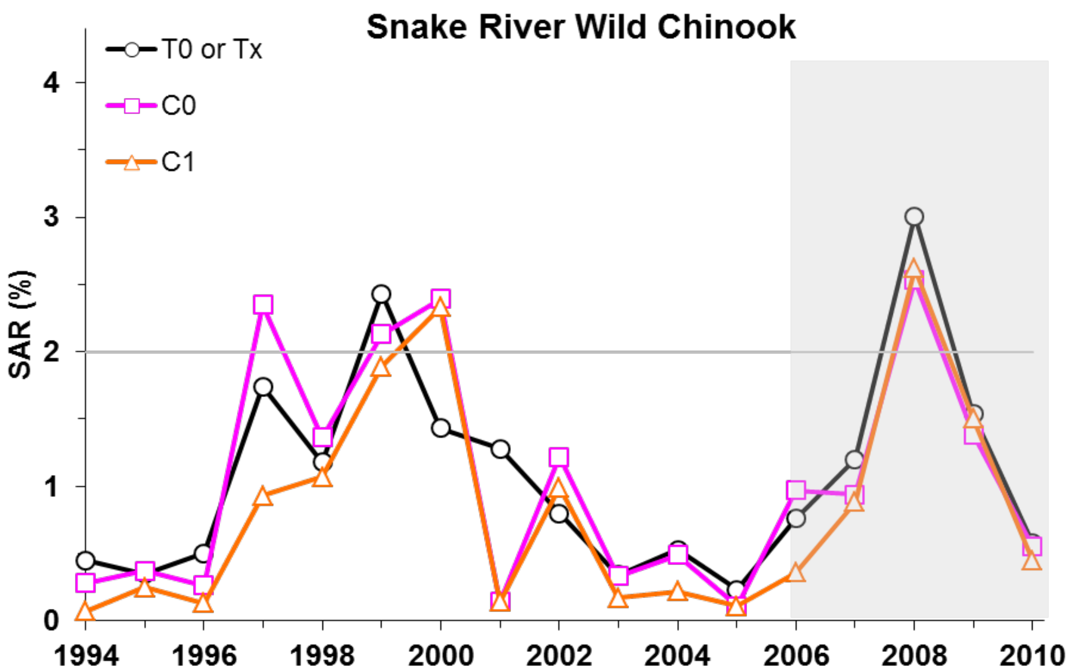


Figure A.5 Estimated LGR-to-GRA SAR for PIT-tagged wild Chinook aggregate in transport (T_0 or T_X beginning 2006) and in-river (C_0 and C_1) study categories for migration years 1994 to 2010 (incomplete adult returns for 2010). The years with the later start of transportation are highlighted. For 2001 and 2005, only 1 in-river SAR was calculated (see methods). Data from Table A.8.

Table A.8 Estimated LGR-to-GRA SAR (%) for PIT-tagged wild Chinook in annual aggregate for each study category from 1994 to 2010 (with 90% confidence intervals).

Mig. 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 yrs[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 [C]	0.57	(0.46 – 0.69)	0.55	0.46 – 0.64)	0.45	(0.18 – 0.75)
17-yr avg.	**1.08**	**(0.74 – 1.42)**	**1.05**	**(0.68 – 1.42)**	**0.83**	**(0.47 – 1.19)**

[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 adult return (only returning 2-salts as of September 10, 2012)

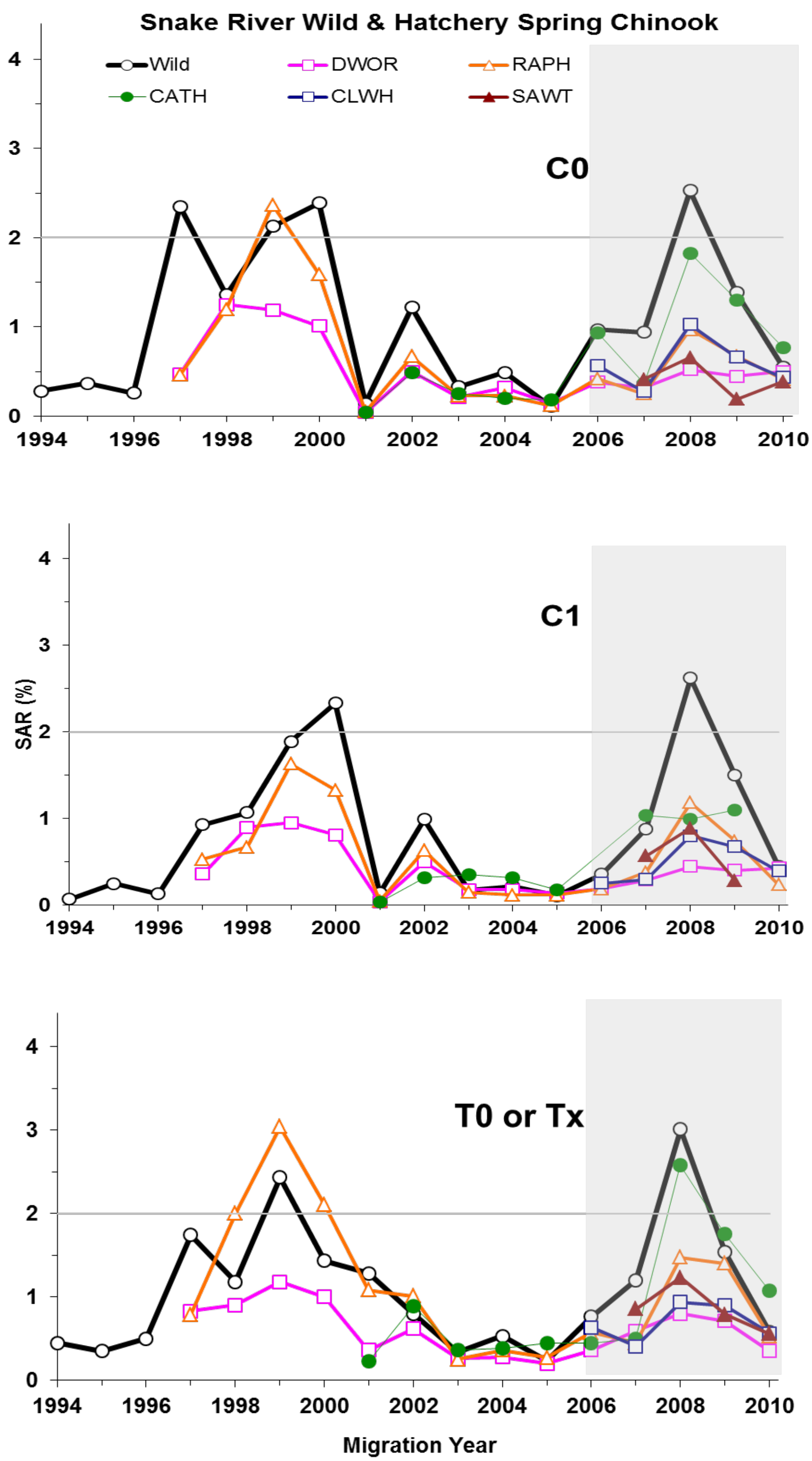


Figure A.6 Estimated LGR-to-GRA SAR for PIT-tagged wild Chinook aggregate and five CSS hatchery spring Chinook groups in transport (T_0 or T_X beginning 2006) and in-river (C_0 and C_1) study categories for migration years 1994 to 2010 (incomplete adult returns for 2010). The years with the later start of transportation are highlighted. For 2001 and 2005, only 1 in-river SAR was calculated (see methods). Wild Chinook data from Table A.8, hatchery spring Chinook data from Tables A.9-A.13.

Table A.9 Estimated LGR-to-GRA SAR (%) for PIT-tagged spring Chinook from Rapid River Hatchery for each study category from 1997 to 2010 (with 90% confidence intervals).

Mig. 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 yrs[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 [C]	0.53 (0.38 – 0.68)	0.41 (0.35 – 0.47)	0.24 (0.00 – 0.82)
14-yr avg.	**1.09 (0.68 – 1.50)**	**0.69 (0.37 – 1.01)**	**0.57 (0.32 – 0.82)**

[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 adult return (only returning 2-salts as of September 10, 2012)

Table A.10 Estimated LGR-to-GRA SAR (%) for PIT-tagged spring Chinook from Dworshak Hatchery for each study category from 1997 to 2010 (with 90% confidence intervals).

Mig. 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 yrs[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	0.71 (0.57 – 0.87)	0.45 (0.36 – 0.53)	0.40 (0.26 – 0.56)
2010 [C]	0.35 (0.23 – 0.49)	0.50 (0.43 – 0.57)	0.43 (0.23 – 0.65)
14-yr avg.	**0.60 (0.45 – 0.75)**	**0.52 (0.34 – 0.70)**	**0.42 (0.28 – 0.56)**

[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 adult return (only returning 2-salts as of September 10, 2012)

Table A.11 Estimated LGR-to-GRA SAR (%) for PIT-tagged spring Chinook from Catherine Creek AP for each study category from 2001 to 2010 (with 90% confidence intervals).

Mig. 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 yrs[B]	**SAR(T_X)_t %**	**SAR(C_0)_crt %**	**SAR(EC_1)_t %**
2006	0.45 (0.24 – 0.67)	0.93 (0.55 – 1.33)	N/A[C]
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 [D E]	1.07 (0.68 – 1.50)	0.76 (0.57 – 0.96)	N/A[F]
10-yr avg.	**0.87 (0.41 – 1.33)**	**0.64 (0.29 – 0.99)**	**0.54 (0.23 – 0.85)**

[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] Only 274 PIT-tagged Catherine Creek hatchery Chinook estimated in C_1 category with no adult returns – the average does not includes this year.
[D] Incomplete adult return (only returning 2-salts as of September 10, 2012)
[E] See Section: Special Considerations for 2010
[F] Only 79 PIT-tagged Catherine Creek hatchery Chinook estimated in C_1 category with no adult returns – the average does not include this year.

Table A.12 Estimated LGR-to-GRA SAR (%) for PIT-tagged spring Chinook from Clearwater Hatchery for each study category from 2006 to 2010 (with 90% confidence intervals).

Mig. 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 C]	0.56 (0.40 – 0.73)	0.43 (0.38 – 0.49)	0.39 (0.18 – 0.61)
5-yr avg.	**0.68 (0.44 – 0.92)**	**0.59 (0.29 – 0.89)**	**0.48 (0.23 – 0.73)**

[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 adult return (only returning 2-salts as of September 10, 2012)
[C] See Section: Special Considerations for 2010

Table A.13 Estimated LGR-to-GRA SAR (%) for PIT-tagged spring Chinook from Sawtooth Hatchery for each study category from 2007 to 2010 (with 90% confidence intervals).

Mig. 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]	0.56 (0.32 – 0.83)	0.38 (0.26 – 0.52)	N/A[D]
4-yr avg.	**0.86 (0.48 – 1.24)**	**0.41 (0.15 – 0.67)**	**0.58 (0.00[E] – 1.21)**

[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 adult return (only returning 2-salts as of September 10, 2012)

[C] See Section: Special Considerations for 2010

[D] Only 84 PIT-tagged Sawtooth hatchery Chinook estimated in C_1 category with no adult returns – the average does not include this year.

[E] The lower limit of 90% confidence interval is shown as 0.00 rather than the negative value resulting from the limited degrees of freedom and lack of precision.

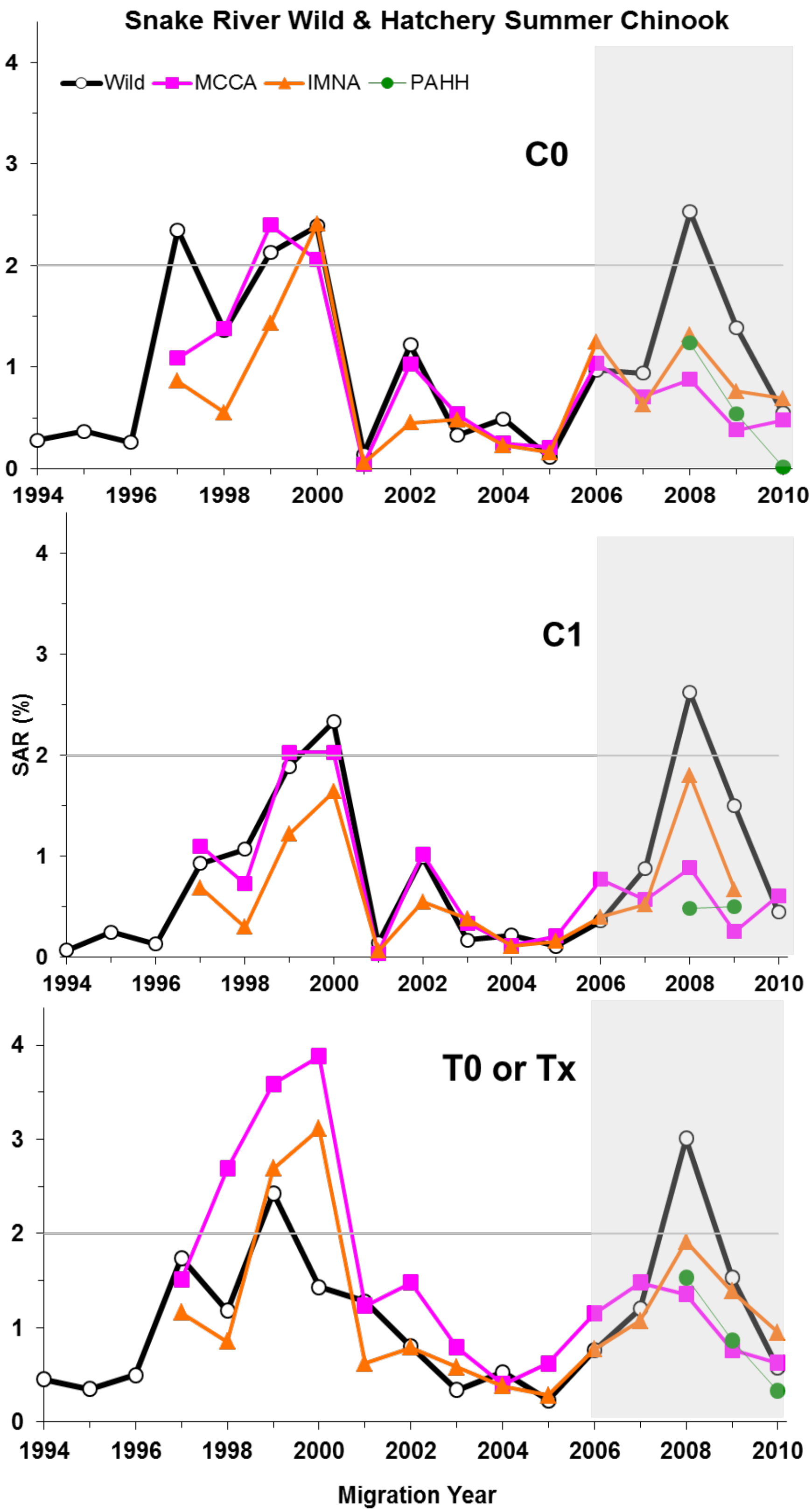


Figure A.7 Estimated LGR-to-GRA SAR for PIT-tagged wild Chinook aggregate and three CSS hatchery summer Chinook groups in transport (T_0 or T_X beginning 2006) and in-river (C_0 and C_1) study categories for migration years 1994 to 2010 (incomplete adult returns for 2010). The years with the later start of transportation are highlighted. For 2001 and 2005, only 1 in-river SAR was calculated (see methods). Wild Chinook data from Table A.8, hatchery summer Chinook data from Tables A.14-A.16.

Table A.14 Estimated LGR-to-GRA SAR (%) for PIT-tagged summer Chinook from McCall Hatchery for each study category from 1997 to 2010 (with 90% confidence intervals).

Mig. 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 yrs[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,D]	0.63 (0.46 – 0.79)	0.48 (0.40 – 0.56)	0.61 (0.00 – 1.46)
14-yr avg.	**1.54 (1.00 – 2.08)**	**0.89 (0.55 – 1.23)**	**0.76 (0.45 – 1.07)**

[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 adult return (only returning 2-salts as of September 10, 2012)
[D] See Section: Special Considerations for 2010

Table A.15 Estimated LGR-to-GRA SAR (%) for PIT-tagged summer Chinook from Imnaha River AP for each study category from 1997 to 2010 (with 90% confidence intervals).

Mig. 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(C1)}	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 yrs[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)	0.69 (0.56 – 0.85)	N/A[E]
14-yr avg.	**1.18 (0.77 – 1.59)**	**0.81 (0.50 – 1.12)**	**0.65 (0.36 – 0.94)**

[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 adult return (only returning 2-salts as of September 10, 2012)
[D] See Section: Special Considerations for 2010
[E] Only 119 PIT-tagged Imnaha River AP hatchery Chinook estimated in C_1 category with no adult returns – the average does not include this year.

Table A.16 Estimated LGR-to-GRA SAR (%) for PIT-tagged summer Chinook from Pahsimeroi Hatchery for each study category from 2008 to 2010 (with 90% confidence intervals).

Mig. 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 – 0.61)	0.02 (0.00 – 0.05)	NA[C]
3-yr avg.	**0.91 (0.00[D] – 2.15)**	**0.60 (0.00[D] – 1.86)**	**0.50 (0.46 – 0.54)**

[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 adult return (only returning 2-salts as of September 10, 2012)**
[C] **Only 550 PIT-tagged Pahsimeroi hatchery Chinook estimated in C1 category with no adult returns – the average does not include this year.**
[D] **The lower limit of 90% confidence interval is shown as 0.00 rather than the negative value resulting from the limited degrees of freedom and lack of precision.**

Wild and hatchery Steelhead

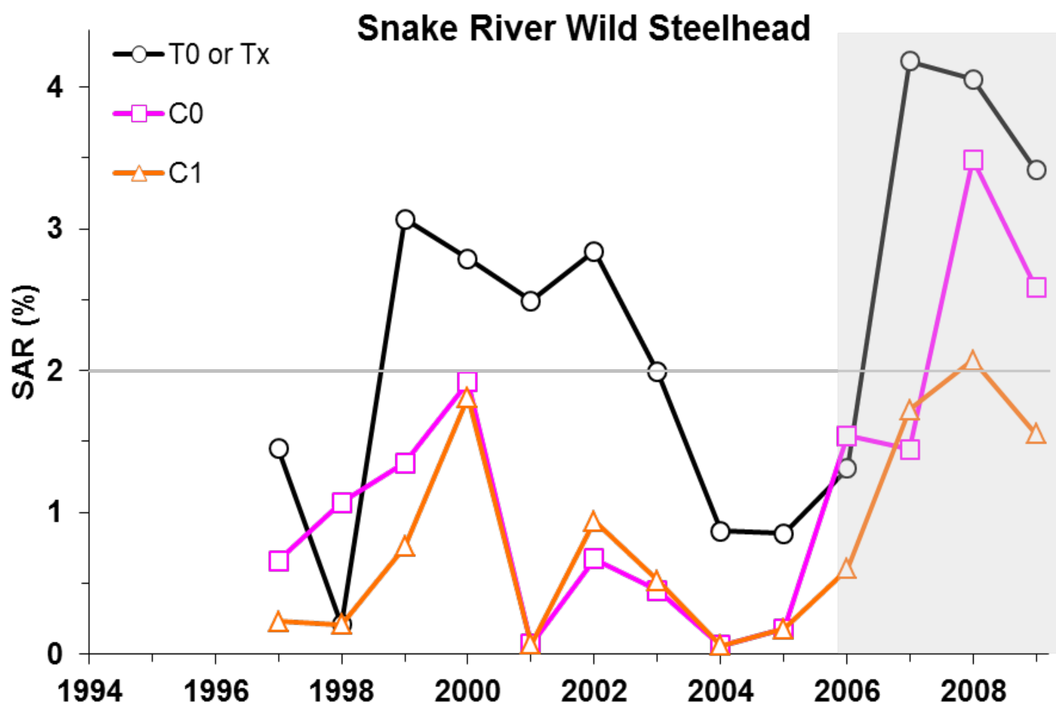


Figure A.8. Estimated LGR-to-GRA SAR for PIT-tagged wild steelhead aggregate in transport (T_0 or T_X beginning 2006) and in-river (C_0 and C_1) study categories for migration years 1997 to 2009. The years with the later start of transportation are highlighted. For 2001, 2004, and 2005, only 1 in-river SAR was calculated (see methods). Data from Table A.17.

Table A.17. Estimated LGR-to-GRA SAR (%) for PIT-tagged wild steelhead in annual aggregate for each study category from 1997 to 2009 (with 90% confidence intervals).

Mig. 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	(0.0 – 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(C1)}		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 yrs[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 [C]	3.41	(2.87 – 3.97)	2.58	(1.96 – 3.26)	1.55	(1.12 – 2.02)
13-yr avg.	**2.27**	**(1.62 – 2.92)**	**1.19**	**(0.66 – 1.72)**	**0.82**	**(0.45 – 1.19)**

[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 September 10. 2012 at GRA.

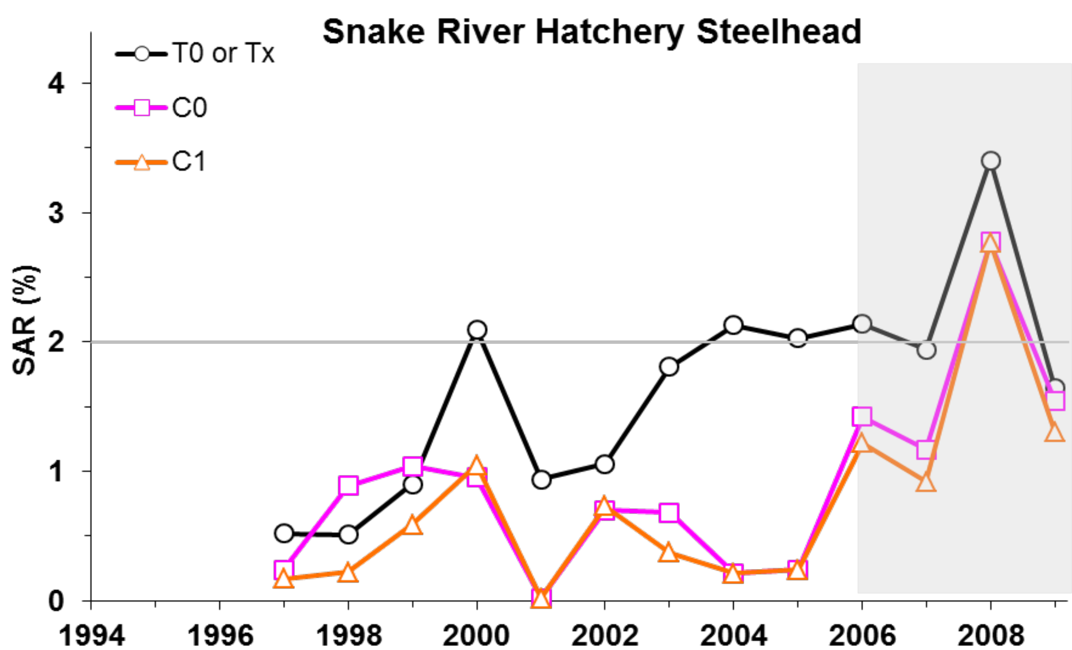


Figure A.9. Estimated LGR-to-GRA SAR for PIT-tagged hatchery steelhead aggregate in transport (T_0 or T_X beginning 2008) and in-river (C_0 and C_1) study categories for migration years 1997 to 2009. The years with the later start of transportation are highlighted. For 2001, 2004, and 2005, only 1 in-river SAR was calculated (see methods). Data from Table A.18. SARs for 2008 and 2009 hatchery steelhead aggregate includes all groups with pre-assignment in those years (see Table A.19 for details).

Table A.18. Estimated LGR-to-GRA SAR (%) for PIT-tagged hatchery steelhead in annual aggregate for each study category from 1997 to 2009 (with 90% confidence intervals).

Mig. Year	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(C1)}	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)
2008 [C]	3.41 (3.25 – 3.56)	2.78 (2.63 – 2.92)	2.77 (2.57 – 2.97)
2009 [D,E]	1.65 (1.55 – 1.75)	1.55 (1.43 – 1.67)	1.31 (1.21 – 1.41)
13-yr avg.	**1.63 (1.21 – 2.05)**	**0.91 (0.53 – 1.29)**	**0.76 (0.38 – 1.14)**

[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] SARs for 2008 hatchery steelhead aggregate includes all groups with pre-assignment (see Table A.12 for details).
[D] All steelhead hatchery groups pre-assigned and included in estimation of SARs
[E] Incomplete steelhead adult returns until 3-salt returns (if any) occur after September 10. 2012 at GRA.

Table A.19. Estimated LGR-to-GRA SAR (%) for PIT-tagged hatchery steelhead, by release basin and run type in 2008 and 2009 (with 90% confidence intervals).

Mig. Year[C]	Basin and Run Type	SAR(T_0) %	SAR(C_0) %	SAR(C_1) %
2008	Grande Ronde A-run [A]	4.89 (4.46 – 5.33)	4.65 (4.18 – 5.15)	3.57 (3.04 – 4.10)
2008	Imnaha A-run [A]	4.84 (4.35 – 5.31)	3.87 (3.35 – 4.42)	4.82 (4.07 – 5.61)
2008	Salmon A-run	5.09 (4.73 – 5.49)	4.41 (4.01 – 4.78)	4.91 (4.25 – 5.60)
2008	Combined A-run	4.96 (4.71 – 5.22)	4.42 (4.14 – 4.70)	4.38 (3.98 – 4.79)
2008	Clearwater B-run	1.96 (1.68 – 2.23)	1.26 (1.10 – 1.43)	1.28 (1.05 – 1.49)
2008	Salmon B-run	0.84 (0.68 – 1.01)	0.92 (0.74 – 1.11)	0.63 (0.37 – 0.92)
2008	Combined B-run	1.34 (1.20 – 1.49)	1.13 (1.02 – 1.26)	1.13 (0.95 – 1.32)
2008 Aggregate [B]		**3.41 (3.25 – 3.56)**	**2.78 (2.63 – 2.92)**	**2.77 (2.57 – 2.79)**
2009 [C]	Grande Ronde A-run	1.72 (1.47 – 2.00)	1.64 (1.37 – 1.91)	1.46 (1.15 – 1.80)
2009 [C]	Imnaha A-run	1.78 (1.48 – 2.06)	1.75 (1.44 – 2.00)	1.51 (1.13 – 1.86)
2009 [C]	Salmon A-run	2.00 (1.81 – 2.20)	1.76 (1.53 – 2.00)	1.94 (1.71 – 2.19)
2009 [C]	Hells Canyon A-run	3.71 (3.10 – 4.31)	2.01 (1.35 – 2.66)	2.42 (1.60 – 3.39)
2009 [C]	Combined A-run	2.04 (1.91 – 2.19)	1.75 (1.60 – 1.90)	1.79 (1.62 – 1.96)
2009 [C]	Clearwater B-run	0.97 (0.76 – 1.16)	1.34 (1.12 – 1.57)	0.97 (0.85 – 1.09)
2009 [C]	Salmon B-run	0.79 (0.63 – 0.95)	0.72 (0.52 – 0.95)	0.77 (0.55 – 1.02)
2009 [C]	Combines B-run	0.87 (0.74 – 0.99)	1.11 (0.95 – 1.28)	0.93 (0.82 – 1.04)
2009 Aggregate [D]		**1.65 (1.55 – 1.75)**	**1.55 (1.43 – 1.67)**	**1.31 (1.21 – 1.41)**

[A] Not pre-assigned to T and R groups. Pre-2006 methods applied for these groups (see **Pre-2006 migration years** ***section in above methods for details).***
[B] SARs for 2008 hatchery steelhead aggregate includes only groups with pre-assignment.
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after September 10. 2012 at GRA.
[D] All steelhead hatchery groups pre-assigned and included in estimation of SARs.

Hatchery Sockeye

Table A.20 Estimated LGR-to-GRA SAR (%) for PIT-tagged sockeye reared from Sawtooth Hatchery for each study category from 2009 and 2010 (with 90% confidence intervals).

Migr. 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]	N/A[C]	0.42 (0.27 – 0.57)	0.11 (0.03 – 0.22)

[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 adult return (only 2-salts as of September 10, 2012)
[C] Only 38 PIT-tagged Sawtooth Hatchery sockeye estimated in transport category with no adult returns.

Table A.21 Estimated LGR-to-GRA SAR (%) for PIT-tagged sockeye reared from Oxbow Hatchery for each study category from 2009 and 2010 (with 90% confidence intervals).

Migr. Year[A]	$SAR(T_X)\_t$ %	$SAR(C_0)\_crt$ %	$SAR(EC_1)\_t$ %
2009[B]	2.84 (1.89 – 3.64)	1.33 (0.89 – 1.86)	N/A[C]
2010 [D]	N/A[E]	N/A[E]	N/A[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] Used same methodology outlined in *Special considerations for 2010* for 2009 Oxbow.
[C] Only 67 PIT-tagged Oxbow hatchery sockeye estimated in C_1category with no adult returns
[D] Incomplete adult return (only 2-salts as of September 10, 2012)
[E] Due to small sample sizes and other issues with 2010 (see Section: Special considerations for 2010), LGR-to-GRA SARs were not possible.

Estimates of TIR and D

Wild and hatchery Chinook

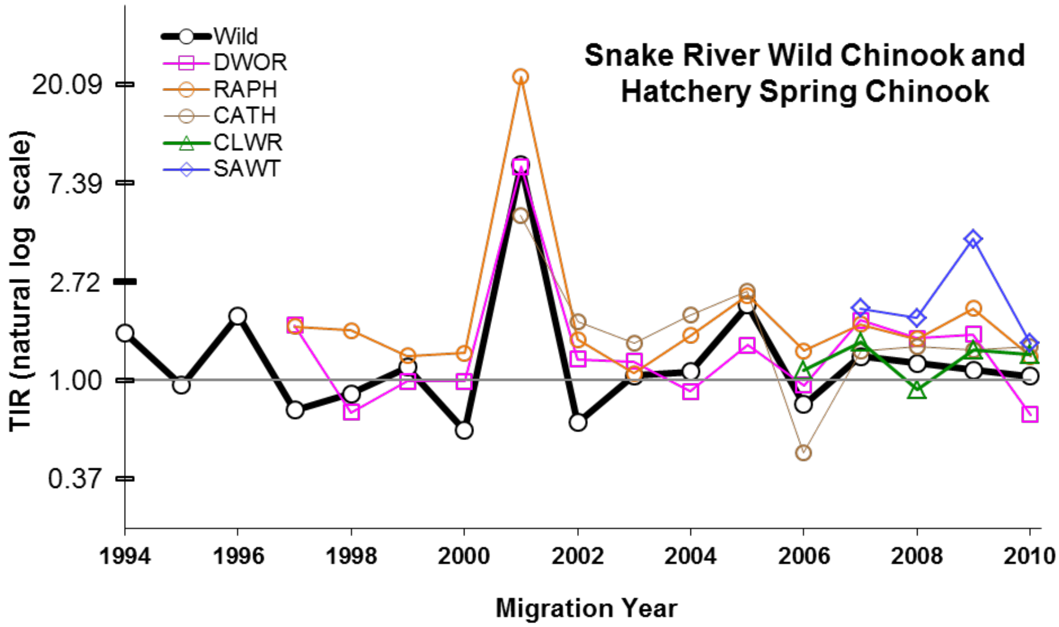


Figure A.10. Trend in TIR on the natural log scale for PIT-tagged Snake river wild Chinook and hatchery spring Chinook for migration years 1994 to 2010. The grey reference line denotes a TIR value of 1 (in-river and transport SARs equal). The years with the later start of transportation are within the grey box. 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.22, hatchery spring Chinook data are from Tables A.23-A.27.

Table A.22. Estimated TIR and *D* of PIT-tagged wild Chinook for migration years 1994 to 2010 (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.

Mig. 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[D]	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 [A]	2.14	(**1.40** – 3.45)	1.07	(0.65 – 1.85)
2006 [B]	0.78	(0.54 – 1.14)	0.47	(0.31 – ***0.75***)
2007 [B]	1.27	(0.91 – 1.71)	0.80	(0.57 – 1.09)
2008 [B]	1.19	(**1.02** – 1.39)	0.82	(0.69 – ***0.97***)
2009 [B]	1.11	(0.89 – 1.41)	0.65	(0.50 – ***0.87***)
2010 [B,C]	1.04	(0.79 – 1.34)	0.62	(0.47 – ***0.81***)
Geomean	1.21	(0.93 – 1.57)	0.62	(0.51 – ***0.75***)

[A] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[B] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[C] Incomplete adult return (only returning 2-salts as of September 10, 2012)
[D] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.

Table A.23. Estimated TIR and *D* of PIT-tagged Rapid River Hatchery spring Chinook for 1997 to 2010 (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.

Mig. 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[D]	21.7	(**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 [A]	2.36	(**1.59** – 3.79)	1.31	(0.83 – 2.30)
2006 [B]	1.35	(0.98 – 1.91)	0.83	(0.60 – 1.19)
2007 [B]	1.77	(**1.25** – 2.57)	1.18	(0.81 – 1.74)
2008 [B]	1.52	(**1.26** – 1.85)	0.87	(0.71 – 1.08)
2009 [B]	2.08	(**1.69** – 2.57)	1.51	(**1.17** – 2.00)
2010 [B C]	1.28	(0.90 – 1.73)	0.93	(0.66 – 1.27)
Geomean	1.86	(**1.31** – 2.64)	1.06	(0.79 – 1.42)

[A] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[B] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[C] Incomplete adult return (only returning 2-salts as of September 10, 2012)
[D] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.

Table A.24. Estimated TIR and *D* of PIT-tagged Dworshak Hatchery spring Chinook for 1997 to 2010 (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.

Mig. 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[D]	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 [A]	1.43	(0.97 – 2.17)	0.77	(0.51 – 1.22)
2006 [B]	0.95	(0.69 – 1.30)	0.60	(0.43 – ***0.83***)
2007 [B]	1.84	(**1.11** – 2.81)	1.31	(0.78 – 2.02)
2008 [B]	1.53	(**1.17** – 1.99)	0.86	(0.66 – 1.13)
2009 [B]	1.59	(**1.21** – 2.13)	0.74	(0.54 – 1.04)
2010 [B C]	0.70	(0.46 – ***0.99***)	0.52	(0.33 – ***0.74***)
Geomean	1.34	(1.00 – 1.80)	0.74	(0.60 – ***0.92***)

[A] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[B] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[C] Incomplete adult return (only returning 2-salts as of September 10, 2012)
[D] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.

Table A.25. Estimated TIR and *D* of PIT-tagged Catherine Creek AP spring Chinook for 2001 to 2010 (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.

Mig. Year	TIR		*D*	
2001[D]	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 [A]	2.48	(**1.02** – 10.6)	1.32	(0.50 – 5.90)
2006 [B]	0.48	(0.25 – ***0.88***)	0.26	(0.13 – ***0.50***)
2007 [B]	1.35	(0.65 – 2.71)	1.02	(0.46 – 2.29)
2008 [B]	1.41	(**1.06** – 1.92)	1.05	(0.72 – 1.53)
2009 [B]	1.35	(0.94 – 1.95)	0.85	(0.55 – 1.35)
2010 [B C E]	1.40	(0.84 – 2.12)	1.05	(0.60 – 1.71)
Geomean	1.61	(**1.14** – 2.28)	0.93	(0.71 – 1.23)

[A] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[B] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[C] Incomplete adult return (only returning 2-salts as of September 10, 2012
[D] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[E] See Section: Special Considerations for 2010

Table A.26. Estimated TIR and *D* of PIT-tagged Clearwater Hatchery spring Chinook for 2006 to 2010 (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.

Mig. 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 C]	1.30	(0.91 – 1.77)	0.87	(0.61 – 1.19)
Geomean	1.21	(**1.01** – 1.45)	0.85	(0.66 – 1.08)

[A] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete adult return (only returning 2-salts as of September 10, 2012)
[C] See Section: Special Considerations for 2010

Table A.27. Estimated TIR and *D* of PIT-tagged Sawtooth Hatchery spring Chinook for 2007 to 2010 (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.

Mig. 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 C]	1.45	(0.75 – 2.58)	0.82	(0.41 – 1.53)
Geomean	2.21	(**1.29** – 3.76)	1.35	(0.78 – 2.35)

[A] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete adult return (only returning 2-salts as of September 10, 2012)
[C] See Section: Special Considerations for 2010

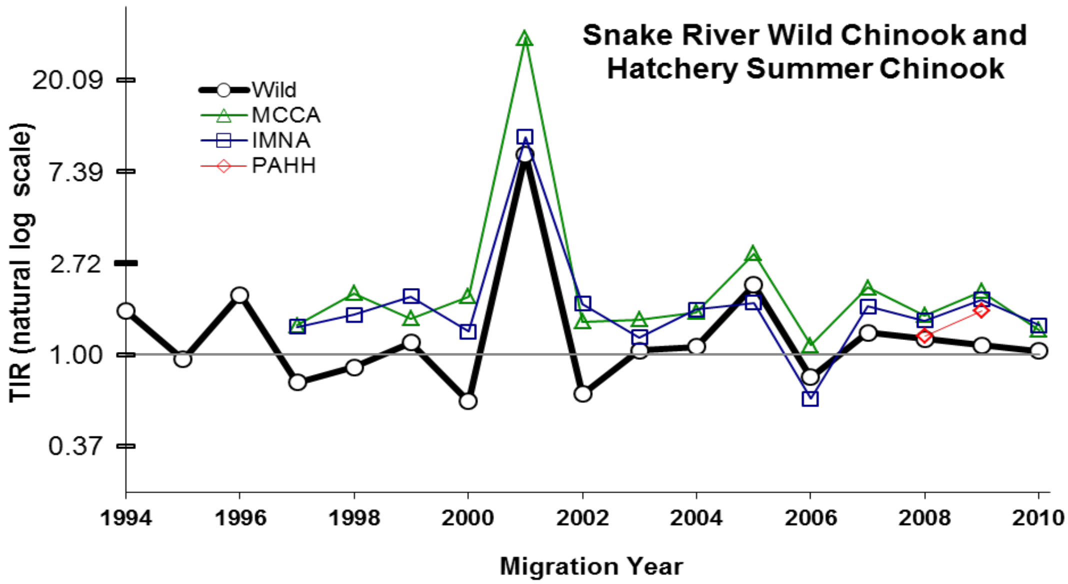


Figure A.11. Trend in TIR on the natural log scale for PIT-tagged Snake River wild Chinook and hatchery summer Chinook for migration years 1994 to 2010. The grey reference line denotes a TIR value of 1 (in-river and transport SARs equal). The years with the later start of transportation are within the grey box. The years with the later start of transportation are highlighted. 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.22, hatchery summer Chinook data are from Tables A.28-A.30. TIR estimate for 2010 PAHH not possible, see footnote C in Table A.30.

Table A.28. Estimated TIR, and *D* of PIT-tagged McCall Hatchery summer Chinook for 1997 to 2010 (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.

Mig. 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[D]	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 [A]	3.02	(**2.32** – 4.12)	1.66	(**1.23** – 2.36)
2006 [B]	1.11	(0.90 – 1.38)	0.74	(0.59 – ***0.95***)
2007 [B]	2.09	(**1.63** – 2.65)	1.78	(**1.35** – 2.31)
2008 [B]	1.54	(**1.26** – 1.94)	0.84	(0.67 – 1.08)
2009 [B]	2.00	(**1.45** – 2.71)	1.17	(0.84 – 1.64)
2009 [B C E]	1.31	(0.92 – 1.76)	0.79	(0.56 – 1.08)
Geomean	2.05	(**1.39** – 3.03)	1.16	(0.85 – 1.59)

[A] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[B] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[C] Incomplete adult return (only returning 2-salts as of July 11, 2012)
[D] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[E] See Section: Special Considerations for 2010

Table A.29. Estimated TIR and *D* of PIT-tagged Imnaha AP summer Chinook for 1997 to 2010 (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.

Mig. 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[D]	10.8	(**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 [A]	1.77	(0.91 – 3.93)	1.11	(0.54 – 2.69)
2006 [B]	0.62	(0.42 – ***0.89***)	0.36	(0.24 – ***0.54***)
2007 [B]	1.70	(**1.05** – 2.50)	1.22	(0.74 – 1.90)
2008 [B]	1.45	(**1.10** – 1.92)	0.89	(0.66 – 1.25)
2009 [B]	1.83	(**1.31** – 2.53)	0.97	(0.68 – 1.39)
2010 [B C E]	1.38	(0.88 – 1.96)	1.16	(0.73 – 1.73)
Geomean	1.67	(**1.25** – 2.22)	0.96	(0.74 – 1.25)

[A] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[B] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[C] Incomplete adult return (only returning 2-salts as of September 10, 2012)
[D] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[E] See Section: Special Considerations for 2010

Table A.30. Estimated TIR and *D* of PIT-tagged Pahsimeroi Hatchery summer Chinook for 2008 to 2010 (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.

Mig. 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]	N/A[C]-		N/A[C]	

[A] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[B] Incomplete adult return (only returning 2-salts as of July 11, 2012)
[C] There are too few C0 adults for this summer Chinook stock to get a meaningful estimate of TIR and *D*. Additional returns may make these estimates possible at a later date.

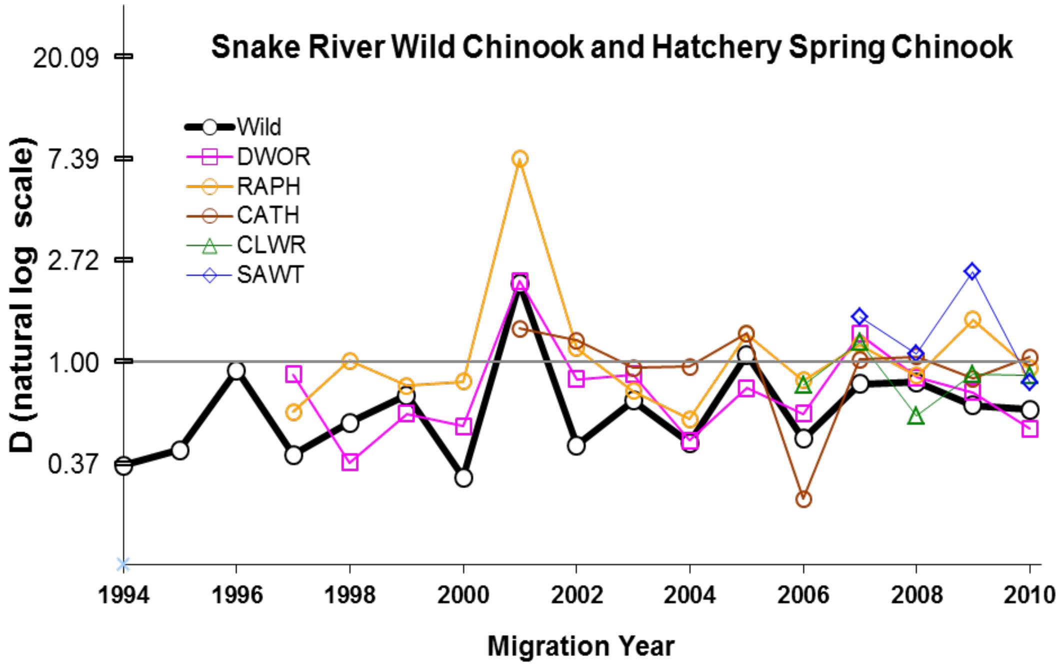


Figure A.12. Trend in *D* on the natural log scale for PIT-tagged Snake River wild Chinook and hatchery spring Chinook in migration years 1994-2010. The grey reference line denotes a *D* value of 1 (in-river and transport post-BON survivals are equal). The years with the later start of transportation are within the grey box. *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.22, hatchery spring Chinook data from Tables A.23-A.27.

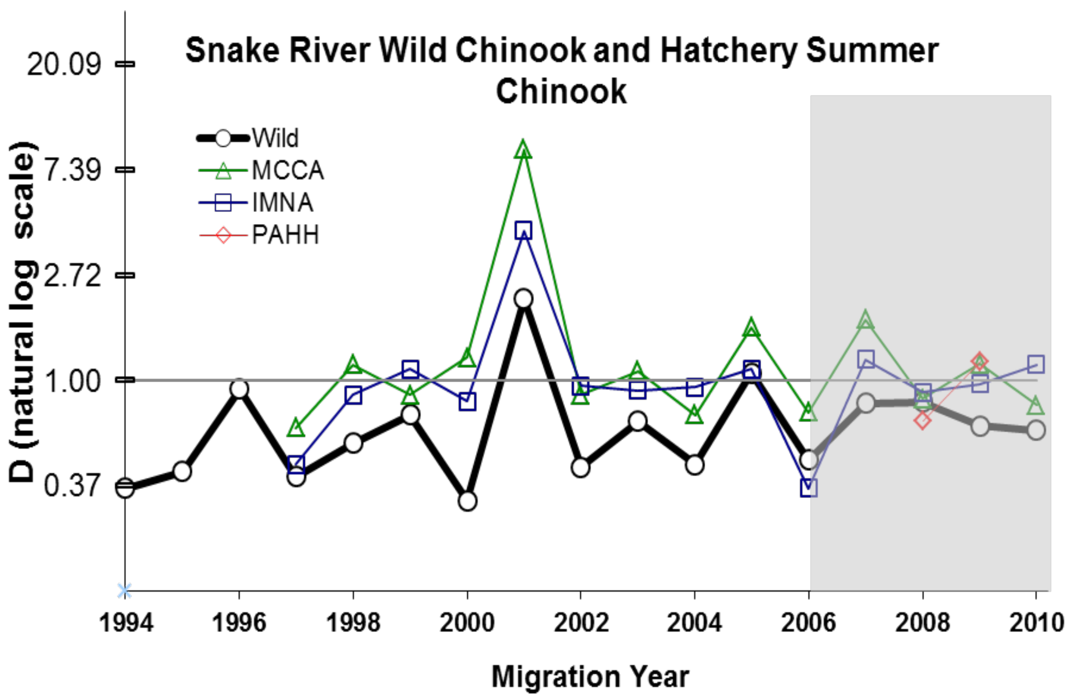


Figure A.13. Trend in *D* on the natural log scale for PIT-tagged Snake River wild Chinook and hatchery summer Chinook in migration years 1994-2010. The grey reference line denotes a *D* value of 1 (in-river and transport post-BON survivals are equal). The years with the later start of transportation are within the grey box. *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.22, hatchery summer Chinook data are from Tables A.28-A.30. *D* estimate for 2010 PAHH not possible, see footnote C in Table A.30.

Wild and hatchery steelhead

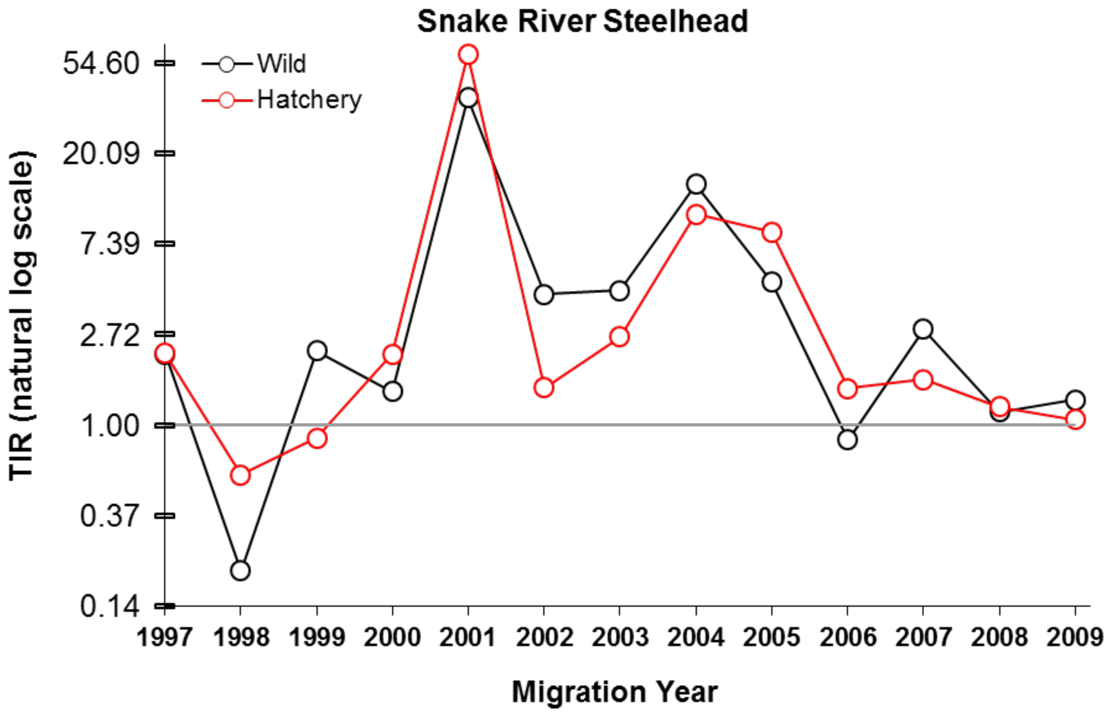


Figure A.14. Trend in TIR on the natural log scale for PIT-tagged Snake River hatchery and wild steelhead in migration years 1997 to 2009. The grey reference line denotes a TIR value of 1 (in-river and transport SARs equal). The years with the later start of transportation are within the grey box. TIR calculation for 2001, 2004, and 2005 differs from other years as in-river SAR component of ratio includes C_1 fish (see methods). Wild steelhead data are from Table A.31, hatchery steelhead data are from Table A.32.

Table A.31. Estimated TIR and *D* of PIT-tagged wild steelhead for migration years 1997 to 2009 (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.

Mig. 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 [D]	37.0	(**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 [A]	14.3	(**7.19** – 42.1)	2.69	(**1.29** – 8.78)
2005 [A]	4.88	(**3.01** – 7.98)	1.30	(0.76 – 2.30)
2006 [B]	0.85	(0.49 – 1.80)	0.52	(0.29 – 1.11)
2007 [B]	2.89	(**2.21** – 3.80)	1.20	(0.87 – 1.74)
2008 [B]	1.16	(0.93 – 1.49)	0.60	(0.45 – ***0.79***)
2009 [B C]	1.32	(0.99 – 1.81)	0.95	(0.68 – 1.41)
Geomean	2.61	(**1.38** – 4.96)	0.95	(0.63 – 1.43)

[A] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[B] TIR and D use SAR for T_X estimated with Group T and C_0 with combined Group CRT.
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after September 10, 2012 at GRA.
[D] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.

Table A.32. Estimated TIR, and *D* of PIT-tagged hatchery steelhead for migration years 1997 to 2009 (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.

Mig. 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 [D]	59.7	(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	10.3	(**5.43** – 17.9)	1.85	(0.91 – 3.46)
2005 [A]	8.44	(**5.04** – 13.4)	3.19	(**1.86** – 5.37)
2006 [B]	1.50	(0.93 – 2.42)	1.01	(0.61 – 1.63)
2007 [B]	1.66	(**1.22** – 2.16)	0.92	(0.66 – 1.30)
2008 [E]	1.23	(**1.15** – 1.31)	0.61	(0.56 – ***0.66***)
2009 [C F]	1.06	(0.97 – 1.17)	0.74	(0.66 – ***0.83***)
Geomean	2.52	(**1.36** – 4.68)	0.93	(0.67 – 1.29)

[A] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[B] No pre-assignment for hatchery steelhead, so one group; transport SARs estimated with T_X smolts.
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after September 10, 2012at GRA.
[D] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.
[E] Hatchery steelhead aggregate value is an aggregate of all pre-assigned groups for 2008, as presented in Table A.26.
[F] Hatchery steelhead aggregate value is an aggregate of all pre-assigned groups for 2009.

Table A.33. Estimated TIR, and *D* of PIT-tagged hatchery steelhead for 2008 and 2009 (with 90% confidence intervals), by release basin and run type. 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.

Mig. Year	Release Basin and Run Type	TIR		*D*	
2008	Grande Ronde A-run [A]	1.05	(0.92 – 1.20)	0.57	(0.46 – ***0.70***)
2008	Imnaha A-run [A]	1.25	(**1.06** – 1.47)	0.57	(0.44 – ***0.75***)
2008	Salmon A-run	1.15	(**1.04** – 1.29)	0.62	(0.53 – ***0.73***)
2008	Combined A-run	1.12	(**1.04** – 1.21)	0.60	(0.53 – ***0.68***)
2008	Clearwater B-run	1.55	(**1.28** – 1.85)	0.77	(0.61 – ***0.94***)
2008	Salmon B-run	0.91	(0.68 – 1.20)	0.41	(0.30 – ***0.56***)
2008	Combined B-run	1.18	(**1.01** – 1.37)	0.55	(0.47 – ***0.65***)
	2008 Aggregate[C]	1.23	(**1.15** – 1.31)	0.61	(0.56 – ***0.66***)
2009 [B]	Grande Ronde A-run	1.05	(0.83 – 1.33)	0.73	(0.58 – ***0.95***)
2009 [B]	Imnaha A-run	1.02	(0.79 – 1.29)	0.71	(0.51 – 1.01)
2009 [B]	Salmon A-run	1.14	(0.97 – 1.35)	0.79	(0.67 – ***0.95***)
2009 [B]	Hells Canyon Dam A-run	1.84	(**1.32** – 2.80)	1.37	(0.95 – 2.18)
2009 [B]	Combined A-run	1.17	(**1.05** – 1.31)	0.81	(0.72 – ***0.91***)
2009 [B]	Clearwater B-run	0.72	(0.55 – ***0.95***)	0.45	(0.34 – ***0.60***)
2009 [B]	Salmon B-run	1.10	(0.77 – 1.60)	0.80	(0.53 – 1.26)
2009 [B]	Combined B-run	0.78	(0.63 – ***0.95***)	0.51	(0.41 – ***0.64***)
	2009 Aggregate[D]	1.06	(0.96 – 1.17)	0.74	(0.66 – ***0.83***)

[A] Not pre-assigned to T and R groups. Pre-2006 methods applied for these groups (see Pre-2006 migration years section *in above methods for details*).
[B] Incomplete steelhead adult returns until 3-salt returns (if any) occur after September 10, 2012 at GRA.
[C] Estimate for aggregate of 3 groups: Salmon A-run, Salmon B-run, and Clearwater B-run.
[D] All steelhead hatchery groups pre-assigned and included in estimation of SARs

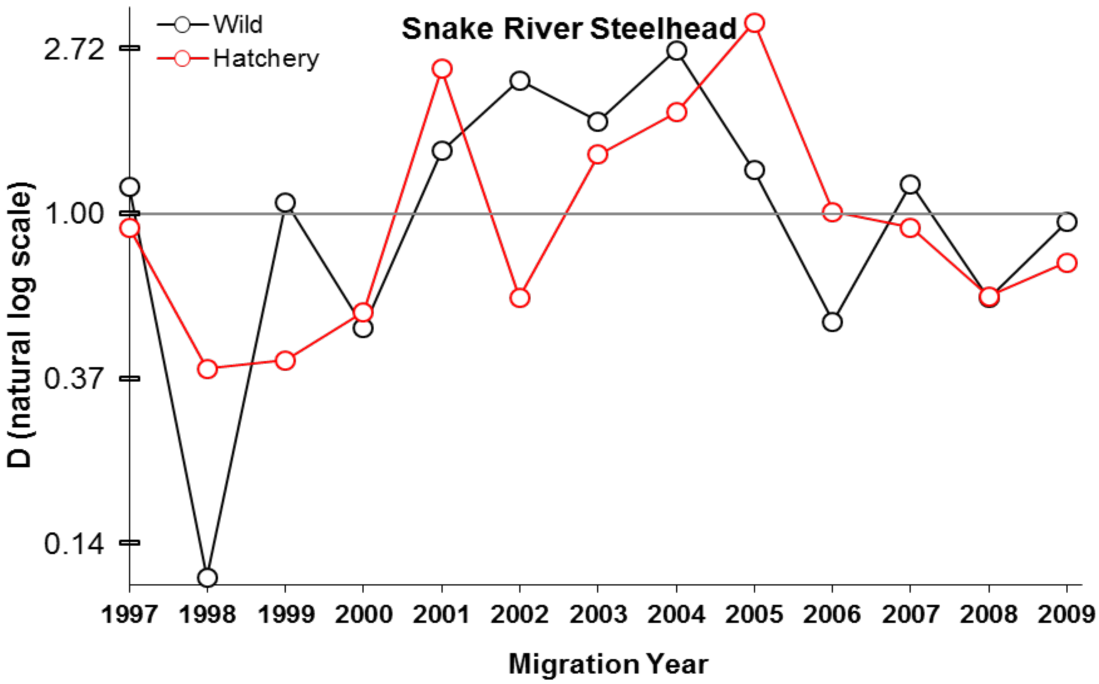


Figure A.15. Trend in *D* on the natural log scale for PIT-tagged Snake River hatchery and wild steelhead in migration years 1997-2009. The grey reference line corresponds to a *D* value of 1 (in-river and transport post-BON survivals are equal). The years with the later start of transportation are within the grey box. *D* calculation for 2001, 2004, and 2005 differs from other years as in-river SAR component of ratio includes C_1 fish (see methods). Wild steelhead data are from Table A.31, aggregate hatchery steelhead data are from Table A.32.

Hatchery Sockeye

Table A.34. Estimated TIR and *D* of PIT-tagged hatchery sockeye reared at Sawtooth Hatchery and released in 2009 and 2010 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migr. Year [A]	TIR	*D*
2009	1.04 (0.83 – 1.30)	0.72 (0.53 – 1.02)
2010[B]	N/A[C]	N/A[C]

[A] TIR and D use SAR T_x estimated with Group T and C_0 with combined Group CRT
[B] Incomplete adult return (only 2-salts as of September 10, 2012)
[C] Only 38 PIT-tagged Sawtooth hatchery sockeye estimated in Transport category with no adult returns. With no T_x SAR, cannot estimate TIR and *D* for this group.

Table A.35. Estimated TIR and *D* of PIT-tagged hatchery sockeye reared at Oxbow Hatchery and released in 2009 and 2010 (with 90% confidence intervals). Lower limit values >1.00 are in bold and upper limit values <1.00 are in bold-italics.

Migr. Year [A]	TIR	*D*
2009[B]	2.13 (**1.23** – 3.37)	N/A[C]
2010[D]	N/A[E]	N/A[E]

[A] TIR and D use SAR T_x estimated with Group T and C_0 with combined Group CRT
[B] Used same methodology outlined in *Special Considerations for 2010* for 2009 out-migrants.
[C] Due to small sample size, could not estimate D for migration year 2009.
[D] Incomplete adult return (only 2-salts as of September 10, 2012)
[E] Due to small sample sizes and other issues with 2010 (see Section: Special considerations for 2010), LGR-to-GRA SARs were not possible. Without SAR estimates, cannot estimate TIR and *D*.

Model comparisons characterizing the relationship between $\log_e$(TIR) and in-river survival (S_R)

Table A.36. Summary table of $\log_e$(TIR) vs. S_R for wild Snake River Chinook and steelhead. Akaike's Information Criterion for small sample sizes (AIC_C), AIC differences (Δi) and AIC weights (w_i) for four models with common or species-specific intercepts and slopes are shown.

Intercept	Slope	AIC_C	Δi	w_i
Common	Common	67.2	0.64	0.30
Species-Specific	Species-Specific	67.2	0.69	0.29
Common	Species-Specific	66.5	0.00	0.41
Species-Specific	Common	85.5	18.97	0.00

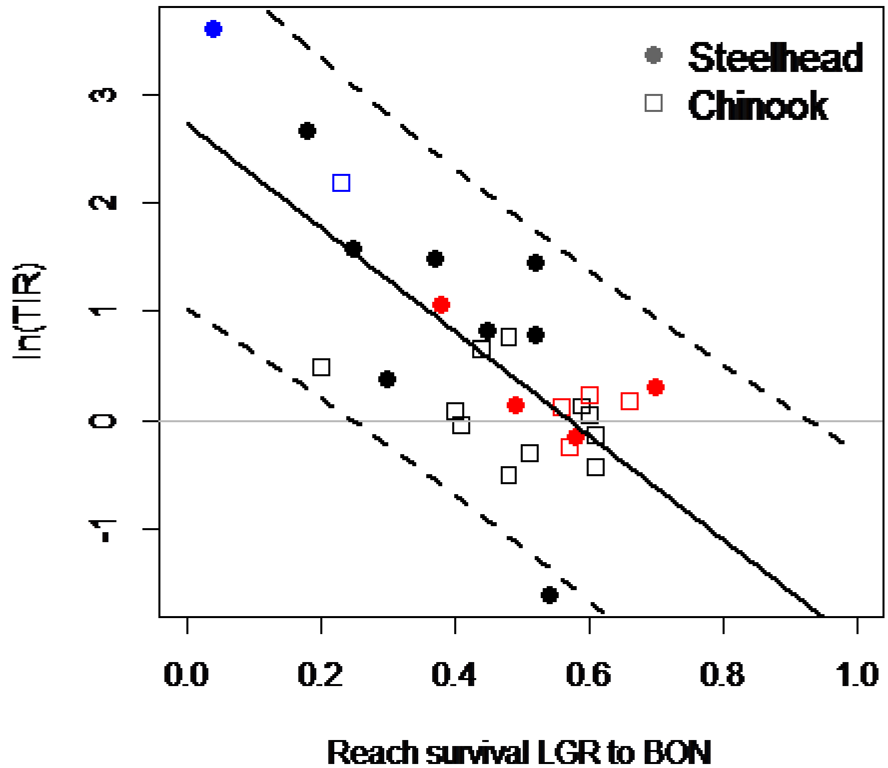


Figure A.16 Natural logarithm of Transportation : In-river Ratio (TIR) versus in-river survival rate (S_R) for wild Chinook (open squares) for juvenile migration years 1994-2009 and wild steelhead (filled circles) for juvenile migration years 1997-2009. The two blue data points are migration year 2001 which had zero spill. The 6 red data points are migration years with court ordered spill (2006-2009). Broken lines represent the 95% prediction intervals for $\log_e$(TIR) from the common slope and common intercept model in table A.36.

Appendix B
Source of PIT-tagged Fish

PIT-tagged Snake River Wild Chinook Aggregate – Composition by Drainage

Table B.1 Number of PIT-tagged wild Chinook parr/smolts from tributaries above Lower Granite Dam (plus Snake River trap) used in the CSS analyses for migration years 1994 to 2011.

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
Average percent of total		**14.1%**	**2.6%**	**17.3%**	**51.6%**	**14.6%**

[A] Snake River trap at Lewiston, ID, collects fish originating in Salmon, Imnaha, and Grande Ronde rivers.

PIT-tagged Rapid River Hatchery Spring Chinook – Salmon River Drainage

Table B.2 Rapid River Hatchery spring Chinook (RAPH) PIT-tagged and released in Salmon River basin specifically for CSS (long time series), 1997 to 2011.

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	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

[A] Tagged in fall 5 months before release; otherwise tagged in winter/spring 1-3 months before release.

PIT-tagged Dworshak NFH Spring Chinook – Clearwater River Drainage

Table B.3 Dworshak Hatchery spring Chinook (DWOR) PIT-tagged and released in Clearwater River basin specifically for CSS (long time series), 1997 to 2011.

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

[A] Tagged in winter/spring 1-3 months before release.

PIT-tagged McCall Hatchery Summer Chinook – Salmon River Drainage

Table B.4 McCall Hatchery summer Chinook (MCCA) PIT-tagged and released in Salmon River basin specifically for CSS (long time series), 1997 to 2011.

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	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

[A] Tagged in winter/spring 1-3 months before release.

PIT-tagged Imnaha Hatchery Summer Chinook – Imnaha River Drainage

Table B.5 Imnaha Hatchery summer Chinook (IMNA) PIT-tagged and released in Imnaha River basin specifically for CSS (long time series), 1997 to 2011.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
1997	50,911	17	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	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

[A] Tagged in winter/spring 1-3 months before release; otherwise tagged in fall 5-7 months before release.

PIT-tagged Catherine Creek AP Spring Chinook – Grande Ronde River Drainage

Table B.6 Catherine Creek Hatchery spring Chinook (CATH) PIT-tagged and released in Grande Ronde River basin specifically for CSS (long time series), 2001 to 2011.

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

[A] Tagged in fall 5-7 months before release.

PIT-tagged Clearwater Hatchery Spring Chinook – Clearwater River Drainage

Table B.7 Clearwater Hatchery Chinook (CLWH)[A] PIT-tagged and released in Clearwater River basin in participation with the CSS , 2007 to 2011. Migration year 2011 was the first year where summer Chinook were tagged and released into the Clearwater River Bain.

Migration Year	Run Type	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
2007	Spring	1,670,006	15.6	133[A]	44,900	0.0269
2008	Spring	1,666,315	16.8	(none taken)	37,595	0.0226
2009	Spring	2,145,480	16.8	(none taken)	68,649	0.0320
2010	Spring	2,251,033	15.3	(none taken)	72,707	0.0323
2011	Spring	2,234,031	16.2	(none taken)	68,327	0.0306
2011	Summer	204,061	15.4	(none taken)	25,488	0.1249

[A] Tagged in winter 3 weeks to 2 months before release.

PIT-tagged Sawtooth Hatchery Spring Chinook – Salmon River Drainage

Table B.8 Sawtooth Hatchery spring Chinook (SAWT)[A] PIT-tagged and released in Salmon River basin in participation with the CSS , 2008 to 2011.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (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

[A] Tagged in winter 1-2 months before release.

PIT-tagged Pahsimeroi Hatchery Summer Chinook – Salmon River Drainage

Table B.9 Pahsimeroi Hatchery summer Chinook (PAHH)[A] PIT-tagged and released in Salmon River basin in participation with the CSS , 2009 to 2011.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (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

[A] Tagged in winter 1-2 weeks before release.

PIT-tagged Snake River Wild Steelhead Aggregate – Composition by Drainage

Table B.10 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 2011.

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)
1997	7,703	5,518	68	248	1,158	711
1998	10,512	4,131	1,032	887	1,683	2,779
1999	15,763	5,095	886	1,628	5,569	2,585
2000	24,254	8,688	1,211	3,618	6,245	4,492
2001	24,487	8,845	867	3,370	7,844	3,561
2002	25,183	10,206	2,368	3,353	6,136	3,120
2003	24,005	5,764	1,197	4,257	6,818	5,969
2004	25,154	7,642	1,922	2,977	7,100	5,513
2005	25,000	8,391	2,749 [B]	3,771	5,652	4,437
2006	16,579	8,301	4	1,950	4,090	2,234
2007	17,857	5,001	1	2,170	4,112	6,573
2008	16,228	7,249	11	1,048	5,648	2,272
2009	16,625	4,066	4	1,494	5,951	5,110
2010	18,529	6,259	0	1,826	5,617	4,827
2011	12,706	3,753	14	2,434	4,205	2,300
Average percent of total		**36.9%**	**3.9%**	**11.8%**	**27.3%**	**20.1%**

[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] Includes 1,400 PIT-tagged wild steelhead released in Asotin Creek (Rkm 234).

PIT-tagged Hatchery Steelhead Aggregate – Composition by Drainage

Table B.11 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 HCD ranging between 57 and 301tags 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.

PIT-tagged Hatchery Steelhead by Drainage and Run-type for 2008

Table B.12 Number of PIT-tagged hatchery steelhead smolts from tributaries above Lower Granite Dam used in the CSS analyses for migration year 2008.

Tributary / run	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
Clearwater – B	CLWH	819,264	4.6	(none taken)	20,018	0.0244
	DWOR	2,254,407	5.9	175	27,276	0.0121
Grande Ronde – A	IRRI	803,847	4.4	134	16,465	0.0205
	LYFE	175,961	4.6	(none taken)	4,000	0.0227
Imnaha – A	IRRI	274,865	4.8	136	14,877	0.0541
Salmon – A	MAVA	868,273	4.6	(none taken)	13,170	0.0152
	HAGE	1,208,489	4.1	(none taken)	18,116	0.0150
Salmon – B	MAVA	752,644	4.7	(none taken)	21,302	0.0283
	HAGE	179,034	4.7	(none taken)	11,330	0.0633

[A] Hatchery at which steelhead were PIT-tagged: CLWH – Clearwater H; DWOR – Dworshak NFH; Irrigon H – IRRI; Magic Valley H – MAVA; and Hagerman NFH – HAGE. Niagara Springs H (NISP) is not included this year since its release of 1200 PIT-tagged smolts (none in monitor-mode) is not on scale with the magnitude of PIT-tagging at the other hatcheries being analyzed.

PIT-tagged Hatchery Steelhead by Drainage and Run-type for 2009

Table B.13 Number of PIT-tagged hatchery steelhead smolts from tributaries above Lower Granite Dam used in the CSS analyses for migration year 2009.

Tributary / run	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
Clearwater – B	CLWH	835,636	4.7	(none taken)	21,191	0.0254
	DWOR	1,798,874	5.5	185	28,306	0.0157
Grande Ronde – A	IRRI	652,424	3.8	187	22,233	0.0341
	LYFE	170,232	4.7	(none taken)	5,974	0.0351
Imnaha – A	IRRI	187,401	4.5	179	20,838	0.1112
Salmon – A	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
Salmon – B	MAVA	771,813	4.8	(none taken)	20,615	0.0267
	HAGE	171,094	4.6	(none taken)	8,344	0.0488
Below HCD – A	NISP	526,743	4.6	(none taken)	7,381	0.0140

[A] Hatchery at which steelhead were PIT-tagged: CLWH – Clearwater H; DWOR – Dworshak NFH; Irrigon H – IRRI; Magic Valley H – MAVA; Hagerman NFH – HAGE; and Niagara Springs H – NISP.

PIT-tagged Hatchery Steelhead by Drainage and Run-type for 2010

Table B.14 Number of PIT-tagged hatchery steelhead smolts from tributaries above Lower Granite Dam used in the CSS analyses for migration year 2010.

Tributary / run	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
Clearwater – B	CLWH	854,960	4.5	(none taken)	23,589	0.0276
	DWOR	1,234,563	6.0	165	28,394	0.0230
Grande Ronde – A	IRRI	617,514	3.9	157	23,083	0.0374
	LYFE	163,197	4.2	(none taken)	5,985	0.0367
Imnaha – A	IRRI	215,467	4.5	147	21,680	0.1006
Salmon – A	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
Salmon – B	MAVA	959,262	5.0	(none taken)	21,596	0.0225
Below HCD – A	NISP	529,667	4.7	(none taken)	8,253	0.0156

[A] Hatchery at which steelhead were PIT-tagged: CLWH – Clearwater H; DWOR – Dworshak NFH; Irrigon H – IRRI; Magic Valley H – MAVA; Hagerman NFH – HAGE; and Niagara Springs H – NISP.

PIT-tagged Hatchery Steelhead by Drainage and Run-type for 2011

Table B.15 Number of PIT-tagged hatchery steelhead smolts from tributaries above Lower Granite Dam used in the CSS analyses for migration year 2011.

Tributary / run	Tag Site[A]	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
Clearwater – B	CLWH	1,117,487	5.1	(none taken)	33,787	0.0302
	DWOR	2,265,405	7.1	168	30,187	0.0133
Grande Ronde – A	IRRI	826,879	4.1	148	22,182	0.0268
	LYFE	197,839	4.8	(none taken)	5,967	0.0302
Imnaha – A	IRRI	158,027	4.3	155	21,887	0.1385
Salmon – A	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
Salmon – B	MAVA	902,866	5.1	(none taken)	20,709	0.0229
Below HCD – A	NISP	538,580	8.2	(none taken)	8,227	0.0153

[A] Hatchery at which steelhead were PIT-tagged: CLWH – Clearwater H; DWOR – Dworshak NFH; Irrigon H – IRRI; Magic Valley H – MAVA; Hagerman NFH – HAGE; and Niagara Springs H – NISP.

PIT-tagged Hatchery Snake River Sockeye

Table B.16 Hatchery sockeye from Sawtooth (SAWT) and Oxbow (OXBH) hatcheries [A] PIT-tagged and released in Salmon River, 2009 and 2011.

Migration Year	Rearing Hatchery	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
2009	SAWT	99,374	30.6	101	52,551	0.5288
2009	OXBH	73,681	10.2	147	10,891	0.1478
2010	SAWT	99,392	28.1	106	51,684	0.5200
2010	OXBH	79,886	10.7	140	11,945	0.1453
2011	SAWT	136,287	54.8	84	51,672	0.3791
2011	OXBH	54,766	9.6	146	9,975	0.1821

[A] Tagged in winter ~2 months before release.

PIT-tagged Upper Columbia Wild Chinook Aggregate – Composition by Drainage

Table B.17 Number of PIT-tagged wild Chinook parr/smolts from tributaries above Rock Island Dam used in the CSS analyses for migration years 2006 to 2011.

Migration Year	Total PIT-tags	Wenatchee River (Rkm 754)	Entiat River (Rkm 778)	Methow River (Rkm 843)
2006	1,895	0	1,895	0
2007	16,177	13,434	1,538	1,205
2008	29,193	16,350	9,541	3,302
2009	18,114	14,605	2,256	1,253
2010	28,229	17,962	8,326	1,941
2011	14,443	10,581	2,916	946
Average percent of total		**59.4%**	**34.1%**	**6.5%**

PIT-tagged Leavenworth Hatchery Spring Chinook – Wenatchee River Drainage

Table B.18 Leavenworth NFH spring Chinook (LEAV) PIT-tagged and released in Wenatchee River basin, 2000 to 2011.

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

[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

PIT-tagged Upper Columbia Wild Steelhead Aggregate – Composition by Drainage

Table B.19 Number of PIT-tagged wild steelhead smolts from tributaries above Rock Island Dam used in the CSS analyses for migration years 2006 to 2011.

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
Average percent of total		**19.1%**	**61.9%**	**19.0%**

PIT-tagged Eastbank Hatchery Complex Steelhead – Wenatchee River Drainage

Table B.20 Eastbank Hatchery Complex steelhead (EAST) PIT-tagged and released in Wenatchee River basin, 2003 to 2010.

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

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).

PIT-tagged Mid-Columbia Wild Chinook Aggregate – Composition by Drainage

Table B.21 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 2011.

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
Average percent of total		**42.7%**	**57.3%**

PIT-tagged Cle Elum Hatchery Spring Chinook – Yakima River Drainage

Table B.22 Cle Elum Hatchery spring Chinook (CLEE)[A] PIT-tagged and released in the Yakima River basin, 2000 to 2011.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (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

[A] Tagged in fall, approximately 4-5 months before release

PIT-tagged Warm Springs NFH Spring Chinook – Deschutes River Drainage

Table B.23 Warm Springs NFH spring Chinook (WSPH) PIT-tagged and released in the Deschutes River basin, 2007 to 2011.

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

[A] Tagged in fall, approximately 4-5 months before release
[B] Tagged in winter, approximately 2 months before release

PIT-tagged Carson NFH Spring Chinook – Wind River Drainage

Table B.24 Carson NFH spring Chinook (CARS)[A] PIT-tagged and released in the Wind River, 2000 to 2011.

Migration Year	Hatchery Release	Fish# / lb	Median Length at Tagging (mm)	PIT-Tags Released	PIT-Tag Proportion
2000	1,430,022	15.6	116	14992	0.0105
2001	1,608,684	14.9	108	14978	0.0093
2002	1,449,361	15.6	116	14983	0.0103
2003	1,673,255	17.1	111	14983	0.0090
2004	1,417,986	17.3	111	14973	0.0106
2005	1,470,134	14.5	120	14958	0.0102
2006	1,209,384	17.3	112	14971	0.0124
2007	1,158,425	17.2	109	14943	0.0129
2008	1,336,741	16.5	103	14884	0.0111
2009	1,216,198	16.9	108	14975	0.0123
2010	1,278,492	16.8	108	14947	0.0117
2011	1,058,771	33.8	104	14953	0.0141

[A] Tagged in fall and winter, approximately 3-5 months before release

PIT-tagged Mid-Columbia Wild Steelhead Aggregate – Composition by Drainage

Table B.25 Number of PIT-tagged wild steelhead smolts from tributaries in the Mid-Columbia River used in the CSS analyses for migration years 2002 to 2011.

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
Average percent of total		**35.6%**	**46.6%**	**17.8%**

Appendix C
Dam-specific Transportation SARs
(Adult returns to Lower Granite Dam without jacks)

Table C.1 Estimated dam-specific transportation SARs (%) of the PIT-tagged wild Chinook aggregate for juvenile migration years 1994 to 2010 (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	SAR(TLGR)		Adult	SAR(TLGS)			SAR(TLMN)		Adult
Year	%	(CI%)	#	%	(CI%)	Adult #	%	(CI%)	#
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 [A]	0.54	(0.39 – 0.69)	32	0.64	(0.42 – 0.87)	21	0.91	(0.45 – 1.45)	8

[A] **Return to GRA incomplete with 2-salts as of September 10, 2012.**

Table C.2 Estimated dam-specific transportation SAR percentages of PIT-tagged Rapid River hatchery spring Chinook for juvenile migration years 1997 to 2010 (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	SAR(TLGR)		Adult	SAR(TLGS) [A]			SAR(TLMN) [A]		Adult
Year	%	(CI%)	#	%	(CI%)	Adult #	%	(CI%)	#
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 [A]	0.50	(0.33 – 0.70)	18	0.61	(0.33 – 0.92)	13	0.42	(0.00 – 0.86)	3

[A] **Return to GRA incomplete with 2-salts as of September 10, 2012.**

Table C.3 Estimated dam-specific transportation SAR percentages of PIT-tagged Dworshak hatchery spring Chinook for juvenile migration years 1997 to 2010 (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) [A] %	(CI%)	Adult #	SAR(TLMN) [A] %	(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 [A]	0.28	(0.16 – 0.41)	12	0.43	(0.15 – 0.74)	6	1.80	(0.51 – 3.68)	3

[A] **Return to GRA incomplete with 2-salts as of September 10, 2012.**

Table C.4 Estimated dam-specific transportation SAR percentages of PIT-tagged Catherine Creek hatchery spring Chinook for juvenile migration years 2001 to 2010 (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) [A] %	(CI%)	Adult #	SAR(TLMN) [A] %	(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 [A]	0.82	(0.39 – 1.31)	8	1.82	(0.94 – 2.76)	11	0.52	(0.00 – 1.60)	1

[A] **Return to GRA incomplete with 2-salts as of Sept 10, 2012**

Table C.5 Estimated dam-specific transportation SAR percentages of PIT-tagged Clearwater hatchery spring Chinook for juvenile migration years 2006 to 2010 (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) [A] %	(CI%)	Adult #	SAR(TLMN) [A] %	(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 [A]	0.48	(0.31 – 0.68)	19	0.82	(0.41 – 1.24)	10	0.60	(0.00 – 1.78)	1

[A] **Return to GRA incomplete with 2-salts as of Sept 10, 2012**

Table C.6 Estimated dam-specific transportation SAR percentages of PIT-tagged Sawtooth hatchery spring Chinook for juvenile migration years 2007 to 2010 (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) [A] %	(CI%)	Adult #	SAR(TLMN) [A] %	(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 [A]	0.56	(0.24 – 0.94)	7	0.70	(0.27 – 1.23)	5	0.00	(0.00 – 0.00)	0

[A] **Return to GRA incomplete with 2-salts as of Sept 10, 2012**

Table C.7 Estimated dam-specific transportation SAR percentages of PIT-tagged McCall hatchery summer Chinook for juvenile migration years 1997 to 2010 (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) [A] %	(CI%)	Adult #	SAR(TLMN) [A] %	(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 [A]	0.75	(0.51 – 0.98)	26	0.43	(0.21 – 0.71)	8	0.51	(0.00 – 1.09)	2

[A] **Return to GRA incomplete with 2-salts as of September 10, 2012.**

Table C.8 Estimated dam-specific transportation SAR percentages of PIT-tagged Imnaha hatchery summer Chinook for juvenile migration years 1997 to 2010 (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) [A] %	(CI%)	Adult #	SAR(TLMN) [A] %	(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
2009	1.40	(1.05 – 1.75)	40	1.68	(1.15 – 2.25)	25	0.65	(0.20 – 1.32)	3
2010 [A]	1.46	(0.97 – 2.02)	21	0.33	(0.10 – 0.66)	3	0.36	(0.00 – 1.06)	1

[A] Return to GRA incomplete with 2-salts as of September 10, 2012.

Table C.9 Estimated dam-specific transportation SAR percentages of PIT-tagged Pahsimeroi hatchery summer Chinook for juvenile migration years 2008 to 2010 (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) [A] %	(CI%)	Adult #	SAR(TLMN) [A] %	(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 [A]	0.25	(0.00 – 0.54)	2	0.61	(0.00 – 1.34)	2	0.00	(0.00 – 0.00)	0

[A] Return to GRA incomplete with 2-salts as of September 10, 2012.

Table C.10 Estimated dam-specific transportation SAR percentages of PIT-tagged wild steelhead in the annual aggregate groups for 1997 to 2009 (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
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[A]	3.06	(2.36 – 3.83)	44	4.82	(3.70 – 5.95)	44	1.25	(0.32 – 2.43)	4

[A] Migration year 2008 is incomplete until 3-salt returns (if any) occur at GRA after September 10, 2012

Table C.11 Estimated dam-specific transportation SAR percentages of PIT-tagged hatchery steelhead in the annual aggregate groups for 1997 to 2009 (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[A]	1.61	(1.47 – 1.75)	377	1.74	(1.57 – 1.93)	224	1.71	(1.46 – 1.99)	112

[A] Migration year 2009 is incomplete until 3-salt returns (if any) occur at GRA after September 10, 2012

Table C.12 Estimated dam-specific transportation SAR percentages of PIT-tagged Clearwater –B hatchery steelhead for 2008 to 2009 (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 [A]	0.93	(0.69 – 1.18)	35	1.03	(0.62 – 1.47)	15	1.12	(0.56 – 1.71)	10

[A] **Migration year 2009 is incomplete until 3-salt returns (if any) occur at GRA after September 10, 2012**

Table C.13 Estimated dam-specific transportation SAR percentages of PIT-tagged Grande Ronde - A hatchery steelhead for 2008 to 2009 (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	5.16	(4.51 – 5.88)	163	5.34	(4.70 – 6.06)	153	5.19	(3.25 – 7.14)	18
2009 [A]	1.73	(1.39 – 2.11)	61	1.78	(1.32 – 2.28)	38	1.69	(1.06 – 2.43)	19

[A] **Migration year 2009 is incomplete until 3-salt returns (if any) occur at GRA after September 10, 2012**

Table C.14 Estimated dam-specific transportation SAR percentages of PIT-tagged Imnaha - A hatchery steelhead for 2008 to 2009 (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	4.18	(3.51 – 4.87)	107	5.94	(5.18 – 6.75)	150	5.06	(3.43 – 6.76)	22
2009 [A]	1.72	(1.32 – 2.13)	50	1.65	(1.65 – 2.17)	27	2.31	(1.53 – 3.14)	22

[A] **Migration year 2009 is incomplete until 3-salt returns (if any) occur at GRA after September 10, 2012**

Table C.15 Estimated dam-specific transportation SAR percentages of PIT-tagged Salmon - A hatchery steelhead for 2008 to 2009 (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	4.74	(4.21 – 5.31)	193	5.91	(5.32 – 6.55)	238	6.33	(4.66 – 8.08)	40
2009 [A]	2.00	(1.75 – 2.29)	147	1.98	(1.64 – 2.36)	82	2.20	(1.67 – 2.74)	44

[A] **Migration year 2009 is incomplete until 3-salt returns (if any) occur at GRA after September 10, 2012**

Table C.16 Estimated dam-specific transportation SAR percentages of PIT-tagged Salmon - B hatchery steelhead for 2008 to 2009 (with 90% confidence intervals). Pre-assignment to Group T began in 2008 for hatchery steelhead [A].

Hatchery Group	SAR(TLGR) %	SAR(TLGR) CI %	Adult #	SAR(TLGS) %	SAR(TLGS) (CI%)	Adult #	SAR(TLMN) %	SAR(TLMN) (CI%)	Adult #
2008	0.82	(0.61 – 1.06)	37	0.90	(0.64 – 1.15)	36	0.96	(0.36 – 1.71)	5
2009 [A]	0.76	(0.54 – 0.96)	34	1.04	(0.74 – 1.38)	28	0.41	(0.16 – 0.75)	5

[A] Migration year 2009 is incomplete until 3-salt returns (if any) occur at GRA after September 10, 2012

Table C.17 Estimated dam-specific transportation SAR percentages of PIT-tagged Sawtooth hatchery sockeye for 2009 to 2010 (with 90% confidence intervals).

Hatchery Group	SAR(TLGR) %	SAR(TLGR) CI %	Adult #	SAR(TLGS) %	SAR(TLGS) (CI%)	Adult #	SAR(TLMN) %	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 [AB]	NA		0	NA		0	NA		0

[B] Only 38 PIT-tagged Sawtooth Hatchery sockeye estimated in transport category with no adult returns.

[A] Return to GRA incomplete with 2-salts as of September 10, 2012.

Table C.18 Estimated dam-specific transportation SAR percentages of PIT-tagged Oxbow hatchery sockeye for 2009 to 2010 (with 90% confidence intervals).

Hatchery Group	SAR(TLGR) %	SAR(TLGR) CI %	Adult #	SAR(TLGS) %	SAR(TLGS) (CI%)	Adult #	SAR(TLMN) %	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 [AB]	NA		0	NA		1	NA		0

[A] Return to GRA incomplete with 2-salts as of September 10, 2012.

[B] 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 D

Estimate 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 do 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 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. As described in Chapter 4, equation 4.4 is used for estimating the T_X smolt numbers, and the expectation equations 4.5 and 4.6, respectively, are used for estimating the C_0 and C_1 smolt numbers in Group T. 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:

$$T_X = X_{12} + X_{1A2} / S_2 + X_{1AA2} / (S_2 \bullet S_3) \quad [C.1]$$

$$C_0^* = E(C_0) + d_0 = R_1 \bullet S_1 \bullet (1-P_2) \bullet (1-P_3) \bullet (1-P_4) \quad [C.2]$$

$$C_1^* = E(C_1) + d_1 = R_1 \bullet S_1 \bullet [P_2 + (1-P_2) \bullet P3 + (1-P_2) \bullet (1-P_3) \bullet P4] - [(d_2 + d_3/S_2 + d_4/(S_2 \bullet S_3)] \quad [C.3]$$

and

$$P[T_X] = T_X / (T_X + C_0^* + C_1^*) \quad [C.4]$$

$$P[C_0^*] = C_0^* / (T_X + C_0^* + C_1^*) \quad [C.5]$$

$$P[C_1^*] = C_1^* / (T_X + C_0^* + C_1^*) \quad [C.6]$$

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 survival less than if the fish 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 2009, 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

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 C.1 through C.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 group and have consistently had the lowest proportion transported in all five years (range 8.3% - 52.2% for DWOR and 12.3% - 62.5% 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 2007 (21.3%). The PIT-tagged wild steelhead aggregate likewise had the highest proportion transported in 2006 (64.9%), while both years 2007 and 2008 had the lowest proportion transport at 40.1% and 40.5%, respectively. 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 have 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 58% - 69% in 2009 and 32% - 58% in 2010. With the later start of transportation in 2007 to 2010 (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 D.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	Transportation			Passage w/o detection			Bypass passage		
source[1]	$Pr(T_x)$	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
SK-SAW									

[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 D.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 D.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 Rhonde (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 for methods).

Table D.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 Rhonde (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 D.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	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	0.226	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	0.334	0.321	0.348	0.649	0.635	0.663	0.016	0.014	0.019

[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 Rhonde (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 D.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	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	0.508	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	0.252	0.247	0.257	0.349	0.344	0.353	0.399	0.393	0.405
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 Rhonde (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.

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 E

Returning Age Composition of Adults

Table E.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 for each smolt migration year between 1994 and 2010.

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 B]	98	321	NA	23.4	76.6	--
	Average (1994 – 2009)			5.6	66.6	27.8

[A] Smolt migration year 2006 – 2010 data are from combined T and R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average
[C] One 4-salt return is included in the 3-salt percentage.

Table E.2 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 2010.

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 B]	118	173	NA	40.6	59.5	--
	Average (1997 – 2009)			12.7	77.0	10.3

[A] Smolt migration year 2006 – 2010 data are from combined T & R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average.

Table E.3 Age composition of returning PIT-tagged DWORSHAK NFH SPRING CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 1997 to 2010.

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 B]	150	220	NA	40.5	59.5	--
	Average (1997 – 2009)			11.1	75.3	13.6

[A] Smolt migration year 2006 – 2010 data are from combined T & R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average.

Table E.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 2010.

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 B]	59	71	NA	45.4	54.6	--
	Average (2001 – 2009)			20.5	78.3	1.3

[A] Smolt migration year 2006 – 2010 data are from combined T & R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average.

Table E.5 Age composition of returning PIT-tagged CLEARWATER HATCHERY SPRING CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 2006 to 2010.

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 B]	119	235	NA	33.6	66.4	--
	Average (2006 – 2009)			21.4	73.2	5.3

[A] Smolt migration year 2006 – 2010 data are from combined T & R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average

Table E.6 Age composition of returning PIT-tagged SAWTOOTH HATCHERY SPRING CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 2007 to 2010.

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 B]	30	39	NA	43.5	56.5	--
	Average (2007 – 2009)			40.5	57.2	2.3

[A] Smolt migration year 2007 – 2010 data are from combined T & R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average

Table E.7 Age composition of returning PIT-tagged MCCALL HATCHERY SUMMER CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 1997 to 2010.

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	434
2010 [A B]	137	145	NA	48.6	51.4	--
	Average (1997 – 2009)			23.4	68.1	8.4

[A] Smolt migration year 2006 – 2010 data are from combined T & R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average
[C] One 4-salt return is included in the 3-salt percentage.

Table E.8 Age composition of returning PIT-tagged IMNAHA HATCHERY SUMMER CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 1997 to 2010.

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 B]	96	103	NA	48.2	51.8	--
	Average (1997 – 2009)			36.0	59.4	4.7

[A] Smolt migration year 2006 – 2010 data are from combined T & R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average

Table E.9 Age composition of returning PIT-tagged PAHSIMEROI HATCHERY SUMMER CHINOOK adults and jacks detected at Lower Granite Dam from smolt migration years 2008 to 2010.

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 B]	7	5	NA	58.3	41.7	--
	Average (2008 – 2009)			30.9	64.4	4.7

[A] Smolt migration year 2008 – 2010 data are from combined T & R groups
[B] Incomplete adult returns through 9/10/2012 at GRA; not included in average

Snake River wild and hatchery steelhead returning age composition

Table E.10 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 each smolt migration year between 1997 and 2009.

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
1998	16	8	0	66.7	33.3	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
2004	26	21	0	55.3	44.7	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 B]	100	192	2	34.0	65.3	0.7
Average (1997 – 2008)				43.6	54.9	1.5

[A] Smolt migration year 2006 – 2009 data are from combined T & R groups
[B] Incomplete adult returns until 3-salt returns (if any) after 9/10/12 at GRA; not included in average

Table E.11 Age composition of returning PIT-tagged HATCHERY SNAKE RIVER STEELHEAD adults detected at Lower Granite Dam from smolt migration years 1997 to 2009.

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
1998	45	32	0	58.4	41.6	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
2002	99	49	1	66.4	32.9	0.7
2003	90	77	0	53.9	46.1	0
2004	21	24	0	46.7	53.3	0
2005	41	26	0	61.2	38.8	0
2006	102	77	0	57.0	43.0	0
2007	163	87	0[A]	65.2	34.8	0
2008	2352	964	18	70.6	28.9	0.5
2009 [A]	1217	970	2	55.6	44.3	0.1
Average (1997 – 2008)				57.4	42.4	0.2

[A] Incomplete adult returns through 9/10/2012 at GRA; not included in average

Table E.12 Age composition of returning PIT-tagged CLEARWATER B HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 - 2009.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt[A]
2008	44	441	14	8.8	88.4	2.8
2009[A]	28	391	2	6.7	92.9	0.5

[A] Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at GRA

Table E.13 Age composition of returning PIT-tagged GRANDE RONDE A HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 - 2009.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt[A]
2008	615	145	2	80.7	19.0	.3
2009[A]	240	122	0	66.3	33.7	0

[A] Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at GRA

Table E.14 Age composition of returning PIT-tagged HELLS CANYON A HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 - 2009.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt[A]
2008	11	3	0	78.6	21.4	0
2009[A]	108	70	0	60.7	39.3	0

[A] Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at GRA

Table E.15 Age composition of returning PIT-tagged IMNAHA A HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 - 2009.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt[A]
2008	497	64	0	88.6	11.4	0
2009[A]	222	50	0	81.6	18.4	0

[A] Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at GRA

Table E.16 Age composition of returning PIT-tagged SALMON A HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 - 2009.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt[A]
2008	1136	155	1	87.9	12	0.1
2009[A]	606	166	0	78.5	21.5	0

[A] Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at GRA

Table E.17 Age composition of returning PIT-tagged SALMON B HATCHERY STEELHEAD adults detected at Lower Granite Dam from smolt migration years 2008 - 2009.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt[A]
2008	86	177	2	32.5	66.8	0.8
2009[A]	25	137	0	15.4	84.6	0

[A] Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at GRA

Snake River hatchery sockeye returning age composition

Table E.18 Age composition of returning PIT-tagged OXBOW HATCHERY SOCKEYE adults detected at Lower Granite Dam from smolt migration years 2009 - 2010.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt[A]
2009	11	43	0	20.4	49.6	0.0
2010[A]	19	22	0	43.6	56.7	0.0

[A] Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at GRA

Table E.19 Age composition of returning PIT-tagged SAWTOOTH HATCHERY SOCKEYE adults detected at Lower Granite Dam from smolt migration years 2009 - 2010.

Smolt Migr Year	Age 1-salt	Age 2-salt	Age 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt[A]
2009	0	265	10	0.0	96.4	3.6
2010[A]	2	23	0	8.0	92.0	0.0

[A] Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at GRA

Upper and Mid-Columbia wild and hatchery Chinook and steelhead returning age composition at Bonneville Dam

Table E.20 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 2010.

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 [B]	40	96	NA	29.4	70.6	--
Average (2000 – 2009)				6.8	80.3	12.8

Table E.21 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 2009

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 [A]	106	89	1	54.1	45.4	0.5
	Average (2006 – 2008)			69.1	30.9	0.0

[A] **Incomplete adult returns until 3-salt returns (if any) after 9/10/2012 at BOA; not included in average**

Table E.22 Age composition of returning PIT-tagged CARSON NFH SPRING CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2000 to 2010.

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 [B]	16	108	NA	12.9	87.1	--
	Average (2000 – 2009)			4.5	86.1	9.5

[A] **One 4-salt return is included in the 3-salt percentage.**
[B] **Incomplete adult returns through 9/10/2012 at BOA; not included in average**

Table E.23 Age composition of returning PIT-tagged CLE ELUM HATCHERY SPRING CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2000 to 2010.

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 [A]	127	186	NA	40.6	59.4	--
	Average (2000 – 2009)			12.0	76.5	2.5

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 9/10/2012 at BOA; not included in average**

Table E.24 Age composition of returning PIT-tagged LEAVENWORTH NFH SPRING CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2000 to 2010.

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 [B]	41	74	NA	35.7	64.4	--
Average (2000 – 2009)				7.6	77.4	15.0

[A] One 4-salt return is included in the 3-salt percentage.
[B] Incomplete adult returns through 9/10/2012 at BOA; not included in average

Table E.25 Age composition of returning PIT-tagged DESCHUTES WILD STEELHEAD adults detected at Bonneville Dam from smolt migration years 2006 to 2009.

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 [A]	69	86	NA	44.5	55.5	--
Average (2006 – 2008)				58.5	41.5	0.0

[A]Incomplete adult returns through 9/10/2012 at BOA; not included in average

Table E.26 Age composition of returning PIT-tagged ENTIAT and METHOW WILD CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2006 to 2010.

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 [A]	4	42	NA	8.7	91.3	--
Average (2006 – 2009)				9.4	80.0	10.6

[A]Incomplete adult returns through 9/10/2012 at BOA; not included in average

Table E.27 Age composition of returning PIT-tagged WENATCHEE WILD CHINOOK adults and jacks detected at Bonneville Dam from smolt migration years 2007 to 2010.

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
2008	8	95	63	4.8	57.2	38.0
2009	3	55	11	4.4	79.7	15.9
2010 [B]	16	58	NA	21.6	78.4	--
Average (2007 – 2009)				3.1	76.0	21.0

[A] One 4-salt return is included in the 3-salt percentage.
[B]Incomplete adult returns through 9/10/2012 at BOA; not included in average

Table E.28 Age composition of returning PIT-tagged WENATCHEE, ENTIAT, and METHOW WILD STEELHEAD adults detected at Bonneville Dam from smolt migration years 2006 to 2009.

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 [A]	32	40	NA	44.4	56.6	--
Average (2006 – 2008)				46.7	53.3	0.0

[A]Incomplete adult returns through 9/10/2012 at BOA; not included in average

Table E.29 Age composition of returning PIT-tagged WENATCHEE HATCHERY STEELHEAD adults detected at Bonneville Dam from smolt migration years 2003 to 2009.

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	--
2009 [A]	44	76	2	63.1	62.3	1.6
Average (2003 – 2008)				46.4	53.4	0.2

[A]Incomplete adult returns through 9/10/2012 at BOA; not included in average

Appendix F
Comparative Survival Study Annual Meeting

Appendix F
Comparative Survival Study Annual Meeting

This appendix contains the material presented at the Comparative Survival Study annual meeting held on April 12th, 2012 at the Embassy Suites hotel in Portland, OR. 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, it can also be found in a compact version in the following pages of this appendix.

http://www.fpc.org/documents/CSS/Presentations%20from%20the%202012%20CSS%20Annual%20Meeting.pdf

Comparative Survival Study Annual Meeting

Date / time: April 12th 2012 8:30 AM to 1:00 PM
Place: Embassy Suites
7900 NE 82nd
Portland, OR 97220

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.

Time	TITLE	(minutes)	presenter
08:30	**Introduction to CSS**	(30)	Jack Tuomikoski
09:00	**Upper Columbia River Chinook and steelhead**	(15)	Robin Elke
09:15	**Variation in age at maturity for PIT-tagged spring/summer Chinook salmon in the Columbia River Basin**	(15)	Steve Haeseker
09:30	**Snake River fall Chinook**	(25)	Jerry McCann
09:55	Break 15 minutes	(15)	
10:10	**CSS workshop part 1 (Intro / Retrospective)**	(60)	Charlie Petrosky & Howard Schaller
11:10	**CSS workshop part 2: (Prospective)**	(30)	Steve Haeseker
11:40	**Questions / Discussion**		ALL

To end at approximately 1:00 PM however, the room is available all day for questions if needed.

List of 2012 CSS Annual Conference Attendants

Name	Organization
Robin Ehlke	WDFW
Charlie Petrosky	IDFG
Eric Tinus	ODFW
Paul Kline	IDFG
Kathryn Kostow	ODFW
Bill Tweit	WDFW
Charles Morrill	WDFW
Tim Roth	USFWS
Jack Tuomikoski	FPC
Margaret Filardo	FPC
Michele Dehart	FPC
Pete Hassemer	IDFG
Ed Bowles	ODFW
Howard Schaller	USFWS
Tom Rien	ODFW
Nicole Cortian	SOS
Gilly Lyons	SOS
Briana Anderson	FPC
Chris Wood	ISAB
Alan Byrne	IDFG
Bob Heinith	Critfic
Rich Aldridge	ISAB
Jeff Fryer	Critfic
Don Campton	USFWS
Brandon Chockley	FPC
Rich Carmichael	ODFW
Tim Copeland	IDFG
Jim Ruff	NPCC
Tom Kahler	DCPUD
Richie Graves	NOAA

Comparative Survival Study Annual Meeting

Presenter: Jack Tuomikoski

CSS Annual Meeting Apr 12th 2012

Background

- Initiated in 1996 by states, tribes & USFWS to estimate survival rates at various life stages
  - Designed to assess hydrosystem operations on state, tribal, and federal fish hatcheries and LSRCP
  - PATH – "can transportation . . . compensate for the effect of the hydrosystem?"
  - NPCC has established the need to collect annual migration characteristics including survival
  - NOAA biological opinions require research, monitoring and evaluation
- Management-oriented large scale monitoring
  - 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**

Background

- **CSS data is 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)
nonparametric bootstrap approach

2002 – **ISRP** Additional evaluate bootstrap,
compare with likelihood methods,
Monte Carlo simulator evaluation

History of ISAB/ISRP Reviews of CSS

2003 – **ISAB** *Review of flow augmentation*
"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) Address: Are PIT tag SARs < run reconstruction SARs and conduct a comprehensive study to determine why

2009 – **ISAB** *Tagging Report*
Compare CSS SARs with Run Reconstruction 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 & TAGGING
- FPC: Logistics, coordination
- PTAGIS: Raw Data; FPC: Reports, Estimates

DATA PREPARATION & ANALYSIS
- CSS Oversight Committee
- Fish Passage Center

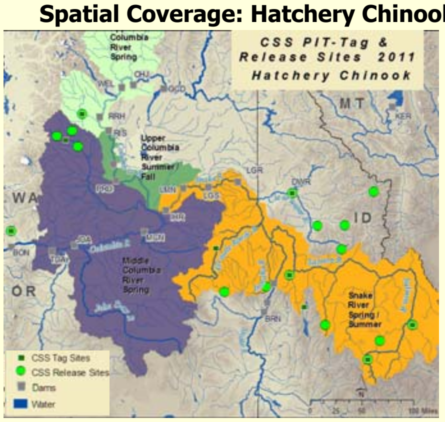
REGIONAL REVIEW
- Draft on BPA & FPC websites
- Regional Public Review; ISAB, ISRP, FPAC, NMFS, etc.

FINAL REPORT
- Posted on BPA & FPC websites

Stocks Included

- **Snake River (SARs)** **17 +**
  - 8 sp/su Hatchery Chinook
  - 2 natural stocks - (sp/su) Chinook & steelhead
  - 5 + hatchery steelhead groups (by basin and A or B)
  - 2 Hatchery Sockeye
  - Fall Chinook – under development
- **Upper Columbia River (SARs)** **5**
  - 1 sp Hatchery Chinook (Leavenworth)
  - 1 Hatchery steelhead (HxW)
  - 2 natural sp Chinook aggregates
  - 1 natural steelhead aggregate
- **Middle Columbia River (SARs)** **5**
  - 2 sp Hatchery Chinook (Carson, Cle Elum)
  - 2 natural steelhead (Deschutes, John Day)
  - 1 natural sp Chinook (John Day)

Spatial Coverage: Hatchery Chinook



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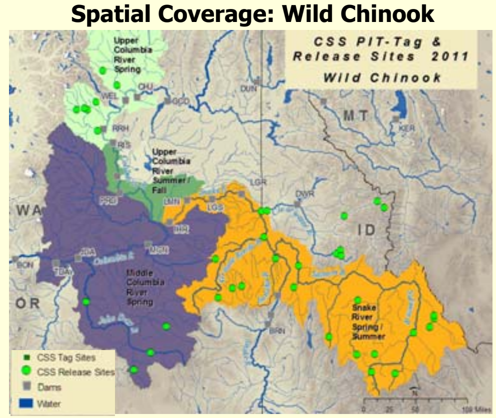
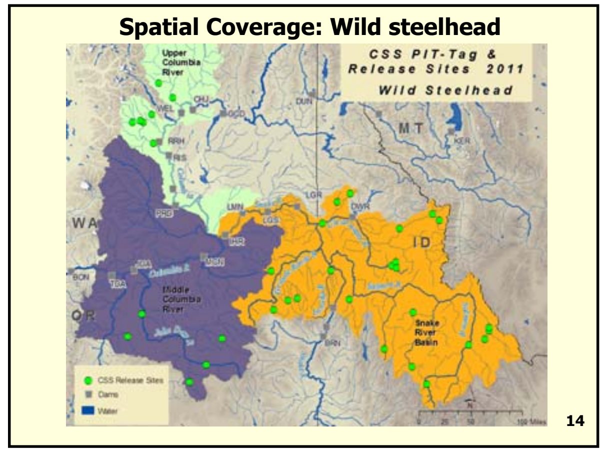
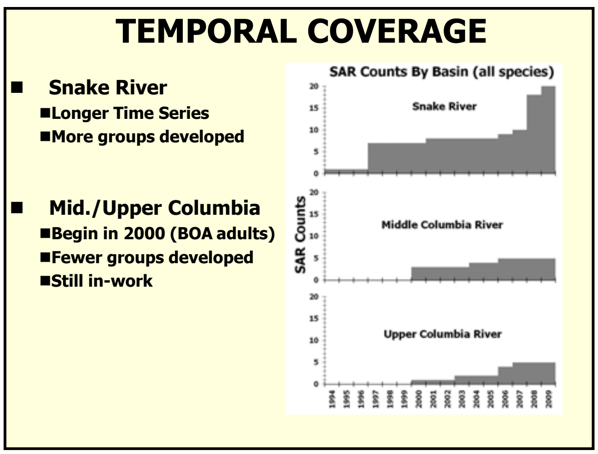
Spatial Coverage: Wild Chinook

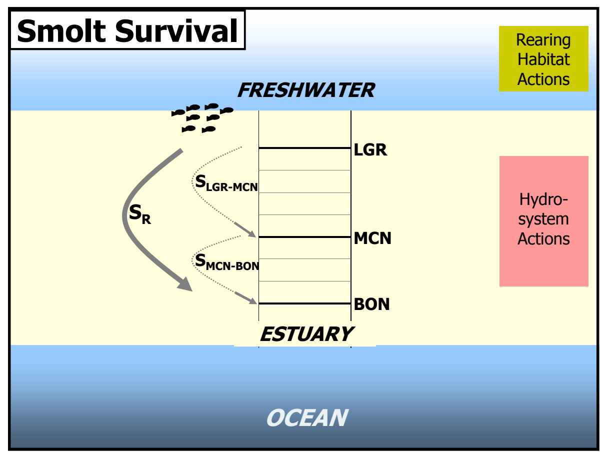


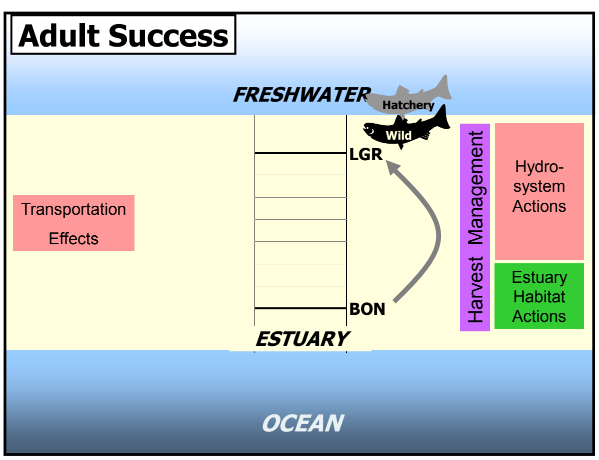
12

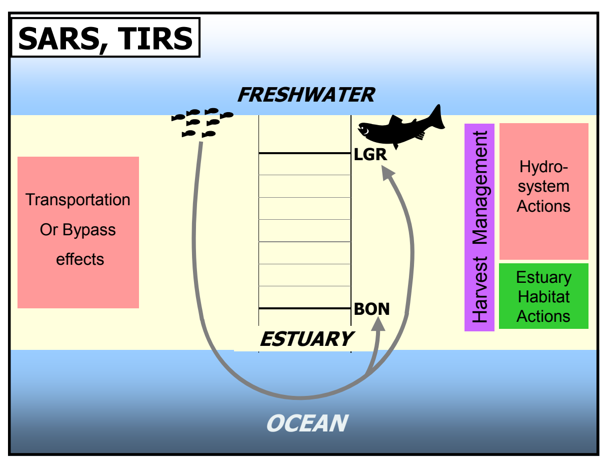

Spatial Coverage: Snake River Hatchery Steelhead
CSS PIT-Tag & Release Sites 2011 Hatchery Steelhead
Upper Columbia River
Middle Columbia River
Snake River Basin
WA
OR
ID
MT
CSS Tag Sites
CSS Release Sites
Dams
Water

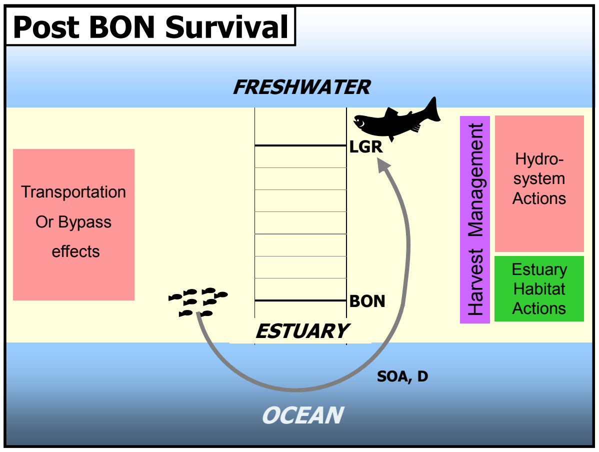

Spatial Coverage: Wild steelhead
CSS PIT-Tag & Release Sites 2011 Wild Steelhead
Upper Columbia River
Middle Columbia River
Snake River Basin
WA
OR
ID
MT
CSS Release Sites
Dams
Water
14

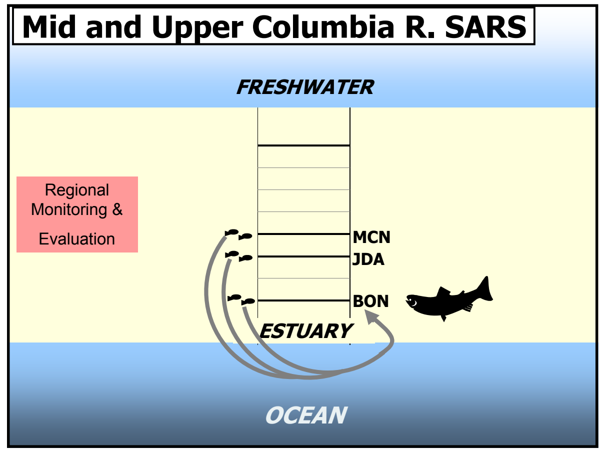

TEMPORAL COVERAGE
Snake River
Longer Time Series
More groups developed
Mid./Upper Columbia
Begin in 2000 (BOA adults)
Fewer groups developed
Still in-work
SAR Counts By Basin (all species)
Snake River
Middle Columbia River
Upper Columbia River
SAR Counts


Smolt Survival
Rearing Habitat Actions
FRESHWATER
LGR
$S_{LGR-MCN}$
S_R
MCN
$S_{MCN-BON}$
BON
Hydro-system Actions
ESTUARY
OCEAN


Adult Success
FRESHWATER
Hatchery
Wild
LGR
Transportation Effects
BON
ESTUARY
Harvest Management
Hydro-system Actions
Estuary Habitat Actions
OCEAN


SARS, TIRS
FRESHWATER
LGR
Transportation Or Bypass effects
BON
ESTUARY
Harvest Management
Hydro-system Actions
Estuary Habitat Actions
OCEAN





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 SAR goal*
  - *By geographic location*
  - *By hatchery group*
  - *Hatchery to Wild*
  - *Chinook to Steelhead*

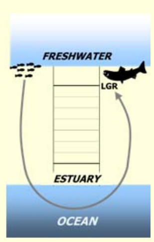
- *Management questions: hydropower operations, hatchery evaluations, habitat evaluations*

2011 CSS Activities

- **Workshop (Jul 26th-28th, 2011)**
  - **GOALS:**
    - **Expand the scope of CSS review**
      - **27 attendees from agencies and universities**
    - **Synthesize information regarding freshwater and ocean factors that affect survival for Columbia River Basin Salmon and steelhead**
  - **Opportunity for leading investigators to:**
    - **share and compare results**
    - **collaboratively develop priorities for future work in CSS**
  - **facilitated by ESSA Technologies Ltd.**
- **2011 Annual Report**

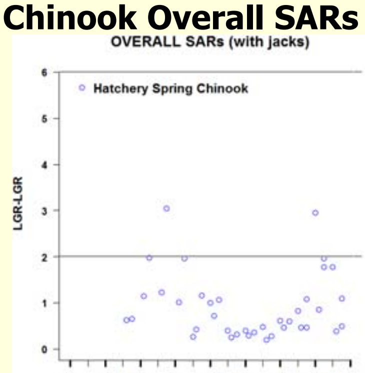
2011 Report

- **Snake River (SARs)**
  - 8 sp/su Hatchery Chinook
  - 2 natural stocks - (sp/su) Chinook & steelhead
  - 5 + hatchery steelhead groups (basin and A or B)
  - 2 Hatchery Sockeye
  - Fall Chinook – under development
- **Report organization**
  - Chinook SARs through 2009
  - Steelhead SARs through 2008
  - Juvenile metrics through 2010



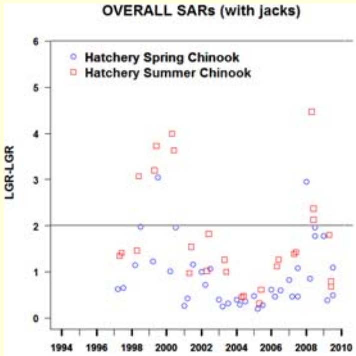
CSS 2011: Chinook Overall SARs

- **NPCC GOAL of 2-6 % SAR for recovery; mean = 4**
- **Sp. Chinook stocks:**
  - **RAPH**
  - **DWOR**
  - **CATH**
  - **SAWT**
- **Nearly all estimates below 2%**
- **High correlation between stocks**



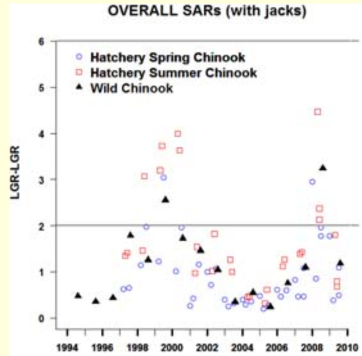
CSS 2011: Chinook Overall SARs

- **Su. Chinook stocks:**
  - MCCA
  - IMNA
  - PAHH
- **Summer stocks higher than spring**
- **High correlation between stocks**
- **1999, 2000, 2008 some estimates above 2%**



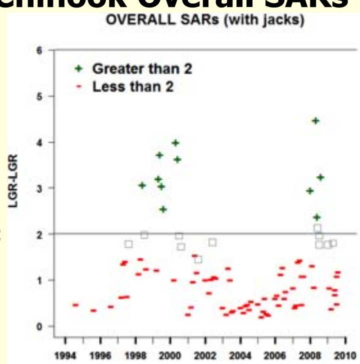
CSS 2011: Chinook Overall SARs

- **Wild sp/su aggregate**
- **High correlation across Chinook stocks**
- **Most are less than 2%**



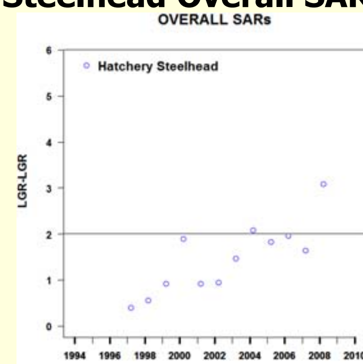
CSS 2011: Chinook Overall SARs

- **12.8% SARs > 2**
- **74.4% SARs < 2**
- **12.8% SARs = NS**
- **Not meeting NPCC goal**



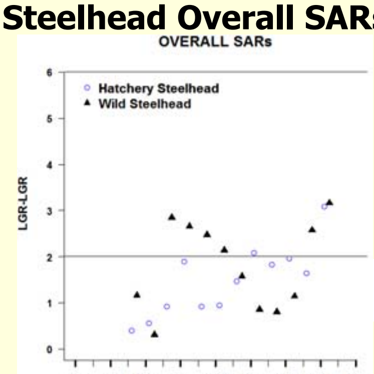
CSS 2011: Steelhead Overall SARs

- **Hatchery Steelhead**
- **Several estimates below 2**
- **2008* Highest in time series**



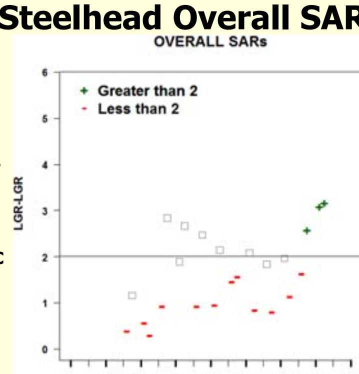
CSS 2011: Steelhead Overall SARs

- **Wild Steelhead**
- **Less correlated than Chinook stocks**
- **Several estimates below 2**
- **2008* Highest in time series**



CSS 2011: Steelhead Overall SARs

- **12.5% SARs > 2**
- **50 % SARs < 2**
- **37.5% SARs = NS**
- **Not meeting NPCC goal**



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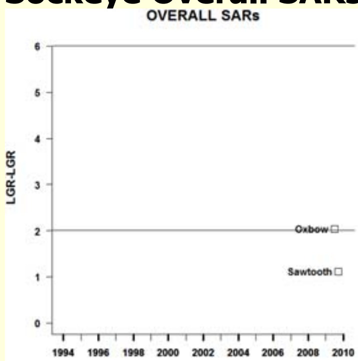
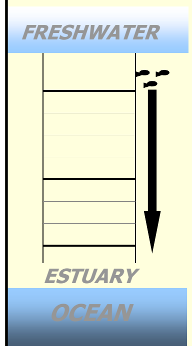
CSS 2011: Sockeye Overall SARs

- First hatchery sockeye SARs
- OXBH, SAWT 2009 MY

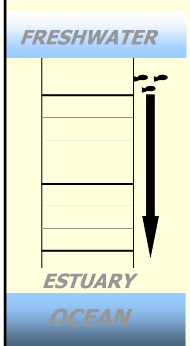


CSS 2011: Juvenile Metrics



- Component of RM&E
- Long Term dataset of annual juvenile metrics
  - Emigration rate
  - Arrival time at dams
  - Juvenile survival
- Finer scale analyses: response to ISAB comment

CSS 2011: Finer-Scale Analyses



- Simultaneous processes
  - Migration (FTT) & Mortality
- If we can predict these, we can predict survival
- GOAL: evaluate effects of operational and environmental features

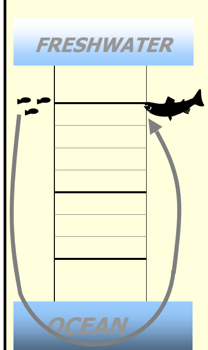
CSS 2011: Finer-Scale Analyses

- Multiple regression model factors
  - Seasonality (Julian Day)
  - Temperature
  - Turbidity
  - Average Percent Spill
  - Surface Passage Structures (TSW, RSW)
  - Water Transit Time (WTT, days)
  - Hatchery Composition

CSS 2011: Finer-Scale Analyses

- The 2010 juvenile emigration characteristics: Water transit time (flow), spill, and Julian date were key variables affecting fish travel time and juvenile survival.
- Juvenile travel times, mortality rates and survival rates through the hydrosystem are strongly influenced by managed river conditions (water transit time and spill levels).
- Improvements for in-river survival and fish travel times can be achieved through reductions in water transit time or increased spill.

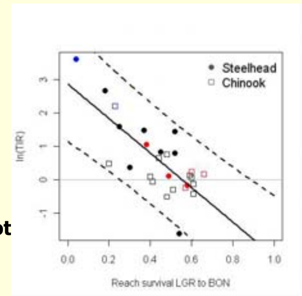
CSS 2011: TIR



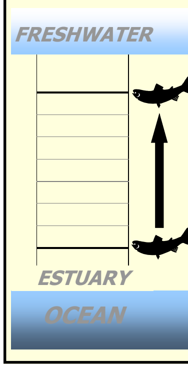
- Used to evaluate transportation program (SR stocks)
- Ratio of Transported ÷ Inriver SARs

CSS 2011: TIR vs. in-river surv.

- TIR is directly related to in-river survival
- As in-river survival increases, TIR decreases
- When in-river surv ~ 55%, transport will not be beneficial (for wild stocks)



CSS 2011: Adult Success BON-LGR



- 3 questions
  - Effect of transportation on adult success?
  - If so, how does this compare with environmental variables?
  - Does transportation affect straying rates?

CSS 2011: Adult Success BON-LGR

- Transported smolts had a lower success rate
  - Average of ~ 6% lower; up to 29% lower
- Transportation was consistently a good predictor of adult success when compared with environmental variables
- Transported hatchery Chinook and hatchery or wild steelhead smolts strayed 10-39 times more often than in-river outmigrants (wild Chinook NS)

Introduction

Upper Columbia Chinook & steelhead

Variation in age at maturity for PIT-tagged spring/summer Chinook salmon in the Columbia River Basin

Snake River fall Chinook

Break 15 minutes

CSS workshop: Introduction and Retrospective Analyses

CSS workshop: Prospective Analyses

Questions / Discussion

SARs and Juvenile Metrics of Upper Columbia Stocks

Presenter: Robin Ehlke

CSS Annual Meeting Apr 12th 2012

CSS Objectives Upper Columbia

- Establish long term survival estimates over full life-cycle for annual generations of upper Columbia salmon and steelhead
- Explore development of SARs to upper most dam
- Explore estimating ocean survival rates for upper Columbia groups
- Utilize additional available mark groups

2

Upper Columbia Mark Groups

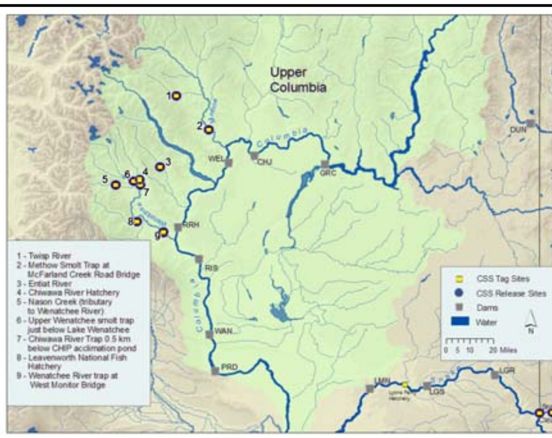
- Five Upper Columbia Mark Groups to develop Upper Columbia River (SARs)
- Leavenworth Hatchery Spring Chinook
- Hatchery Wild Cross Steelhead
  - Chelan, Eastbank, Turtle Rock
- Two natural spring Chinook aggregate groups
  - Wenatchee
  - Entiat/Methow
- Natural steelhead aggregate group
  - Entiat/Wenatchee/Methow

3

Upper Columbia juvenile and adult metrics – 2011 CSS

- Utilizing existing PIT Tag groups and supplementing existing tagging programs
  - Juvenile passage metrics, travel time, instantaneous mortality and survival from Rock Island to McNary
  - Smolt to Adult Return rates for these mark groups from McNary to Bonneville Dam.
  - Analyses of passage metrics and SARs relative to environmental variables

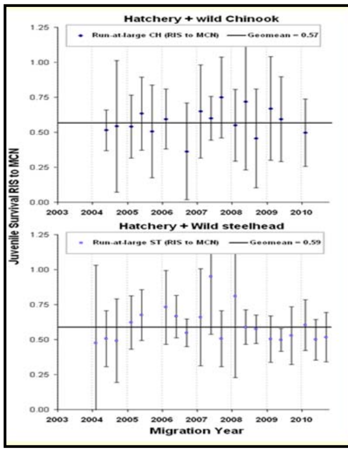
4



Smolt to Adult Return

- Upper Columbia Smolts from McNary to Bonneville Dam
  - Reported SARs do not include or account for juvenile mortality occurring through the Upper Columbia to McNary
  - For this reason the reported SARs are unrealistically high
  - As an example, for Wenatchee the SARs would be ~ 58% of reported if RIS to MCN juvenile survival were taken into account

6



Rock Island to McNary Juvenile Survival

- ❖ Hatchery and Wild Chinook geomean survival 0.57
- ❖ Hatchery and wild steelhead geomean survival 0.59
- ❖ Larger mark groups and improved downstream detection would improve precision of estimates

7

Juvenile Passage Metrics/Environmental conditions

- Fish Travel Time
  - Faster with higher flow and with Julian date
- Instantaneous Mortality
  - Decreased for hatchery and wild yearling chinook in the RIS-MCN reach as spill levels increased at Wanapum and Priest Rapids
  - Increased for hatchery and wild steelhead with increase in Julian date
- Reach Survival
  - Increased with higher flow and spill

8

SAR MCN to BON wild and hatchery Chinook

Entiat/Methow River Wild Chinook 0.5%-3% 2006-2009 in 2008 SARs exceed 2%

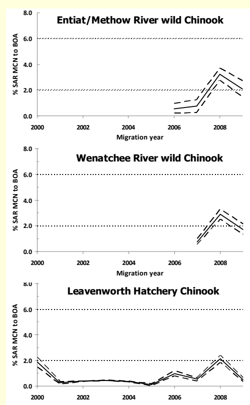
❖Not including juvenile survival through the upper Columbia River Reach

Wenatchee River Wild Chinook 0.5%-3% 2006-2009 in 2008 SARs exceed 2%

❖Not including juvenile survival through the Upper Columbia River Reach

Leavenworth Hatchery Chinook geometric mean SAR 2000-2009 0.53

❖Not including juvenile survival through the upper Columbia River Reach



9

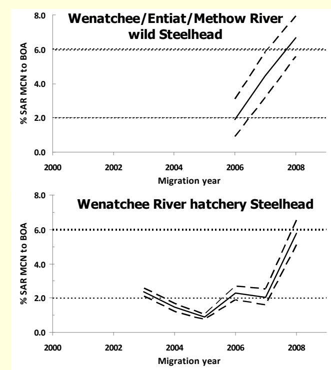
SAR MCN to BON wild and hatchery steelhead

Wenatchee/Entiat/Methow wild Steelhead 2006-2008 geometric mean SAR 3.85

❖ Not including juvenile survival through the upper Columbia River Reach

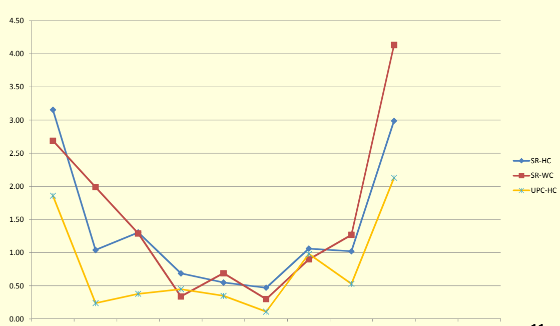
Wenatchee River Hatchery Steelhead 2003-2008 geometric mean SAR 2.09

❖ Not including juvenile survival through the upper Columbia River Reach



10

SAR LGR to BON for Snake River MCN to BON for Upper Columbia



11

Conclusion

- ❖The Overall Upper Columbia MCN-BON SARs for 2000-2009 of hatchery spring Chinook were highly correlated with wild and hatchery spring chinook SARs from the Middle Columbia (average r=0.77) and with wild and hatchery spring/summer chinook SARs from the Snake River (average r=0.84)
- ❖Indication that stocks have similar responses to shared FCRPS migration and ocean life cycle experience
- ❖Upper Columbia mark groups showed patterns of response to environmental variables consistent with Snake and Middle Columbia mark groups

12

Conclusion

- ❖ Collaboration and Coordination with other Upper Columbia specific marking efforts increases cost effectiveness and the benefits to the region
- ❖ Monitoring the effect of hydro system passage on Upper Columbia population groups from existing marking is value added for managers

13

Variation in age at maturity for PIT-tagged spring/summer Chinook salmon in the Columbia River Basin

Presenter: Steve Haeseker

CSS Annual Meeting Apr 12th 2012

1

Age at maturity

Age composition of returning adults

Essential component of most forecasting models

- Survival / SR models ➡ allocate BY forecast across return years
- Sibling / cohort models ➡ used as independent and dependent variable

Can vary across populations and over time

2

Questions about age at maturity

Does overall survival or outmigration route affect age at maturity?

What are the patterns of variation?
- Among stocks
- Over time

High jack returns in 2009?

How might the results improve forecasting?

3

Age at maturity data

Requires adult sampling	Potential issues
Scales	Aging error? Source population?
Coded wire tags	Expansion factors, reading tags, requires high sampling effort, little coverage of wild stocks

PIT tags
- negligible aging error
- known population and individual ID
- high sampling rates
- consistent sampling effort across stocks
- near real-time observations, non-lethal
- coverage of several wild stocks

4

Summarizing age at maturity data

Mean age (at maturity):
10% age-3, 70% age-4, 20% age-5 = 4.1 years

Proportion age-3 (jacking rate):
age-3 returns / total returns

Sibling relationships:
age-3 v. age-4 and age-4 v. age-5 regressions

5

Comparative Survival Study PIT-tag analyses

10 stocks, juvenile outmigration years 1997-2008:

Hatchery spring Chinook: Carson, Leavenworth, Cle Elum, Dworshak, Catherine Creek, Rapid River

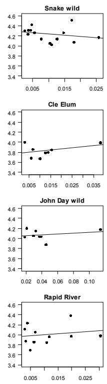
Hatchery summer Chinook: McCall, Imnaha

Wild spring Chinook: John Day River, Snake River

6

Mean age versus SAR

Mean age



No relationship between SAR and mean age

7

Mean age versus outmigration route

Paired t-test of transported versus in-river outmigration routes

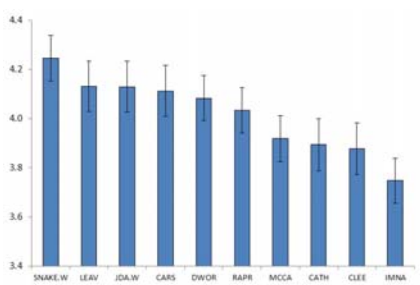
Stock	*P*-value
Snake River wild	0.43
Catherine Creek AP	0.98
Dworshak	0.76
Rapid River	0.97
McCall	0.47
Imnaha River AP	0.82

No relationship between outmigration route and mean age

8

Mean age

Mean age



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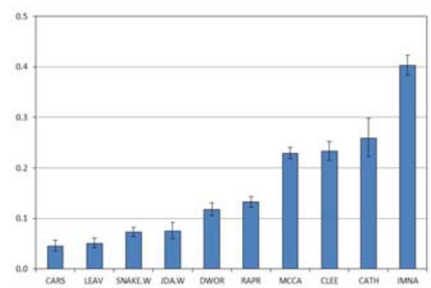
Mean proportion age-3

Proportion age-3

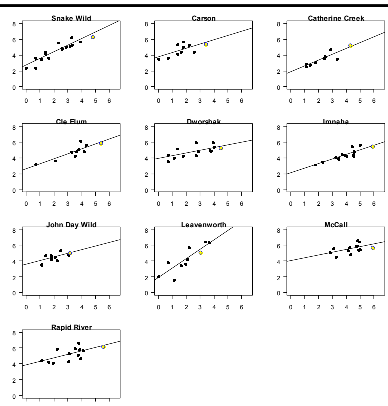


Mean age and proportion age-3 varies by stock

10

Sibling relationships

Log (Age-4)

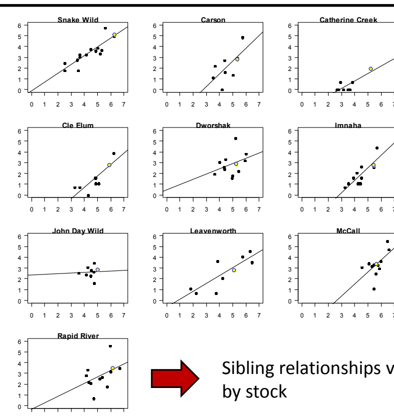


Log (Age-3)

11

Sibling relationships

Log (Age-5)

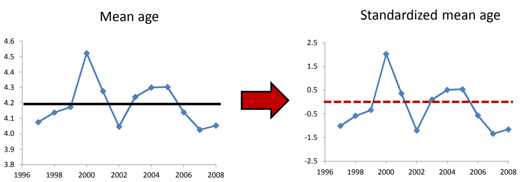


Sibling relationships vary by stock

Log (Age-4)

12

Standardized mean age over time and across stocks



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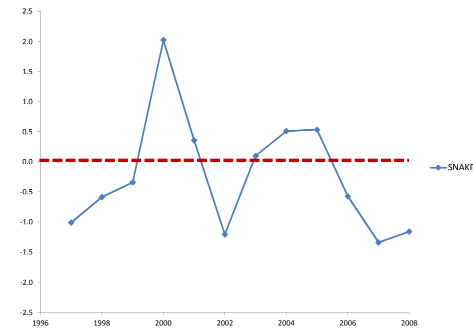
Standardized mean age over time and across stocks



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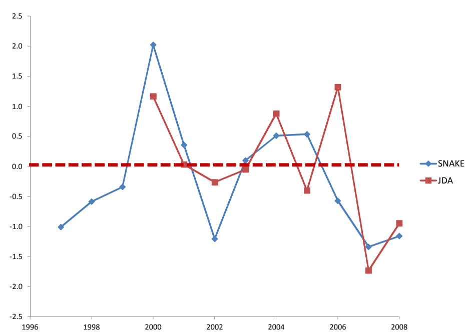
Standardized mean age over time and across stocks



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Standardized mean age over time and across stocks

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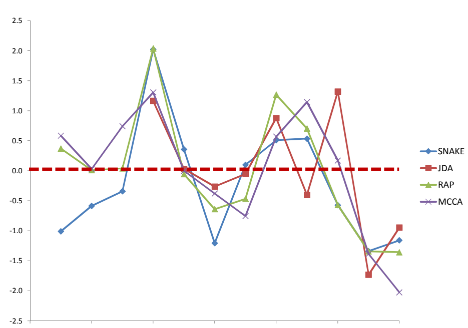
Standardized mean age over time and across stocks



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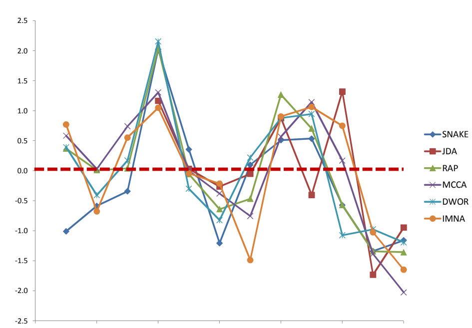
Standardized mean age over time and across stocks



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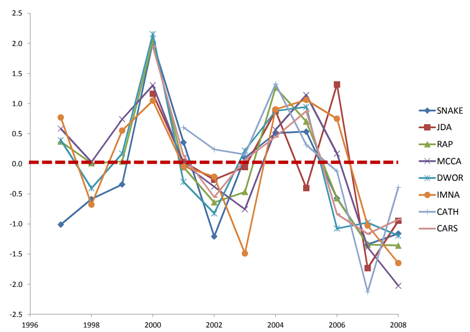
Standardized mean age over time and across stocks



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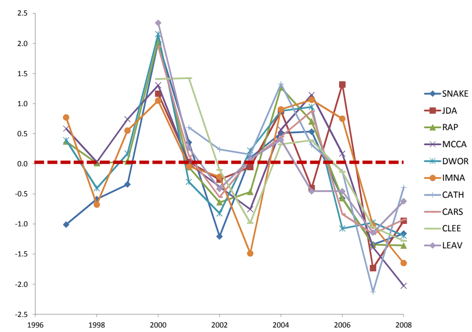
Standardized mean age over time and across stocks



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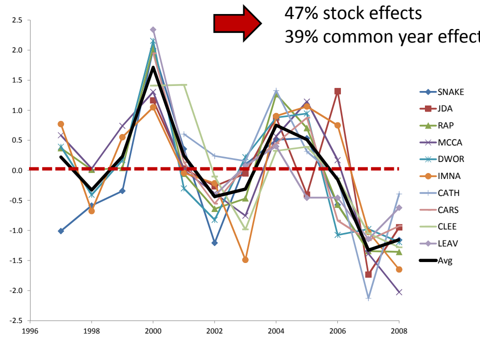
Standardized mean age over time and across stocks

47% stock effects
39% common year effects



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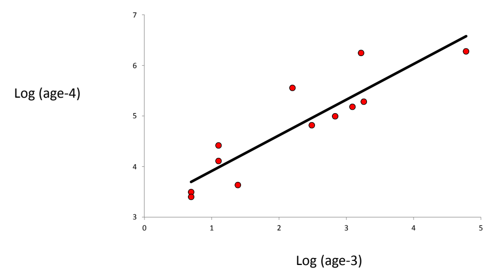
Sibling residuals across stocks



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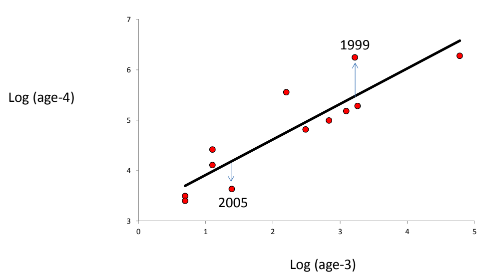
Sibling residuals across stocks



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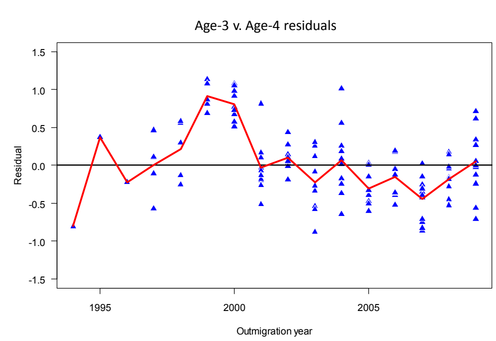
Sibling residuals across stocks



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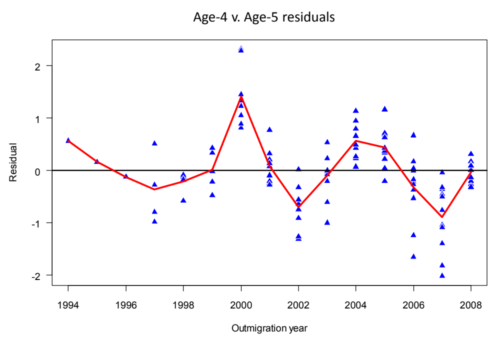
Sibling residuals across stocks



17

How to improve forecasting

Important differences in age at maturity between stocks

- Where possible, stock-specific forecasts
- Understand the run composition of aggregate stock groups
- Monitor changes in age over time, especially compared to other stocks

Common year effects on age at maturity across stocks

- Allow for temporal variation in models (e.g., Kalman filter)
- Recent age composition may be better than long-term average
- Evaluate candidate environmental factors that may be associated with observed changes in age at maturity

18

Snake River Fall Chinook

Modeling Holdover Probability

Presenter: Jerry McCann

CSS Annual Meeting Apr 12th 2012

Background

- CSS was requested to develop estimates of subyearling fall Chinook SARs.
- CSS approach compares SARs for transported fish to fish undetected in-river (C0) at transport dams.
- Holdover fish can bias estimates of C0 SARs.

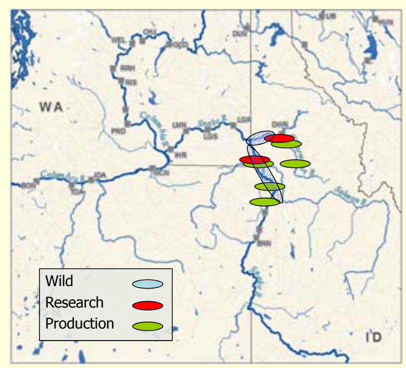
2

Background

- In 2011 CSS developed models for predicting holdover probability.
- This approach was used to identify release groups that are most likely to holdover.

3

Subyearling Fall Chinook PIT-tag Releases



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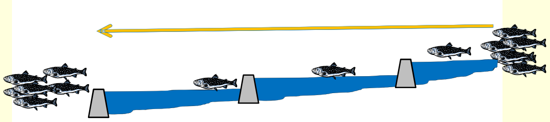
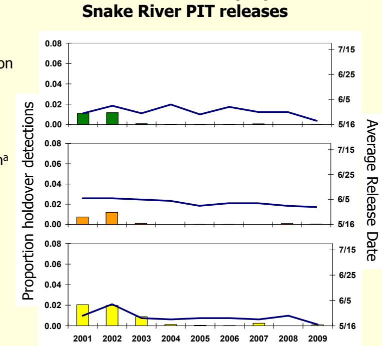
What is a holdover?

Subyearling Migration - fish migrate past dams in year of release/emergence

Holdover – yearling migration - fish migrate past some dams as yearlings – the year after release/emergence



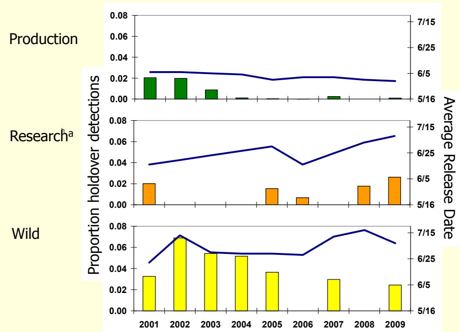
Observed holdover detect proportions in Snake River PIT releases



[a] Research releases included experimental release groups (2000-2004) as well as surrogate releases (2005-2009 except 2007)

6

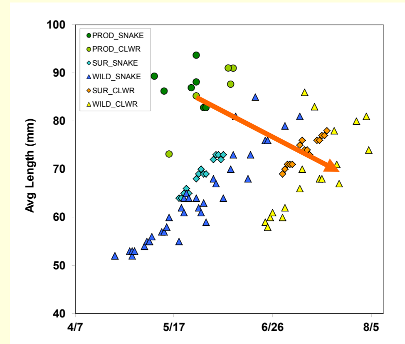
Observed holdover detect proportions in Clearwater River PIT releases



[a] Research releases included experimental release groups (2000-2004) as well as surrogate releases (2005-2009 except 2007)

7

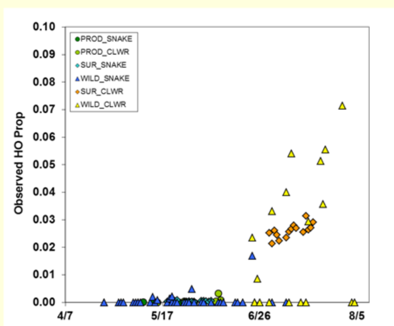
Release date and length at release for PIT tagged Ch0 in 2009



Later releases at shorter lengths = Higher Holdover Probability

8

Proportion Holdovers by release date for PIT tagged Ch0 in 2009



Later releases at shorter lengths = Higher Holdover Probability

9

Analytical Approach

- **Logistic model: Model holdover probability using holdover detection probability**

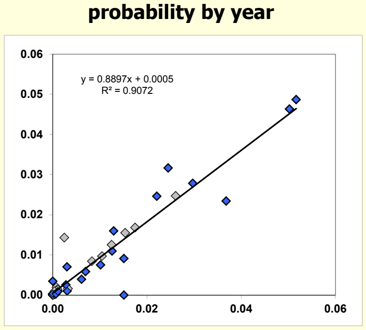
1. **Holdover Det (Y/N) = Rel_date + Rel_length + date*length**
   - Typically research/surrogate and wild releases included in this Modeling group

2. **Holdover Det (Y/N) = Rel_date**
   - Usually Production releases in this Modeling group

- **Fitted models successfully for 7 out of 9 years**
  - Measured Fit Using Somer's D, p values for effects.

10

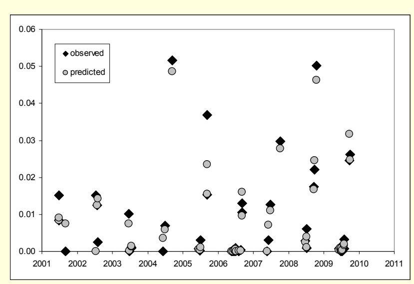
Observed vs predicted holdover detection probability by year



Sample size ~10,000 or greater for production hatchery releases

11

Observed vs predicted holdover detection probability by year



Sample size ~10,000 or greater for production hatchery releases

12

Conclusions

- Models successfully predicted holdover detection probability using length and release date.
- Holdover probability appears to be related to release date and release length.
- We can estimate relatively unbiased SARs on PIT-tagged subyearling Chinook.
- Next steps
  - Identify groups for SAR estimation.
  - Add years of juvenile data to HO analysis.

13

14

Comparative Survival Study Workshop

Introduction:

Approaches for assessing hydrosystem effects in the face of variable marine conditions

Charlie Petrosky, Idaho Department of Fish and Game

Comparative Survival Study 2012 Annual Meeting

April 12,2012



Comparative Survival Study Workshop

July 26-28, 2011

Objectives:

1. Synthesize recent evidence & insights on:
   a. What is relative importance of various factors (FCRPS operations, freshwater/ocean conditions, fish attributes) in determining salmon & steelhead survival rates?
   b. How to use retrospective analysis to build tools that evaluate & optimize FCRPS operations to meet NPCC SAR objectives?
   c. Implications of questions *a* and *b* on identifying additional populations that need estimates of SAR and S_R through FCRPS to meet CSS objectives?
2. Provide opportunity for leading investigators to share & compare recent results, & collaboratively develop priorities for future CSS work.
   Broaden scope of review of CSS work by incorporating input from other researchers doing similar types of analyses

2

Comparative Survival Study Workshop

July 26-28, 2011

- 27 scientists, US & Canada, 9 agencies, 3 universities & ESSA
- Presentations:
  - Delayed Hydrosystem Mortality Hypothesis
  - CSS survival rate patterns
  - Environmental variability throughout life cycle of Oregon coastal coho
  - Life stage specific survival and factors influencing performance
  - Spatial & temporal patterns in SR residuals, SARs, marine survival rates
  - Freshwater & marine influences on life-stage specific survival rates
  - Bypass effects on SARs
  - Adult success and stray rates as function of passage history
  - Tools to analyze existing and alternative FCRPS operations
  - Generating SARs and S_R for populations lacking such estimates
- Workshop report Marmorek et al. 2011; App. G in CSS 2011 annual report

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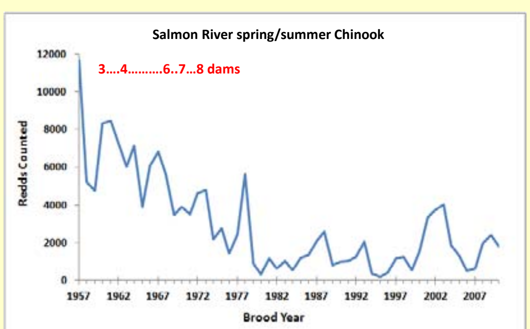
4

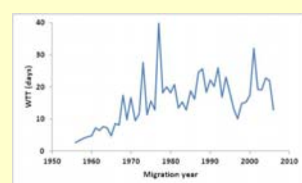
Decline in salmon abundance associated with dam construction …



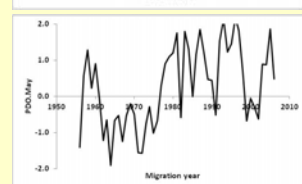
IDFG index redd counts

5

Dramatic changes in outmigration conditions with dams…

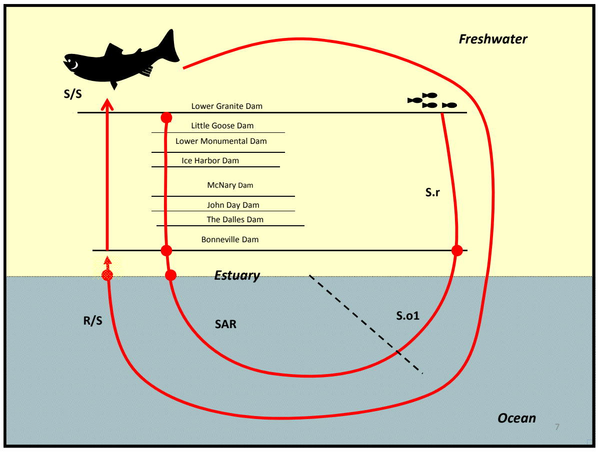


marine conditions were not static…



Need to account for both

6



Linking SARs and Life Cycle Survival Rates…

- 2-6% SAR objectives (ave. 4% SAR; NPCC 2009)
  - Evaluate SARs in face of varying ocean conditions
  - Adapt freshwater management actions (tributaries & FCRPS)
- SARs to meet NMFS (interim) survival and recovery criteria (2000 BiOp)*
  - 2% SAR - meets long-term (100 yr) survival
  - 4% SAR - meets (48 yr) recovery
  - 6% SAR - meets short-term (24 yr) survival
- Other goals: ICTRT (2007) viability, broad-scale recovery, sustainable fisheries, etc.
  - Regardless of goals, similar analyses needed to link SARs and life cycle survival rates

*Marmorek et al. 1998 - PATH FY98 Final Report

8

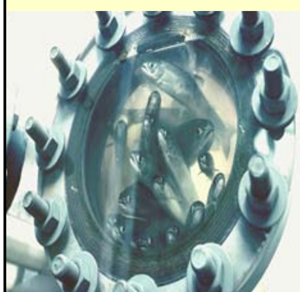
2000 FCRPS BiOp

- Management options to meet NMFS (interim) survival and recovery criteria
  - A1 - status quo
  - A2 - maximize transport
  - A3 – Snake River dam removal
- Ability to meet criteria
  - A3 > A1 or A2 across hypotheses (most likely to meet & least risk)
- Key uncertainty = amount of hydrosystem delayed mortality
  - Mortality that occurs in marine environment as consequence of hydrosystem experience
  - Transported fish relative to in-river migrants
  - In-river migrants

Marmorek et al. 1998 - PATH FY98 Final Report

9

Evidence for Hydro-Related Delayed Mortality H_A



•Mechanisms (literature review)

•Stress at dams, crowding, disease exposure, migration delay, energy loss, altered estuary timing

•Direct Evidence

•Delayed mortality of transported smolts (D < 1), and in-river smolts (especially collection/bypass)

•Indirect Evidence of substantial delayed mortality

•Temporal and spatial patterns of population response; declines in SAR; response to good flows

Budy et al. 2002

10

A decade later…

Spawners & recruits:

•10 more brood years
•18 Snake River & 3 John Day River Chinook populations
•Contrast in ocean conditions
•Continue/expand long-term data sets (input from States, Tribes, ISAB)

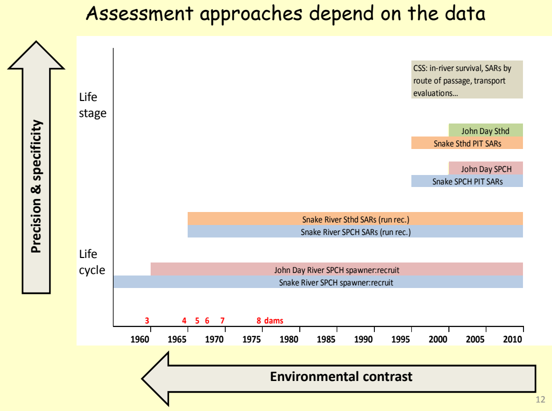
Comparative Survival Study:

•PIT tag SARs:
  •Snake River wild & hatchery Chinook & steelhead
  •John Day River wild Chinook and steelhead
•In-river survival rates
•Transport to in-river SAR ratios (TIRs)
•Differential delayed mortality of transported smolts (*D*)
•Increased detection sites
•Court-ordered spill program (contrast in river conditions)

Additional & more specific M&E data across variable river & ocean conditions

11

Assessment approaches depend on the data



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Assessing hydrosystem mortality

Address past criticisms:

- •Spawner-recruit estimates - precision, uncertainty in models, number of populations
- • Use of reference populations – same response to ocean conditions as Snake populations?
- •Past estimates of differential & delayed mortality during period of poor ocean conditions

Recent CSS analyses:

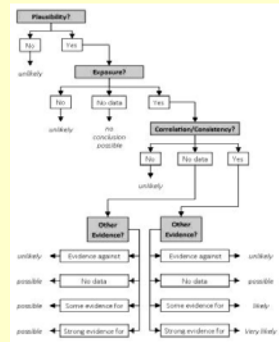
- •Estimate hydrosystem effects <u>with</u> <u>&</u> <u>without</u> using reference populations
  - •Differential mortality (8 vs. 3 dam)
  - •Hydrosystem delayed mortality (in ocean)
- • CSS PIT tag data – increased precision, overall SARs & by passage route, isolate mechanisms
- •Examine <u>multiple</u> lines of evidence – consistent results?

13

Weight of Evidence Framework –

Multiple lines of evidence for relative importance of major factors

Plausible mechanism?
Exposure to causal factor?
Correlation/consistency of response?
Threshold for response?
Specificity of response?
Experiments lead to similar response?
Response to removal of stressor?



Forbes 2002, Burkhardt-Holm Sheurer 2007, ESSA 2011

Comparative Survival Study Workshop Report – Marmorek et al. 2011

14

Summary

- •CSS Workshop background and description of approaches for assessing hydrosystem effects in face of variable marine conditions
  - •Broaden scope of review for CSS work by incorporating input from other researchers doing similar analyses
- •Hydrosystem delayed mortality - occurs in marine environment as consequence of hydrosystem experience
  - •i.e, is marine survival independent of river conditions?
- •Weight of evidence: retrospective analyses (multiple approaches & scales), testable H_a → experimental management
- •CSS Workshop Results:
  - •*<u>Retrospective analyses</u> – assessing freshwater and marine influences on survival rates of Snake River Chinook salmon and steelhead*
    - •Howard Schaller
  - •*<u>Prospective analyses</u> - tools to explore operational alternatives -*
    - •Steve Haeseker

15

Retrospective analysis of survival rates for stream-type Chinook salmon and steelhead in the Snake and John Day rivers

CSS Annual Meeting
April 12, 2012

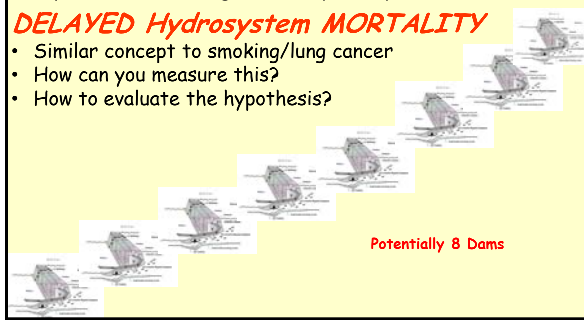


Key Concepts:

Is there evidence linking estuary and early-ocean mortality to the migration experience through the hydrosystem?

DELAYED Hydrosystem MORTALITY

- Similar concept to smoking/lung cancer
- How can you measure this?
- How to evaluate the hypothesis?



Challenges and management objectives

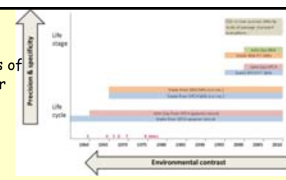
Multiple factors operating at same time

- Capitalize on temporal patterns of variation
- Capitalize on spatial patterns of variation
- Consistency from multiple lines of evidence
- Delayed mortality decrease with improved ocean

SAR objectives of 4% average, 2% minimum

Approach

Weight of evidence Multiple lines of evidence for relative importance of major factors influencing survival rates

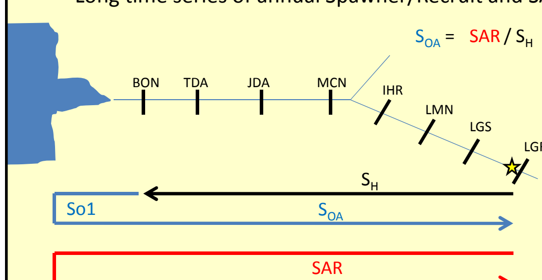


- Estimate hydrosystem and ocean effects without using reference populations
  - Temporal approach evaluating river variables influence on ocean survival (SoA & So1)
  - Contrast period before major hydro impact with the present
- Estimate hydrosystem and ocean effects using a reference populations
  - Spatial and Spatial/Temporal approaches evaluating river & ocean variables influence on survival (SAR & SRI)
  - Contrast populations through 8 vs. 3 dams
- Examine multiple lines of evidence – consistent results

What factors influence survival at each life stage?

Data

CSS PIT-tag SARS for multiple cohorts per year
Long time series of annual Spawner/Recruit and SARs
Long time series of annual Spawner/Recruit and SARs



Factors examined

Hatchery — Hatchery %

Seasonality — Julian day

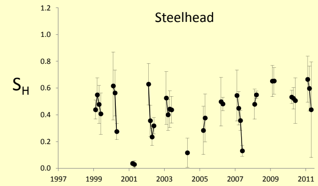
Freshwater — Percent spill; Spillway surface passage; Water transit time (WTT)

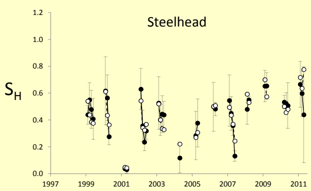
→ S_H

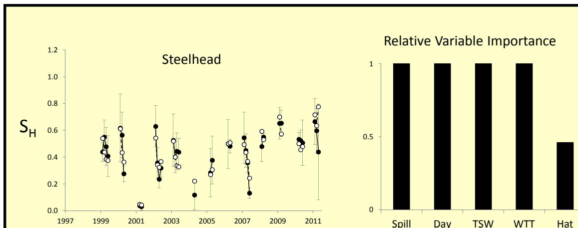
Ocean — Near shore (upwelling); Broad scale (PDO)

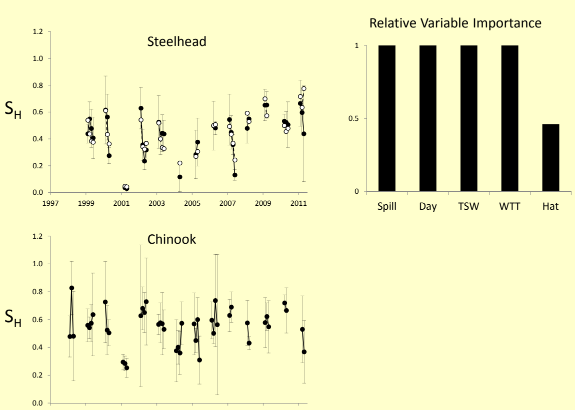
→ S_{OA}, So1, SAR, & SRI

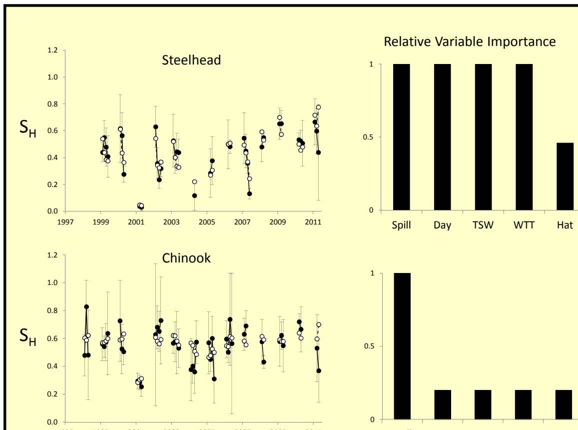
Conducted multiple linear regressions between environmental factors and survival rates using multimodel inference tools







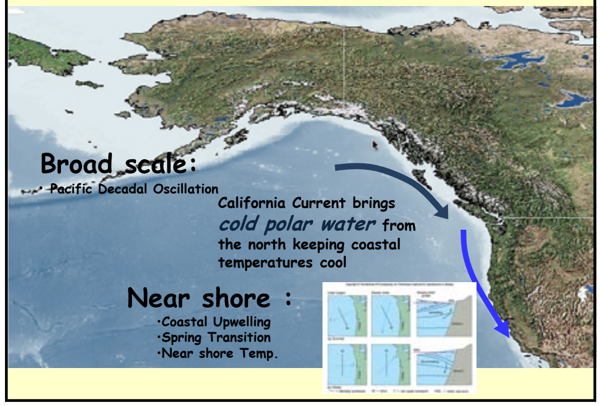




Temporal Analyses

- Influence of river & ocean conditions on survival rates
  - Employ long time series:
    - Pre & post Snake River dam completion
    - Survival rates for different life stages (SRI,SAR,So1)
    - Variables for ocean conditions
    - Variables for river conditions during seaward migration
- For different life stages & species - contrast the set of ocean & river conditions that explain variation in survival rates (temporal)
- Temporal/spatial contrasts to estimate FCRPS impacts - differential and delayed hydrosystem mortality

Candidate Ocean Variables



Candidate River Variables

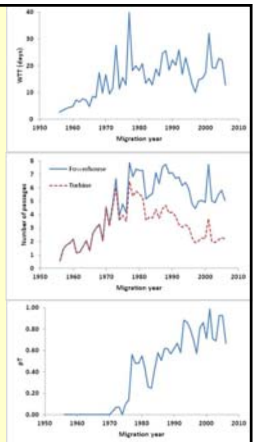
Water travel time (Lewiston – BON Dam):
- •2 days pre-dam
- •10-40 days (19 day ave.) post-dam
- •

In-river migrants now pass through:
- •up to 8 powerhouses
- •up to 4 turbines
- •depending on spill

Collection and transport:
- •25% - 99% of smolts transported (1977-2006)

Mean daily maximum temperature
- •Snake River mean maximum temperature at Lewiston 9.9 to 13.2C

Petrosky & Schaller 2010



Multiple Regression Analysis

- **Evaluate multivariate models of SRI, SAR & So1**
- **Best fit models to isolate influence of ocean and in-river conditions on survival rates**
  - *Coefficients and consistency of results across species and life stages*
- **Use models to estimate FCRPS impacts - differential and delayed hydrosystem mortality**

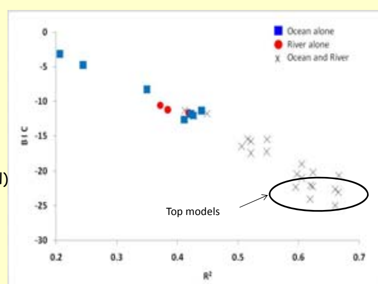
Marine survival (So1)

So1 Chinook

River & Ocean important

Best fit, simplest models exhibit lower marine survival for:

- Warm PDO (Spring)
- Reduced Upwelling (April)
- Increased WTT (slower velocity)
- 72% reduction in marine survival due to hydrosystem impacts
- Similar results for steelhead



Petrosky & Schaller 2010

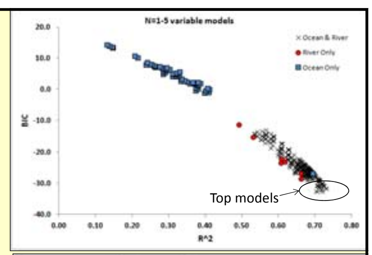
SRIs Chinook

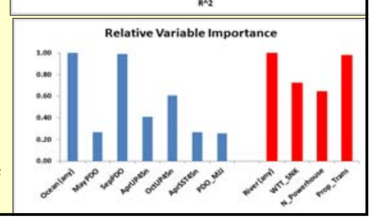
River & Ocean important

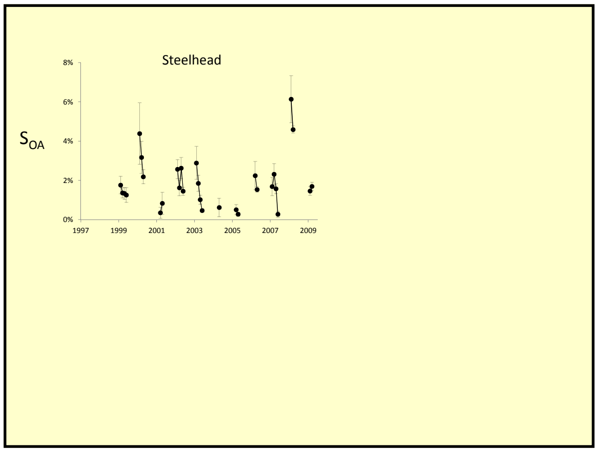
Best fit, simplest models exhibit lower survival for:

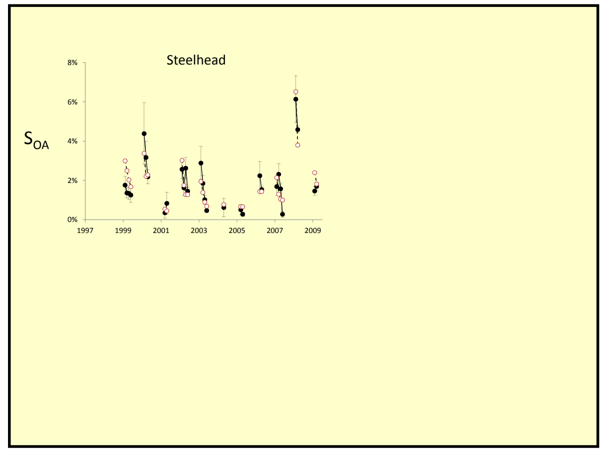
- Warm PDO
- Reduced Upwelling (Apr)
- Increased Powerhouse encounters & WTT
- Increased Proportion transported

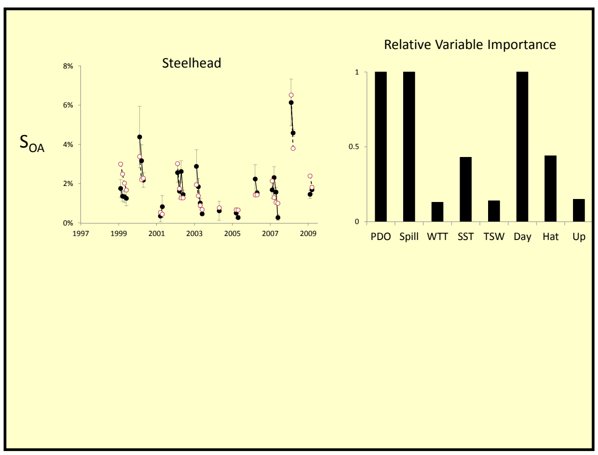
SARs showed similar results (Chinook & steelhead)

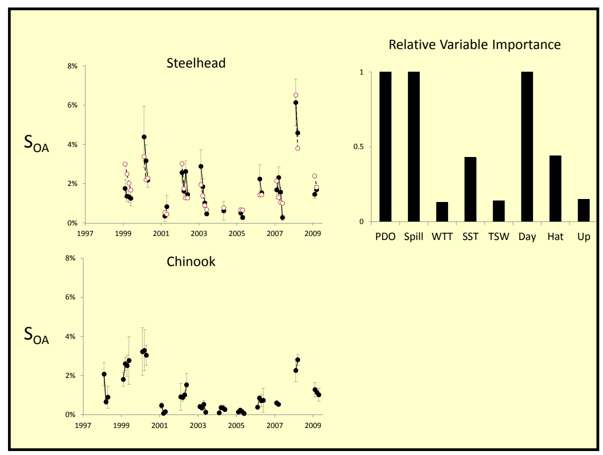


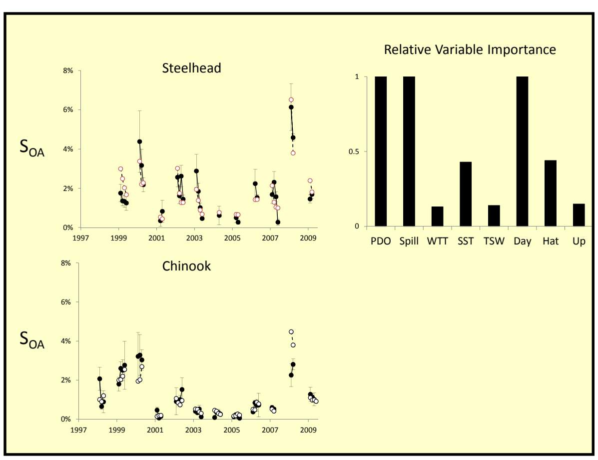



Steelhead
SOA
8%
6%
4%
2%
0%
1997
1999
2001
2003
2005
2007
2009


Steelhead
SOA
8%
6%
4%
2%
0%
1997
1999
2001
2003
2005
2007
2009


Steelhead
Relative Variable Importance
SOA
PDO
Spill
WTT
SST
TSW
Day
Hat
Up


Steelhead
Relative Variable Importance
SOA
PDO
Spill
WTT
SST
TSW
Day
Hat
Up
Chinook
SOA


Steelhead
Relative Variable Importance
SOA
PDO
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WTT
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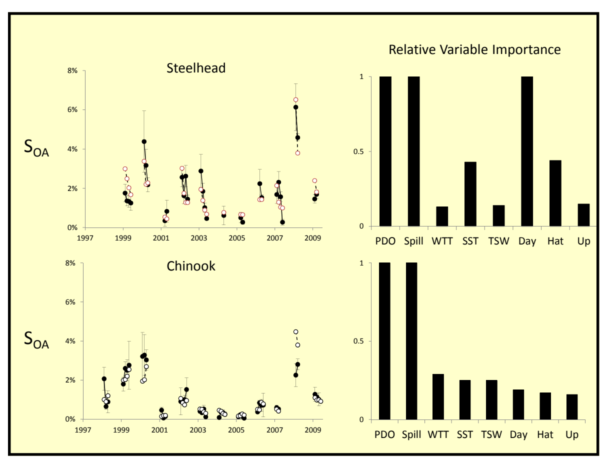
TSW
Day
Hat
Up
Chinook
SOA


Steelhead
Relative Variable Importance
SOA
PDO
Spill
WTT
SST
TSW
Day
Hat
Up
Chinook
SOA
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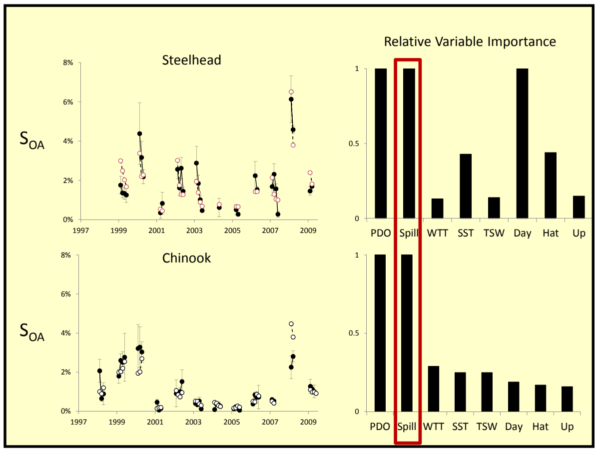
WTT
SST
TSW
Day
Hat
Up



Spawner-recruit spatial contrast

Treatment = Snake populations
•(3 dams → 8 dams)

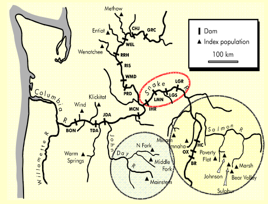
Reference = John Day populations
•(2 dams → 3 dams)

•Spawner-recruit residuals or multi-stock model

•Estimate differential mortality

•Estimate total mortality for Snake (differential + JDA passage mortality)

•Estimate delayed mortality for Snake (total mortality – passage mortality)



e.g., Schaller et al. 1999; Deriso et al. 2001; Schaller & Petrosky 2007

SAR spatial contrast

(↑ Precision-PIT tags)

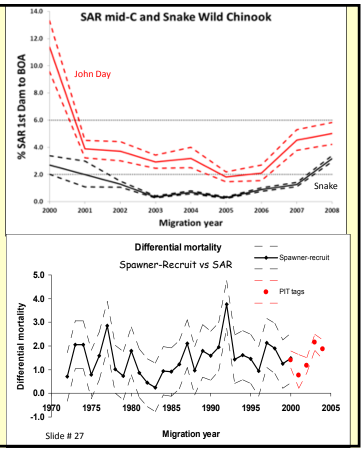
Treatment = Snake aggregate
•(8 dams)

Reference = John Day aggregate
•(3 dams)

•Shorter time series, life stage specific

•Estimate differential mortality between ESUs

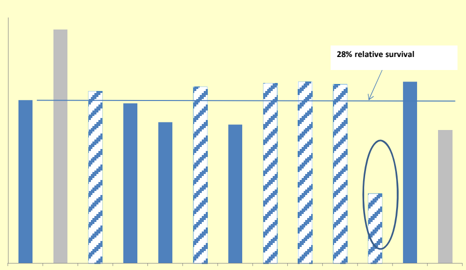
e.g., Schaller et al. 2007 – CSS 10-yr report; Schaller & Petrosky 2007; Schaller, Petrosky & Tinus in prep.



Conclusions from Spatial Analysis

- Differential mortality from wild SARs (*↑ precision*) corresponds with estimates from S-R models (*↑ contrast*)
- Snake River wild Chinook survived 1/4 to 1/3 as well as downriver populations since hydropower system completion

Estimates of differential mortality wild spring/summer Chinook populations



Blue = spatial, Gray = temporal, and blue hatch = temporal/spatial

Differential Mortality

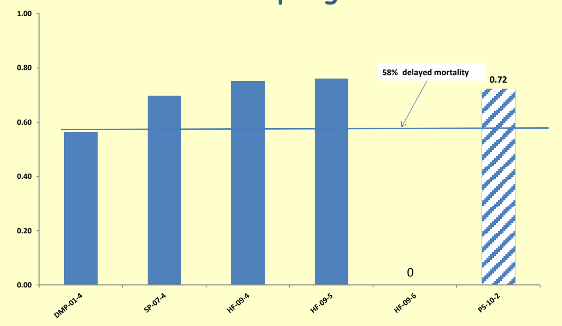
- **Differential mortality from temporal analysis correspond with estimates from spatial analysis**
- **All studies: survival of fish passing through the complete hydrosystem is 28% of those populations that pass through 5 fewer dams**
- **Outlier**
  - assumes common productivity (Ricker "a") for all populations
  - passage survival of downriver population ~ 100%

Slide # 30

Estimate Delayed Hydrosystem Mortality

- Temporal – regression models for So1 & SoA
- Spatial- delta model S/R contrast

Estimates of delayed mortality of Snake River wild spring/summer Chinook



Solid = delta model S-R contrast, hatch = regression approach using Snake populations

Slide # 32

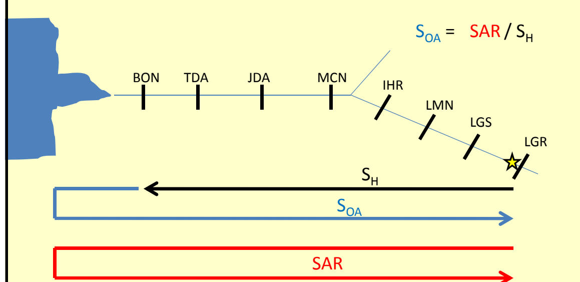
Delayed Hydrosystem Mortality

- **Effect of increased Hydrosystem Development:**
  - >3 fold decline in Chinook 1st year ocean survival rate
  - >5 fold decline in Chinook SRIs
- **Evidence of Delayed Hydrosystem Mortality**
  - estimate of delayed mortality from temporal analysis was similar to spatial/temporal comparisons (Schaller and Petrosky 2007)
- **Outlier -** inconsistent with empirical information:
  - assumes common productivity for all populations
  - and survival of downriver population ~ 100%

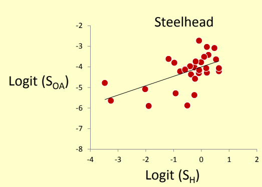
Slide # 33

How is ocean survival related to freshwater survival?

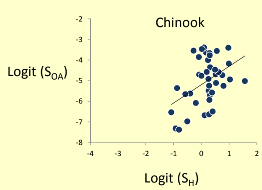
PIT-tag mark-recapture data from migration years 1998-2009



Ocean survival related to Freshwater survival

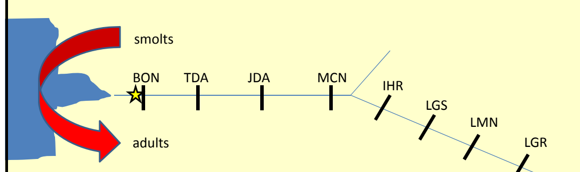


$r = 0.57$, $P < 0.02$



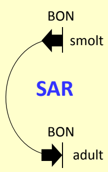
$r = 0.44$, $P < 0.01$

Bypass events influence ocean survival?



Bypass events influence ocean survival?

- Logistic regression
- Yearling Chinook and steelhead, MYs 2000-2009
- Analyzed hatchery and wild, accounted for differences
- Model-averaged the estimated bypass effects



	JDA	MCN	IHR	LMN	LGS	LGR
Smolt 1	0	0	0	0	0	0
Smolt 2	1	0	0	0	0	0
Smolt 3	0	1	0	0	0	0

Spring/summer Chinook salmon

Each bypass event reduced post-BON SARs by 10%

Steelhead

Each Snake bypass event reduced post-BON SARs by 9%

Each McNary or John Day bypass event reduced post-BON SARs by 20%

Management implications

Direct and route-specific survival estimates unlikely to reflect full impacts of passage routes

Actions that reduce powerhouse passage (bypass + turbine) expected to increase SARs

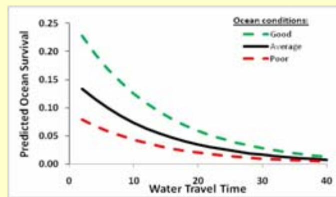
Conclusions

- NPCC 2%-6% SAR goal – extremely difficult to achieve <u>without</u> major changes to seaward migration conditions in the mainstem
- Especially in face of climate change (e.g. warming & increased variability in ocean conditions)
- River conditions during seaward migration have strong influence on survival rates at later life stages
- Analyses of Snake River population performance continued to show the hydrosystem is a key factor influencing delayed mortality - Multiple methods, independent data (SRI,SAR, & So1)
- CSS Workshop 2011
  - *"The evidence presented for … delayed mortality arising from earlier experience in the hydrosystem is strong and convincing."*
  - *"It is difficult to imagine how [other factors] would align so well both in time and space with the establishment of the hydro system.*

Conclusions

Tools to improve understanding role of hydropower management on overall survival in the face of variable ocean and climate conditions:

- reduced WTT
- reduced number of powerhouse passage (↑spill)
- other actions to speed migration of juvenile migrants



Prospective Analyses from the CSS Workshop

Presenter: Steve Haeseker

CSS Annual Meeting Apr 12th 2012

1

Looking back over the data and analyses…

We have learned a lot over last 10 years!

Life-cycle data and analyses were responses to agency/tribal/ISAB requests and questions.

CSS Workshop provided additional opportunity for broad review-
Prospective analyses synthesize the retrospective work in a manner that may be useful in a variety of applications in the region.

Workshop Question:

How can we use recent analyses to build tools that evaluate and optimize FCRPS operations for the above-listed groups of anadromous fish to meet established NPCC objectives for listed Snake and upper Columbia River salmon and steelhead SARs?

2

1) How do changes in juvenile and ocean survival rates influence SARs?

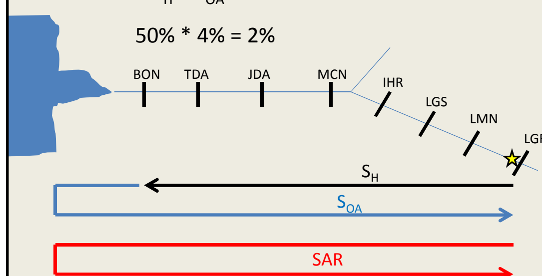
Which juvenile survival values (if any) achieve 4% average SARs?

3

1) How do changes in juvenile and ocean survival rates influence SARs?

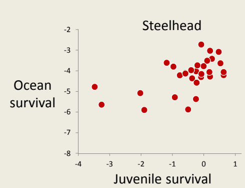
$S_H * S_{OA} = SAR$

50% * 4% = 2%

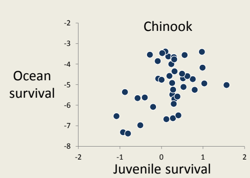


4

Positive correlations between juvenile and ocean survival rates



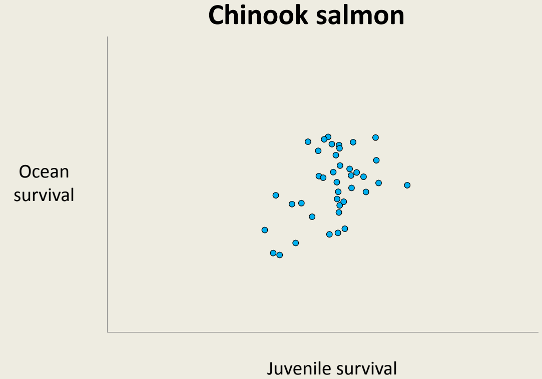
r = 0.57, $P < 0.02$



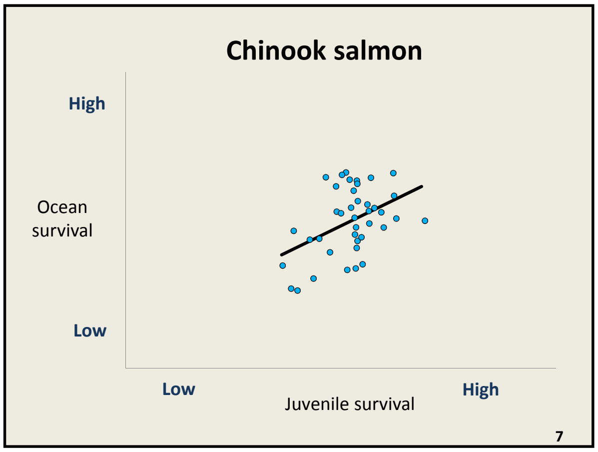
r = 0.44, $P < 0.01$

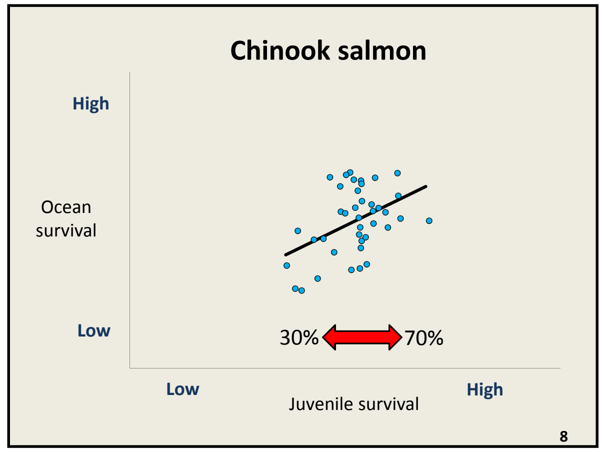
5

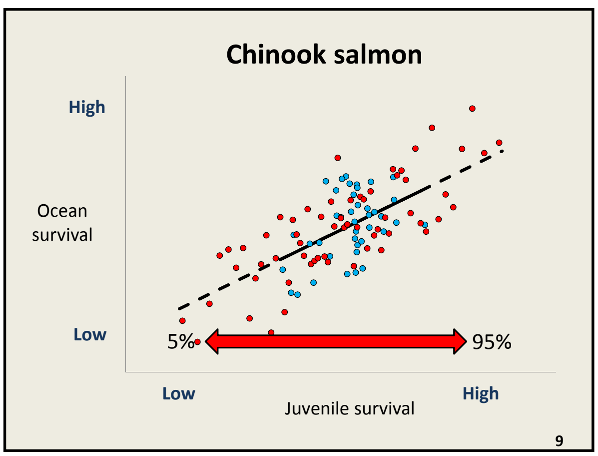
Chinook salmon

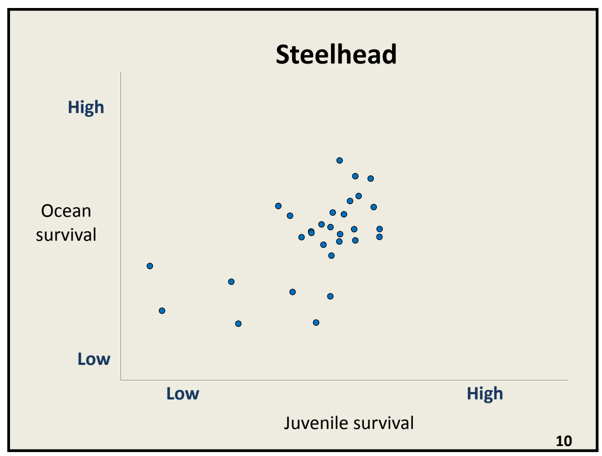


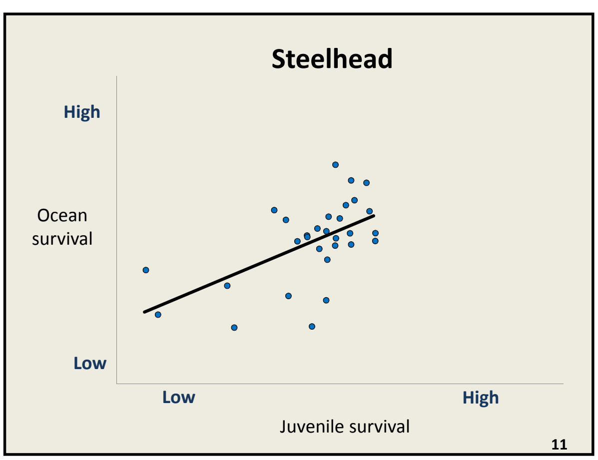
6

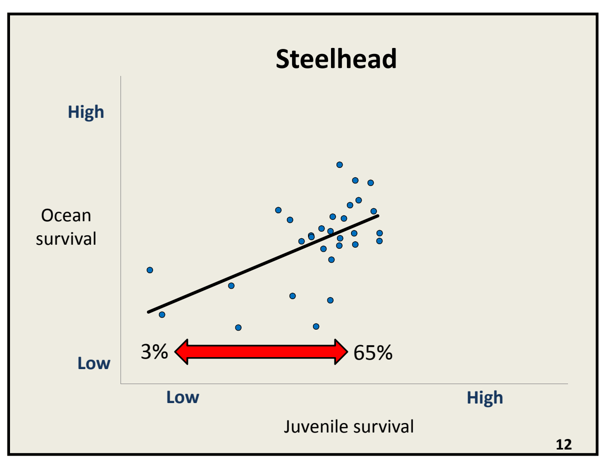

Chinook salmon
High
Ocean
survival
Low
Low
Juvenile survival
High
7

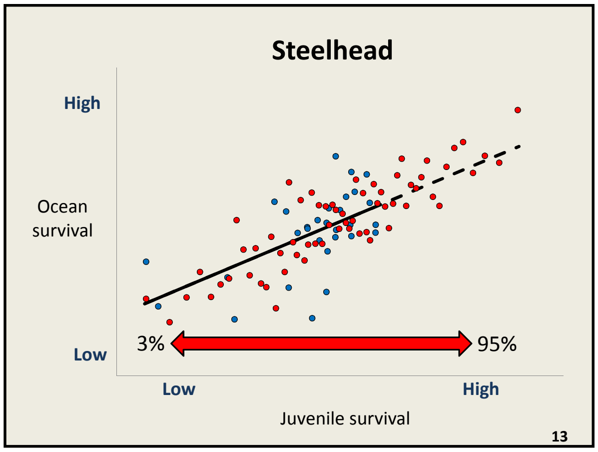

Chinook salmon
High
Ocean
survival
Low
30%
70%
Low
Juvenile survival
High
8


Chinook salmon
High
Ocean
survival
Low
5%
95%
Low
Juvenile survival
High
9


Steelhead
High
Ocean
survival
Low
Low
High
Juvenile survival
10


Steelhead
High
Ocean
survival
Low
Low
High
Juvenile survival
11


Steelhead
High
Ocean
survival
Low
3%
65%
Low
High
Juvenile survival
12



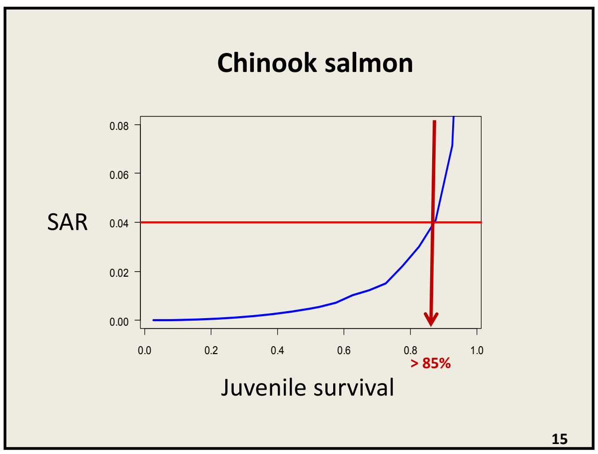
Approach

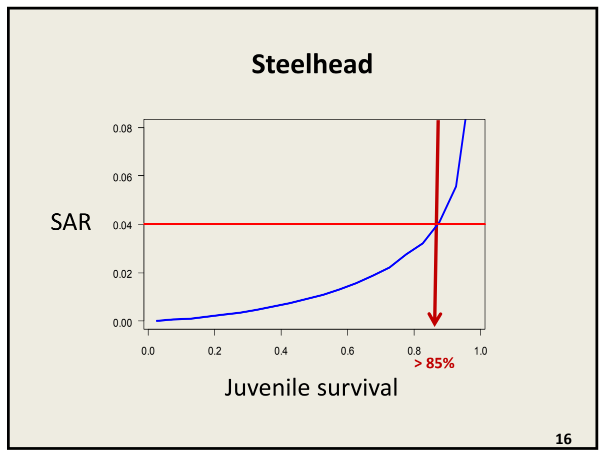
Allow juvenile survival to vary between 5% and 95%

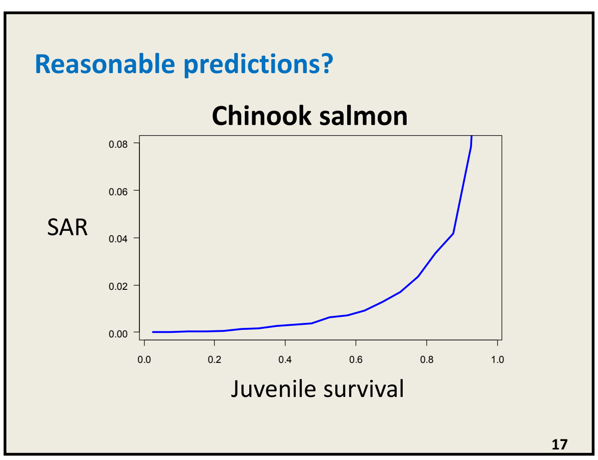
Simulate ocean survival rate using regression with observed variability

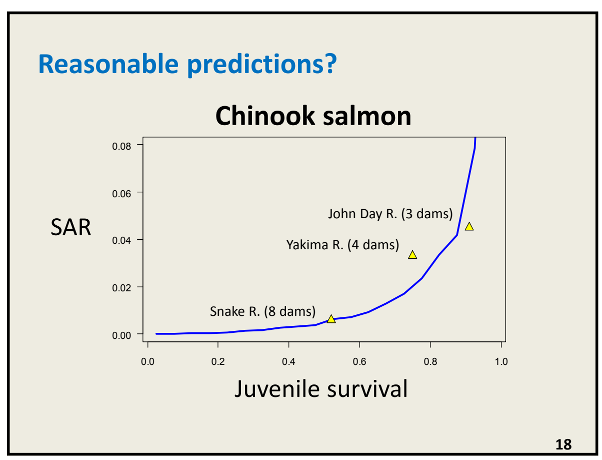
Calculate mean SAR associated with each juvenile survival rate

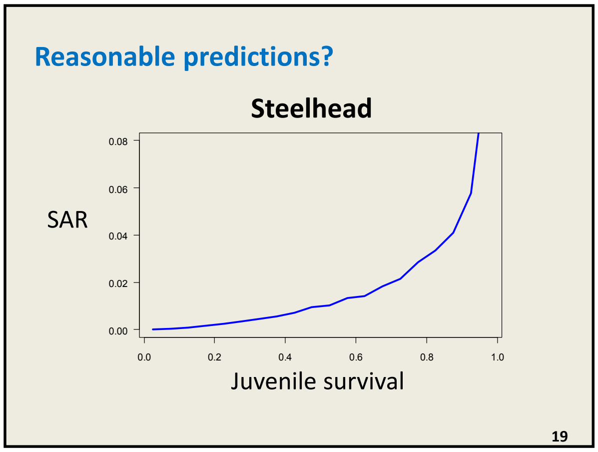
14

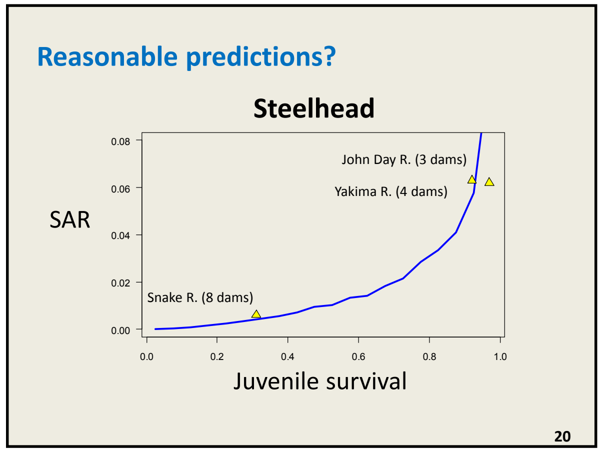


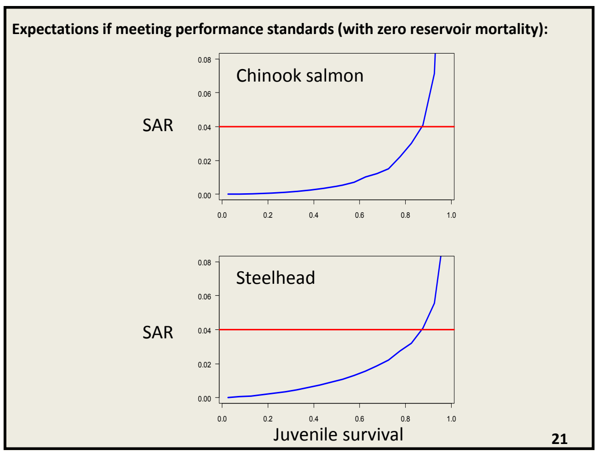


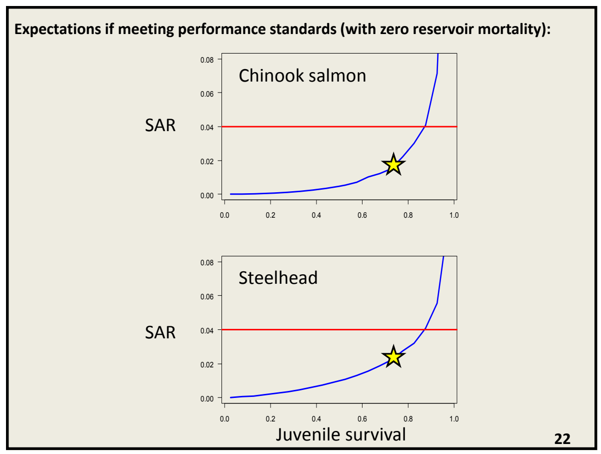






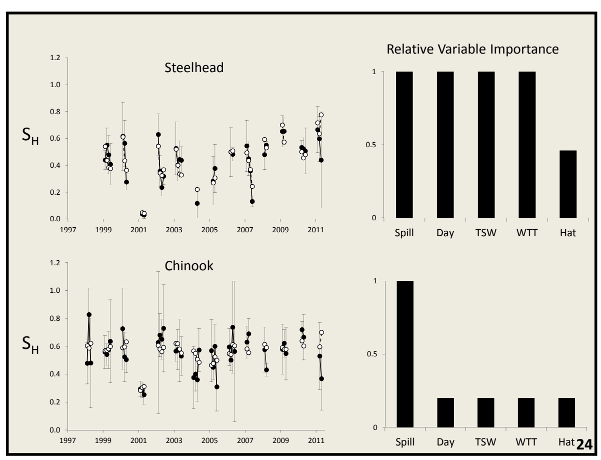






2) What operations might achieve 85% juvenile survival rates?

23



Approach

Used model-averaged coefficients

Held WTT and spill percentages at fixed levels

Calculated mean juvenile survival rates

25

Steelhead

Spring flow levels

Spill (%)	Low	Average	High
0	0.04	0.09	0.17
10	0.08	0.17	0.30
20	0.15	0.29	0.45
30	0.26	0.44	0.62
40	0.41	0.61	0.76
50	0.58	0.75	0.86
55	0.66	0.82	0.90
60	0.73	0.86	0.93

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Steelhead

Spring flow levels

Spill (%)	Low	Average	High
0	0.04	0.09	0.17
10	0.08	0.17	0.30
20	0.15	0.29	0.45
30	0.26	0.44	0.62
40	0.41	0.61	0.76
50	0.58	0.75	0.86
55	0.66	0.82	0.90
60	0.73	0.86	0.93

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Chinook salmon

Spring flow levels

Spill (%)	Low	Average	High
0	0.19	0.19	0.19
10	0.27	0.27	0.27
20	0.38	0.38	0.38
30	0.50	0.50	0.50
40	0.62	0.62	0.62
50	0.73	0.73	0.73
55	0.77	0.78	0.78
60	0.81	0.81	0.81

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Chinook salmon

Spring flow levels

Spill (%)	Low	Average	High
0	0.19	0.19	0.19
10	0.27	0.27	0.27
20	0.38	0.38	0.38
30	0.50	0.50	0.50
40	0.62	0.62	0.62
50	0.73	0.73	0.73
55	0.77	0.78	0.78
60	0.81	0.81	0.81

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3) What operations might achieve SARs averaging 4%?

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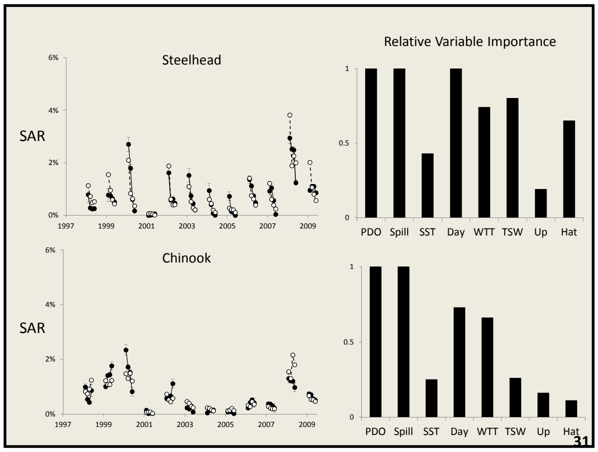

Approach

Used model-averaged coefficients

Maintained historical patterns in ocean conditions (1998-2009)

Held WTT and spill percentages at fixed levels

Calculated mean SAR

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Steelhead

Spring flow levels

Spill (%)	Low	Average	High
0	0.0	0.0	0.1
10	0.1	0.1	0.1
20	0.2	0.2	0.3
30	0.4	0.6	0.9
40	1.0	1.5	2.1
50	2.4	3.6	5.0
55	3.8	5.5	7.6
60	5.8	8.3	11.3

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Steelhead

Spring flow levels

Spill (%)	Low	Average	High
0	0.0	0.0	0.1
10	0.1	0.1	0.1
20	0.2	0.2	0.3
30	0.4	0.6	0.9
40	1.0	1.5	2.1
50	2.4	3.6	5.0
55	3.8	5.5	7.6
60	5.8	8.3	11.3

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Chinook salmon

Spring flow levels

Spill (%)	Low	Average	High
0	0.0	0.0	0.0
10	0.0	0.0	0.1
20	0.1	0.1	0.2
30	0.2	0.3	0.4
40	0.6	0.8	1.0
50	1.5	2.0	2.6
55	2.4	3.2	4.1
60	3.9	5.0	6.3

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Chinook salmon

Spring flow levels

Spill (%)	Low	Average	High
0	0.0	0.0	0.0
10	0.0	0.0	0.1
20	0.1	0.1	0.2
30	0.2	0.3	0.4
40	0.6	0.8	1.0
50	1.5	2.0	2.6
55	2.4	3.2	4.1
60	3.9	5.0	6.3

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Conclusions

Snake River simulations and data from other stocks both indicate that juvenile survival rates need to be > 85% to achieve 4% SAR goals.

Juvenile models indicate that spill levels of 55-60% may achieve 85% juvenile survival across a range of flow conditions.

SAR models indicate that spill levels of 55-60% may achieve the 4% SAR goal under a similar series of ocean conditions.

Analyses highlight need for active Adaptive Management experiments. Existing/enhanced PIT releases provide monitoring framework for testing predictions.

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Question & Answer Session

Question- Steve dissolved gas issues as we increase spill to those levels?

Answer- We have looked at that currently right now the corp. of engineers publishes percentages on their TMT website. Looking at those levels the corp. says it is feasible if they are within this 50-70% range without exceeding dissolved gas levels.

Question/statement - 2007 most recent year rather low flow year but high spill, spill was at 50%?

Answer – No, more like 40-45% in snake, in Columbia about the same average across those models. SAR's were 40% in 2007 model suggesting 40% like 2007 – we see increase in SAR's Models suggest linear response. Expediential response pretty dramatic increase, looking at PW passage is affected by spill percentages, 30% of fish turbine or bypass.

Question – What would C_0 group % of fish went through serve as comparisons?

Answer - C_0 group in river migrants didn't go through by pass system. % of run ends up being C_0 or undivided various with spill, years spill is reduced very few fish.

Question on holdovers move these groups, Seemed like a strong ability to predict to leave those in and adjust?

Answer - Yes

Question for Steve- Increasing in river survival rates to 85% when do you run into dissolved oxygen other ways to increase travel time other than spill?

Answer- Yes, changes in water travel time, water travel time is fixed level of reservoir elevations. Water transit times how much water coming in and pool level. Reservoir levels to improve speed of water. Models suggesting in river SAR's to go up when water transit time increased. Pool elevations to improve speed of water, water moves fast SAR's go up, can't do much about snow pack levels.

Question – Size of smolt and wild vs. hatchery programs. Bigger programs out there with 100 million hatchery fish going into the rivers, have you looked at that?

Answer – Haven't looked at that yet, each hatchery different age structure. Hatchery specific rearing practices age Rearing practices age-maturity we are seeing –annual variability.

Question - When you increase spill he could expect dissolved oxygen or gas to increase? Limit spill based on dissolved oxygen. They won't violate that rule, will that dampen your SAR results?

Answer - Last year we looked at uncontrolled spill levels, dissolved gas affect uncontrolled spill levels. Not seeing lots of problems with dissolved gas estimates relative to spill levels. Spill 50-60% range that the army corp. of engineer estimates to flow levels. Spill used for low flow conditions- not exceeding those dissolved gas levels. Their model-suggest they could spill more than what is happening.

Question - Multiple powerhouse routes show higher delayed mortality with multiple powerhouse spill routes passages. Anyone looked at fish that go through multiple bypass routes?

Answer - Unfortunately we can't detect, we don't have precise information. Bypass assessment to drill down we looked at probability of going through powerhouse. Does that increase delayed mortality, both ocean survival to overall SAR's can't say how many spillway just probability they went through. Multiple lines of evidence, using probability – eventually be able to narrow that down.

Question - Estimates Turbine survival vs. spill survival? 50-65% higher level of survival did you run model?

Question - Yes, run model expect to get 90% powerhouse efficiency?

Answer - Practically account for differences in immediate survival rates. Changing spill proportions would change survival, shift fish from spill/powerhouse accumulation changes in SAR's. Delayed mortality affects later on couple of dams down from that or in the ocean.

Question - Biop case as adaptive FCRPS – concrete passage, given what we have heard today are we seeing it becoming irrelevant spirit of adaptive management how we? Management decisions not accounting for the line of evidence and am I interrupting that correctly? How to get this science out and in a complete discussion? Allowing us to turn the dials, hinting at what might occur?

Answer - To test this Looking at performance standards, not sufficient and what does it take to get that in place. Not just dams but later on other things going on to affect this. Mortality going on in reservoir not just goes on dam/tail race. Full life cycle accumulative effects, concrete survival missing the boat other things going on and a accumulative effect, not sure policy level discussion. Another step to share information with region, haven't had these in the past, first step is to begin discussion. Adaptive management – new information should be incorporated. What are the different options moving forward? Different route for the future, return rates/survival rates, can't keep doing what we are doing, we have seen even with the best ocean conditions don't just set us over the hump. We need to make changes these models are hopeful and encouraging. First step in process and make big dent in survival rates for those stocks.

Statement – Richie Graves (NOAA) - I want to remind people there are adult and juvenile reach performance standards and adult performance standards. Cross check in river survival to escape using the frozen version of the compass model. Apply these values. Spill conditions that occurred compared to estimates, found survival estimates for Snake River spring Chinook to be lower and steelhead way higher. Reduce travel times steelhead over preforming.

Statement - Do you have other performance standards, standard or metric? Are they called different things having to do with it all – standard or metric?

Question- CSS would incorporate strains or that's more opportunistic.

Answer- Opportunistic- if you could do with pit tags, exciting you could study that. Important to incorporate that. The increase in pit tag detectors have helped. We have been working with others. There are limits of fish you tag cost/conservation. Be pretty difficult trying to make as many smolts, modify release levels. Lots of room to make changes.

Question/statement - Exciting to have CSS develop more data and have it become available with some bottom line conclusions. I do think it is important to point out uncertainties in the models and to keep uncertainties in mind.

Answer – Models are fairly accurate moving forward, uncomfortable in the variability in ocean conditions only looking in pact that account for variability which determined something happening in ocean vs. management decisions.

Question - Offer guidance on how many pit tags you need to put out there to get the results that you are getting and do what you do?

Answer – Looking at patterns talked about it but haven't actually done it yet. Aggregate MPG's to determine sample size and push question forward.

Question-2001-Information management we should have spilled more? So to raise that situation 30% in river to 70% transport, I don't feel comfortable and am unsure of that management decision.

Answer – At the time everyone's belief adaptive management experiments 2004 & 2005. Low in snake region made decision to spill and information suggests there may be a different way. Can also influence in river fish can't speak to comfort level.

Question - Curious graph snake river vs. JD SAR's vs. relative proportion of hatchery rates and how did you handle that?

Answer - In river fish vs. SAR's data is a combination of hatchery vs. wild, hatchery lower didn't really see that with Chinook. In the case of steelhead small difference lower SAR's with wild fish Chinook similar patterns in survival rates, steelhead small difference.

Question - How did you deal with correlations between Julianne day affect fish water vs. various ocean conditions?

Answer - Effect of arrival date trying to account for fish arrive earlier or later – when you look at the seasonal pattern we didn't see a seasonal pattern for Chinook we did see one for steelhead.

Question - Does arrival time effect SAR's?

Answer - We looked at Bonneville John Day SAR's exceeded the early snake river fish. You can look back at analysis in 10 year report. We may continue to analyze.

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MEMORANDUM

TO: Brad Trumbo, COE

Michele DeHart

FROM: Michele DeHart

DATE: May 22, 2012

RE: CSS Annual Review response to comments

Following is the response to the questions you submitted to Steve Haeseker, USFWS, regarding the presentations at the April 12, 2012 Comparative Survival Study Annual Review meeting. The CSS Oversight Committee has reviewed your questions and provided the following responses. The Comparative Survival Study is a life cycle monitoring program which evaluates routes of passage. The CSS holds an Annual review meeting each April to present analyses and findings. The question and answer session at the end of the meeting is recorded and is transcribed and included in the CSS Annual Report along with the presentations. In this years' Annual Review we discussed new groups that had been added to the CSS analyses, and presented the findings and discussions of a workshop held in July of 2011. The report of the July workshop is posted on the Fish Passage Center website and is included as an appendix in the 2011 CSS Annual Report (Tuomikoski et al. 2011). Reviewing this document would provide valuable background information and addresses some of your questions. The CSS has been implemented for over a decade and has generated long time series' of data from many stocks within the Columbia River Basin. Each CSS report is posted on the FPC website, along with regional and Independent Scientific Advisory Board comments, recommendations and responses. The analyses, data and methods discussed at the CSS Annual review synthesize the information that has been collected to date over the years of the study. Reviewing these reports will provide additional understanding of methods and analyses and address your questions. Your questions regarding weighting of passage route data, can be answered by a review of the extensive methods sections in the CSS Annual Reports. The brief point responses to your questions are:

- There is no weighting by passage route in these analyses

- Multiple spill passages are assessed in CSS analyses

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- Your statements regarding lack of attention on tailrace egress issues is not accurate
- Increasing spill levels will allow more fish to avoid powerhouse passage, avoid delayed mortality, experience less forebay delay, experience faster travel time, and experience higher reach survival
- Delayed mortality associated with smolt transportation is recognized by the region
- A significant body of scientific information, and work by various researchers indicate that delayed mortality is associated with powerhouse passage

Question 1 (actually asked of Howard by Chelan PUD):

Q: Howard demonstrated multiple powerhouse passages during the outmigration led to greater delayed mortality but how did multiple powerhouse passages compare to multiple spill passages? A comparison has not been made between multiple powerhouse and multiple spillway passages relative to delayed mortality. Howard reiterated how heavily powerhouse passage affected delayed mortality and also claimed that route specific passage data was not available for the spillway to make the comparison.

I am certain there are spillway passage and survival data available and this would have been just as simple to model as the powerhouse passage. Please clarify what was meant by route specific spillway passage and survival not being available.

Response:

Howard presented three sets of models, which provide multiple lines of evidence with respect to the association of delayed mortality with powerhouse passage. The first set of models were multiple regressions relating long time series of spawner-recruit residuals, annual SARs and first-year ocean survival rates to ocean conditions and conditions in the FCRPS during seaward migration (Petrosky and Schaller 2010; Schaller et al. in prep.). These results indicate that both river and ocean conditions are important to marine survival rates and reduced survival in the marine life stage was associated with increases in water travel time, number of powerhouse passages and proportion of smolts transported. Because the 'number of powerhouse passages' variable is the inverse of proportion spill (see Petrosky and Schaller 2010 methods), these results indicate that delayed mortality would decrease with increased spill proportions.

The second set of models were multiple regressions relating CSS PIT- tag juvenile survival rates, SARs and marine survival rates to ocean conditions and conditions in the FCRPS during seaward migration (Haeseker et al. 2012). These results also indicate, with finer-scale data, that both river and ocean conditions are important and that reduced survival in the marine life stage was associated with decreases in spill proportion. The first and second sets of data modeled observed responses of cohorts of fish (annual or biweekly) to passage and ocean conditions experienced by that cohort,.

The third set of models described in Howards' presentation were based on SARS of PIT tag detections or non-detections at the various FCRPS dams (Tuomikoski et al. 2010). Detected smolts were known to have been collected/bypassed at specific project(s); non-detections would have passed via either spill or turbine routes. We do not have precise knowledge of spill vs. turbine routes for individual non-detected fish at specific projects; however, when spill proportion is high, most non-detects pass via spill. The key point of Howard's presentation was that multiple lines of evidence reach the same conclusion regarding delayed mortality associated with powerhouse passage and that marine survival is related to freshwater passage conditions.

In addition, the CSS annual report for 2010 (Tuomikoski et al. 2010), provides some insight into multiple spillway passage and multiple powerhouse passage. The 2010 report included analyses of SAR relative to downstream migration history. In these analyses the study group consisted of juvenile Chinook and steelhead that were alive and detected at Bonneville Dam. Their subsequent survival to Bonneville as an adult was analyzed relative to their specific downstream passage history. The smolt-to-adult return rates of juvenile fish that were detected at individual projects, multiple projects and never-detected as juveniles were compared relative to their juvenile passage history. In this analysis, juveniles that were never-detected primarily represent fish that experienced multiple spillway passages. These never-detected juveniles also include fish that may have passed through turbine units. We know from decades of spillway versus turbine survival studies that mortality from spillway passage averages about 1%, compared to an average mortality of 15% through turbine units. These analyses of migration history in the 2010 CSS report may underestimate that actual impact of powerhouse passages because: 1) fish had to arrive at Bonneville alive to be included in the study group, and 2) a small proportion of the fish that are not detected at each project pass through the turbine route. Despite these issues, the analysis found that each bypass system experience reduced subsequent survival in the ocean, and that multiple bypass system experienced further reduced ocean survival, indicating that delayed mortality is occurring with bypass system experience. The NPCC Independent Scientific Advisory Board reviewed the 2010 CSS report and concluded that delayed mortality is associated with powerhouse passage. In addition the FPC summarized several analyses by different researchers that indicate that delayed mortality is occurring as a result of powerhouse passage (FPC memo date)

The 2010 CSS Annual Report also compared SARs for single or multiple bypasses at Lower Granite, Little Goose, and Lower Monumental dams vs. a group not detected at the same three dams. Again, the non-detected group primarily represented multiple spillway passed smolts but may underestimate the actual SAR for this group (see caveat above because the undetected group includes turbine passed fish). Here, the SAR compared for each treatment was measured from Lower Granite as a smolt to Lower Granite as an adult. Those analyses found that SARs for non-detected yearling Chinook SARs averaged 52% higher, and non-detected steelhead SARs averaged 91% higher, than smolts that were bypassed at one or more of the three collector dams.

Question 2:

Steve, you were asked a similar question about shifting powerhouse passage proportion to the spillway to manipulate the analysis and results essentially getting the result you want to see either way. The simple answer that you gave reiterated that SAR predictions rely on delayed mortality that is affected much more by powerhouse passage.

What I want to know here is how the different passage routes are weighted in the models you folks have created. If powerhouse passage is weighted greater than spill passage this would essentially point to a breakdown of a proportionally larger number of powerhouse passages relative to spillway passages for the overall run which may be misleading given the passage and survival data from the many studies the Corps has supervised in the past.

Response: The models are not “weighted” according to passage route; the passage histories of bypass (detected) vs. not bypassed (non-detected) are analyzed using logistic regression. See Methods section in Chapter 7 of the CSS 2010 annual report (Tuomikoski 2010).

Question 3:

Steve, the following are statements you made during the Q&A session:

"BioP performance standards are not sufficient because mortality and survival complications occur system wide, not only at the dams and concrete survival does not address this."

I agree with you, but you followed that up with this:

"If we want to keep status quo on survival and SAR we should just continue what we are doing, but if we really want to improve these fisheries we need to broaden our horizons and evaluate alternative operations such as more spill."

What I would like to know about the above statement is this; how is more spill an alternative operation or something that has not already been addressed? More spill has been the agenda for years while powerhouse passage has been shunned and egress continues to suffer because we are only focusing on one passage route.

Response: For decades since the late 60s powerhouse passage and smolt transportation has been the singular focus of fish passage mitigation for hydro system development in the Columbia Basin. Over three decades, significant funding and research investments have been focused on powerhouse bypass and collection systems development, barge and truck transportation, screen bypass systems, turbine modification, bypass outfalls and turbine intake structures. The expenditures on all types of engineering solutions and contraptions are stunning. Spill for fish passage only began to be considered when these approaches failed. The decades of singular focus on powerhouse bypass systems and smolt transportation ended with the ESA listings of Snake River salmon and steelhead populations. Only after these populations were listed as threatened and endangered was spill considered as an alternative through federal court decisions. Most recently, spring and summer spill for fish passage was ordered by the federal court beginning in 2005. The results of implementing spill for fish passage are clear in the data since 2005.

More spill is an alternative operation because data indicates that it may allow increase in SAR with the present hydrosystem configuration. More spill is an alternative operation because more spill will allow more juvenile migrants to avoid powerhouse passage and the delayed mortality that is associated with powerhouse passage. More spill is an alternative to the present set of operations because the current set of operations does not attempt to maximize spill levels at each of the projects. Spill levels can be increased within the present dissolved gas standards. Studies at some projects such as John Day show that project survival is higher with higher spill levels. A large body of scientific work shows that higher spill levels decrease fish travel time, increase reach survival, decrease forebay delay, speed up juvenile egress times and increase SAR.

(There was no question 4 in the list we received.)

Question 5:

There was a lot of discussion about ocean conditions relating to survival at the workshop, but how confident are we with what is known about ocean conditions and fish survival? Where did the data come from?

Response: We are confident from the literature and our own studies that ocean conditions, particularly during the year of ocean entry, affect marine survival rates of anadromous salmonids. We are also confident that the migration experience through the FCRPS also affects marine survival rates of Snake River salmon and steelhead. Using information-theoretic approaches, we have identified ocean and seaward migration variables which best explained the survival rate variation for several data sets including: long time-series of spawner-recruit residuals (Schaller et al. in prep.), SARs and first year ocean survival rates (Petrosky and Schaller 2010), and PIT-tag based SARs and marine survival rates (Haeseker et al. 2012). In general, the river and ocean variables that most consistently describe marine survival rate variation include: % spill, number of powerhouse passages, water travel time, Pacific Decadal Oscillation and upwelling index. These papers provide detailed descriptions of the environmental and survival rate data sources.

Question 6:

It was clearly stated at the workshop that survival will suffer during the ocean stage of life history for powerhouse passed fish, but how much confidence is put into that data? This ties back to me question of how are the passage routes weighted in the models? Is this assumption based on models or actual PIT tag data that shows higher returns of adults who experienced fewer powerhouse passages during the outmigration? I don't believe the data is strong enough to provide an assumption like that when it is not unheard of for SARs to be below 1%. While 1% may be 10,000 fish, this percentage is still too small to make that assumption based on 1 million outmigrants that never returned. I know for steelhead, transport brings a lot of B-run fish back to Idaho each year and you include transport as a powerhouse passage route.

Response: Again there is no weighting of powerhouse passage routes. All of the analyses are based upon actual PIT tag data. We have confidence in the empirical model result that bypassed fish return at lower rates than fish that passed projects undetected (primarily spill, when provided). As stated in response #2, the models are not “weighted” according to passage route; the passage histories of bypass vs. not bypassed are analyzed using logistic regression. The CSS results (slide 37 of Tuomikoski presentation) have also indicated for steelhead and spring/summer Chinook that transportation will not be beneficial when juvenile survival exceeds about 55%. The CSS prospective models suggest that it would be possible to achieve juvenile survival well exceeding 55%, through increased spill passage. Clearly transportation is beneficial only when steelhead in-river survival is below 55%, and this is based on empirical PIT tag data. We cannot address “your belief” that the data is strong enough. These analyses are based upon PIT tag data collected since 1998 and multiple lines of evidence that consistently point to the same results. Many years of data and analyses show that delayed mortality is associated with smolt transportation. In addition a growing body of evidence clearly shows that smolt transportation impairs adult upstream success and increases straying into non-natal tributaries, especially for steelhead. We should also point out that until spill was implemented as a passage measure, upwards of 90% of Snake River steelhead were transported in some years. However, these high transportation rates did not preclude the listing of A run and B run steelhead under ESA.

Literature cited:

Haeseker, S.L., McCann, J.A., Tuomikoski, J., Chockley, B. 2012. Assessing freshwater and marine environmental influences on life-stage-specific survival rates of Snake River spring-summer Chinook salmon and Steelhead. Transactions of the American Fisheries Society 141:121-138

Petrosky, C. and Schaller, H. 2010. Influence of river conditions during seaward migration and ocean conditions on survival rates of Snake River Chinook salmon and steelhead. Ecology of Freshwater Fish 19(4):520-536

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Appendix G

Response to Comments

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MEMORANDUM

TO: Rich Alldredge, Chair, ISAB
ISAB Administrative Oversight Panel
Bruce Measure, Chair, NPCC
Paul Lumley, Executive Director, CRITFC
John Stein, Science Director, NOAA Fisheries Science Center

Michele DeHart

FROM: Michele DeHart, FPC

DATE: November 30, 2012

RE: Response to ISAB comments on the Draft 2012 Comparative Survival Study Annual Report

Attached, please find the Comparative Survival Study (CSS) Oversight Committee responses to ISAB comments on the draft 2012 Comparative Survival Study Annual Report. As in past years the ISAB comments are insightful and have improved the report overall. The response to each of the ISAB's comments is presented in *Italic font* following the original comment.

Independent Scientific Advisory Board
for the Northwest Power and Conservation Council,
Columbia River Basin Indian Tribes,
and National Marine Fisheries Service
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Review of the Comparative Survival Study's Draft 2012 Annual Report

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ISAB 2012-7
October 15, 2012

ISAB Review of the Draft 2012 CSS Annual Report

Contents

ISAB Review of the Draft 2012 CSS Annual Report

Background

The Northwest Power and Conservation Council's 2009 amendments to the Columbia River Basin Fish and Wildlife Program call for a regular system of independent and timely science reviews of the Fish Passage Center's (FPC) analytical products. This regular system of reviews includes evaluations of the Comparative Survival Study's draft annual reports. These ISAB reviews began two years ago with the evaluation of the CSS's draft 2010 Annual Report (ISAB 2010-5), followed by a review of the draft 2011 Annual Report (ISAB 2011-5). This ISAB review of the draft 2012 CSS Annual Report is the ISAB's third review of CSS annual reports in response to the Council's 2009 Program.

Overview

The draft 2012 CSS Annual Report is well organized and well written. The ISAB acknowledges the continued progress by the CSS in addressing key questions and reporting results. As the dataset includes more years and a wider range of environmental conditions, the ability to address how the river environment affects juvenile salmon migration rates and survival continues to improve. The long time series in survival rates by species, hatchery and wild stocks, and watersheds are valuable in this regard. The CSS authors should continue to produce yearly updates.

The ISAB members who attended the CSS Annual Meeting April 12, 2012 would like to acknowledge the very useful exchange of information that took place.

This ISAB review begins by suggesting topics for consideration by the region as a whole. These overarching issues, presented in bulleted format, are related to material presented in the draft 2012 CSS Annual Report, but the topics are not specifically limited to consideration by the CSS team. Next the ISAB provides general comments to be considered in revising the draft 2012 CSS report or, if time does not allow, for possible inclusion in subsequent CSS Annual Reports. These comments for the CSS team are presented in a numbered list for ease of discussion, but the list is not in any priority order. Finally, the ISAB review provides specific editorial comments and suggestions to aid in preparation of the final 2012 report.

Topics for Consideration by the Region

- An evaluation is needed for whether the NPCC's 2-6% SAR goals and objectives are sufficient to meet salmonid species conservation, restoration, and harvest goals. Chapter 4 describes SAR Program goals as being for spring/summer Chinook and thus not tailored for other species, races, and age of smolts. These SAR goals should be broken out by species, race, and age at smoltification rather than one goal across all species. Coho, fall Chinook, and steelhead have different juvenile life histories, and it is likely inappropriate to generalize SAR objectives for viability across these species. The analyses in Chapter 5 lead to the important conclusions that overall SARs for Snake River subyearling fall Chinook are "well short of the NPCC goal of 4% SAR needed for recovery" and that there is little or no benefit to transport. But given that fall Chinook migrate as subyearling smolts (whereas spring/summer Chinook migrate as larger, yearling smolts), the NPCC's 2-6% SAR objectives may be higher than needed to meet conservation, restoration, and harvest goals for fall Chinook. As with other species, the NPCC (2009) SAR objectives should be updated to specify the critical points in the life cycle where smolt and adult numbers should be estimated and to identify ESU-specific SARs necessary for survival and recovery.

  Response: *We agree that the NPCC goals are not appropriate for fall Chinook. We removed reference to these goals in Chapter 5 with regards to comparing those goals to Snake River fall Chinook SARs.*

- Development of technology to improve PIT-tag recovery in the estuary is needed. PIT-tags detected on bird colonies in the estuary are used to augment NOAA Trawl detections below Bonneville. The problems with trawl detections indicate this is a difficult area for PIT-tag recovery contributing to uncertainties concerning smolt migration and survival.

  Response: *Research and development funding is limited and funding priorities are considered region wide by the funding and management agencies in the context of all fish and wildlife mitigation, research and development needs. A broad range of considerations comprise the final funding decisions, including realistic management mitigation options and the potential application of results. The CSS study activities are not the only important activities in the region. The CSS Oversight Committee strives to adapt to management decisions regarding funding priorities and coordinates with other research and development activities to maximize benefit and wide application of results. Development of estuary PIT tag recovery should be considered within the context of region wide priorities for research and development funding.*

- In response to last year's ISAB advice to discuss and compare CSS results with other studies using different methods (e.g., McComas et al. 2008, also more recently Harnish et al. 2012) the CSS stated (CSS 2011, Appendix F): "*Response: The CSS-OC concludes that it is not currently possible to estimate smolt survival for PIT-tagged fish below BON through the Columbia River estuary. The CSS-OC is aware of the McComas et al. (2008) study; however, the results are not robust enough for application of acoustic tag survival estimates through the estuary to CSS PIT-tag groups, or to the retrospective estimates of S.oa and S.o1.*" The CSS-OC has made an important conclusion. If PIT-tags cannot be used and acoustic tag results are not "robust enough" to estimate estuarine survival, a thorough review of this issue is needed, especially given the increasing scientific evidence of survival bottlenecks in the Columbia River estuary and extensive efforts to restore estuarine habitats to improve salmonid survival. A review is needed of estimation methods for smolt survival below Bonneville Dam through the Columbia River estuary using PIT-tags, acoustic tags, and other methods. If necessary, existing methods should be improved or new methods developed to estimate estuarine survival of salmonid smolts (see ISAB 2012-6; Levings et al. 1989; Macdonald et al. 1988).

  Response: *We understand that the ISAB is suggesting that a review of smolt survival estimation through the Columbia River estuary should be conducted. The CSS analyses conducted thus far could be useful to this scientific review. Specifically, recent CSS analyses indicate that fresh water passage history, including number of powerhouse passages, effect subsequent survival and adult return. Future reviews of smolt survival through the Columbia River estuary should consider previous fresh water passage history, power house passages, and the subsequent effect of smolt survival through the estuary.*

- Measurement error in SAR estimates associated with PIT-tags needs comprehensive examination and description in a report dedicated to this issue.

  Response: *The CSS study has been designed within the findings of PIT tag effect studies conducted by NOAA Fisheries during the development of the PIT tag technology. The fishery management agencies and tribes and the CSS Oversight Committee are addressing the question of PIT tag SARs relative to run reconstruction SARs. These efforts have been described in previous CSS reports. Both run-reconstructions SARs and PIT tag SARs have potential biases. As described in previous responses to comments, the USFWS is conducting a study of potential PIT tag effects on returning spring Chinook adults. This is a four year study with the first group of marks out migrating in 2011. In 2012 the first jack returns from this study occurred. Full adult returns from the first cohort in this study will be completed in 2014. The full study results of all four years of juvenile marking will be completed in 2018.*

When adult returns are complete from this study the results will be presented to the region by the USFWS and the CSS Oversight Committee.

General Comments for CSS Consideration

1. A topic of much interest that is related to the 2012 CSS Annual Report is the relationship between proportion of spill and juvenile survival. The topic may be framed by considering a conclusion from the FPC's History of Spill Report,[1] *"Increasing proportion of spill provided for fish passage at hydroelectric projects has resulted in higher juvenile spring/summer Chinook, fall Chinook, sockeye and steelhead survival and faster juvenile fish travel time through the FCRPS."* The ISAB considers this conclusion to be a strong hypothesis worthy of further investigation in the context of reviewing the draft 2012 CSS Annual Report. In Chapter 3 the authors provide some evidence that spill has an impact on fish travel time and instantaneous mortality while Figure 3.5 shows that spill had relatively little effect on instantaneous survival (Z) of sockeye and steelhead below McNary Dam. Furthermore, a variety of other factors also had similar importance as spill for species where spill was found to be a key variable. A correlation matrix and scatter plots showing relationships among independent variables would be informative. Additional effort is needed in using models to quantify the effect of spill and water travel time (WTT) on each species, while holding other variables in the model constant. An analysis of competing hypotheses is needed with particular attention to the possibility of model selection bias. Clarification is needed concerning how the results translate to management guidelines. This type of analysis would inform managers as to how much benefit can be expected by altering spill levels and reservoir elevations.

   Response: *Extensive modeling analyses of the relationships among fish travel time, juvenile survival, adult return rates and environmental variables such as spill and water travel time (i.e. flow) have been on-going and are continuing. These modeling analyses were presented in several regional forums including the 2012 CSS Annual Review meeting. In addition these initial analyses were presented in Haeseker et al. (2012). The CSS Oversight Committee pursues publication of these larger CSS analyses to benefit from expanded peer review. In addition, these model analyses were the subject of the 2011 CSS Workshop including regional and other scientists conducting similar analyses. The workshop results are available*

[1] Historical Spill Summary 1981 to 2011. FPC 46-12; April 18, 2012. http://www.fpc.org/documents/memos/46-12.pdf

and have also been added as an appendix to the 2011 Annual Report. These analyses continue and are being reviewed and refined. In addition Appendix F of the 2012 CSS Annual Report includes the presentations from the 2012 CSS Annual Review meeting.

We found that percent spill was important for explaining variation in fish travel time for the majority of the species and reaches that were analyzed, with increases in spill associated with faster fish travel times. In terms of instantaneous mortality rates, we found that spill was relatively important for about half of the species and reaches that were analyzed, with increases in spill associated with reductions in mortality rates. Our approach to analyzing survival rates was to focus on improving understanding of how environmental factors influence the mortality and travel time processes, which in combination determine survival rates. The data indicate that there are several factors which influence mortality rates and several factors that influence fish travel times; some of those factors influence both processes and some of those factors only influence one of those processes. Because there are several factors influencing these rates at the same time, we feel that correlation matrices and scatter plots would not be very helpful. Instead, we have employed multiple regression methods within an information theoretic framework to help identify the factors that are most important for influencing the mortality and travel time processes. In the revision, we have provided tables that quantify the expected changes in survival that could occur with changes in water transit time and spill, holding other variables in the models constant (Tables 3.4 – 3.7). Our decision to use multi-model inference techniques instead of selecting one model eliminates most, if not all problems with model selection bias. Tables 3.4 – 3.7 clearly show how our results translate to management guidelines along with how much benefit can be expected by altering spill levels and reservoir elevations.

2. Attention needs to be given concerning the interplay and effects of spill and surface bypass structures. The report should more completely describe surface bypass structures and consider their influence on smolt survival.

   Response: *Attention is given to the interaction of spill, surface bypass and other passage operations in CSS analyses. The CSS report includes the consideration of the presence of surface passage structures in CSS analyses of juvenile survival and travel time in Chapter 3 and in model analyses of freshwater passage conditions and their effect on juvenile survival and travel time. In Chapter 3, page 42, we state, "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". We do not agree that the CSS report should include a detailed description of surface bypass and their influence on smolt survival. Surface bypass structures are developed, installed, tested and evaluated under the US Army Corps of Engineers Anadromous Fish Passage Evaluation Program (AFEP). Detailed descriptions of these* *structures; their testing and evaluation are conducted under a separate program and is beyond the scope of the CSS. The CSS reports the effect of these structures on the passage parameters which are monitored by the study.*

3. A tremendous amount of SAR data have been collected including survival estimates after smolts leave Bonneville Dam. It would be useful to associate these data with estuarine and oceanographic conditions to further evaluate factors affecting salmon survival and abundance. The ISAB recommends additional collaboration between CSS researchers and ocean researchers on this issue. (See Pyper et al. 2005; Mueter et al. 2005.)

   Response: *Haeseker et al.(2012) is an analysis of CSS data and includes ocean variables, fresh water passage variables in analyses of adult return rates. These analyses were presented at the 2012 CSS Annual Review meeting and are included in the Appendix F of the 2012 Annual Report. Several ISAB members attended the 2012 CSS Annual Review meeting and participated in discussions of this analysis including ocean variables. The CSS Oversight Committee pursues publication of these larger analyses of CSS data to benefit from the formal peer review process.*

4. The relationship between annual variation in stock composition and survival is difficult to see from the material presented in the report. Explicit evaluation of the effect of annual variation in stock composition of PIT-tagged aggregate samples of wild and hatchery fish on annual variation in survival estimates could provide useful insights.

   Response: *The CSS Oversight Committee is evaluating the potential of reporting Snake River wild Chinook and Steelhead SARs by smaller geographic groups (e.g. MPG) where there is adequate tag data. Wild fish SARs are reported as aggregate groups because tag numbers are generally too low to calculate survival and SAR for individual wild stocks. It is important to remember that the CSS strives to utilize existing mark groups and mark groups used for other studies to maximize efficiency and minimize cost to the degree possible. In the case of wild stocks, the low existing population numbers necessitate aggregation of groups, particularly when evaluating relative survival by route of passage.*

5. As noted in the ISAB review last year (ISAB 2011-5), there is a need to investigate PIT-tag related mortality and shedding of PIT-tags. The CSS agrees this is an issue that needs to be examined.

   Response: *The CSS implementation is conducted within the findings of results of PIT tag development and testing that were conducted by NOAA Fisheries during the development of PIT tag technology. In addition the USFWS is conducting a specific study of PIT tag effects on* *returning adults which is discussed in response to previous general comments. The USFWS continues to keep the CSS Oversight Committee apprised of the study of PIT tag effects through their representation on the CSS Oversight Committee.*

6. An overarching comment is that connections of the migration and survival with larger ecological concerns should be emphasized more. It would be beneficial to increase collaboration with researchers working on other species, food webs, habitat, physiology, contaminants, and disease. Such combined studies might give added insights into mechanisms causing the observed temporal patterns in migration and survival. With respect to ocean ecosystem issues, the CSS staff are commended for publication of two recent peer-review journal papers (Petrosky and Schaller 2010; Haeseker et al. 2012) that relate climate, river, and ocean conditions to annual trends in smolt-to-adult survival estimates. Nevertheless, the ISAB continues to emphasize the need to improve scientific collaboration between CSS staff and estuary-ocean experts working on BPA-funded programs to address migration and survival of Columbia River salmon and steelhead in the estuary and ocean.

   Response: *Past CSS workshops (Marmorek et al. 2004; 2011) and various scientific meetings (American Fisheries Society, Salmon Ocean Ecology- Newport, OR March 2012) have provided opportunity to collaborate with other scientists and estuary-ocean ecologists. The CSS Oversight Committee has found these collaboration opportunities productive, and plans to continue these activities as time and budgets allow.*

7. Age terminology should be clearly defined and the convention used should be consistent across species. The age convention used for fall Chinook (in Chapter 5) appears to differ from that typically used for other Pacific salmon. For example, sub-yearling (age 0+) smolts migrating downstream in 2006 are said (page 106) to have returned as 5-year olds in 2011, but under the usual conventions for determining age in salmon, if they hatched from eggs deposited late in 2005, then would reach age 5 at spawning time late in 2010.

   Response: *For Chapter 5 we have adopted the convention used historically in CSS reports of referring to adult return age as ocean age such as "1-salt" or "years in ocean-salt", so that for subyearling fall Chinook jack returns would be "1-salt"; 2-salts would be adults returning after 2 years in the ocean etc…up to 5-salt returns.*

8. The limitations of the dataset used to estimate TIRs and the preponderance of higher point estimates for survival of transported fish suggest that conclusions concerning benefits of transportation are premature. Caution in interpreting such results is encouraged.

   Response: *This comment appears to refer to fall Chinook TIRs, as we have an established time series of wild and hatchery spring/summer Chinook and steelhead TIRs across a range* *of FCRPS and ocean conditions. We have tried to qualify our statements in Chapter 5 to reflect the uncertainty inherent in the data. We still find little or no benefit to transportation based on the results that we have analyzed. See detailed response to comments under comments specific to Chapter 5 below.*

9. The potential for ocean harvest to be a source of bias in SAR estimates should be quantified.

   Response: *Ocean harvest should not be a source of bias in SAR estimates for stream-type Chinook, steelhead or sockeye populations, based on negligible exploitation rates (and near-absence of CWT recoveries) in ocean fisheries (e.g., PFMC 2012). Snake River fall Chinook SARs are affected in ocean fisheries; however, exploitation rate estimates for these managed stocks are reported in PFMC and Pacific Salmon Commission technical documents. These exploitation rate estimates are widely available, and the CSS Oversight Committee considers effects of ocean harvest to be primarily an accounting issue, rather than a source of bias in SARs.*

Chapter Specific Comments

Throughout the document, many useful tables and figures are provided that enhance understanding of complex results. The detailed Table of Contents is useful for guiding the reviewers and readers through the manuscript. Inclusion of a Glossary of Terms, which includes acronyms, is appreciated.

Chapter 1. Introduction

As in 2011, the Introduction provides an excellent description of the history and objectives of the CSS program and of the methodologies used. This section provides a useful orientation to coordination and collaboration with other PIT-tagging projects, a summary of historical in-river conditions and transportation, and the organization and content of the report.

The Introduction is informative, but some additional information is needed.

- The addition of a table with an historical timeline of key objectives and results from past years of CSS work would be useful.

  Response: *The CSS Oversight Committee will explore adding this type of table in future reports but are not able to construct a table of this type in time for the final report.*

- The inclusion of detailed description of some methods but not others is somewhat confusing. In the introduction, a section containing a brief review of primary methods would be sufficient. To avoid redundancy, detailed methods would be better placed in the methods sections of the appropriate chapters that use these methods.

Response: *We realize that there is some redundancy in the description of methods. Previous ISAB reviews (2011) have noted this redundancy but have recognized that in a detailed data intensive report such as the CSS Annual Report, redundancy can be helpful. We agree with the ISAB comments, there is some redundancy, but for this report it serves a helpful purpose. The CSS report serves a broad audience with varying levels of technical understanding*

- When describing the juvenile and adult PIT detector systems, it would be informative to indicate what proportion of total juveniles and adults are detected by the detectors at each dam.

Response: *Detection probabilities at each of the different detections systems (both for adults and juveniles) are highly variable and dependent on many factors (e.g., project, project operations, flows, location of detector, etc.). Describing detection probabilities at each of the projects would be complicated and likely confusing to the readers.*

- A brief (1-page) abstract at the beginning of the report that summarizes major conclusions in the 2012 report would be useful.

Response: *The CSS Oversight committee has included an Executive Summary to the beginning of the final 2012 CSS Report. This Executive Summary is typically not written until the final version of the report is issued.*

The CSS examined the holdover issue involving fall Chinook in Chapter 5, which makes sense because fall Chinook migrate as subyearlings and yearlings. However, there was no discussion of steelhead holdovers. After release most hatchery steelhead will migrate to the ocean as yearlings, but some might delay emigration to age 2 or residualize in the watershed. In contrast, it appears that most Chinook mini-jacks are excluded from PIT-tag analyses by only using juveniles that are detected at the first detection site.

Response: *A detailed discussion of how steelhead holdovers are avoided was provided on page 14 of the Draft 2012 CSS Report (Lines 24-32). Specifically, the draft report states: "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. 2005; 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."*

Fallback and straying of salmon and steelhead is an important issue that can confound SAR estimates, and it would be worthwhile for the CSS report to address the issue so the reader knows the issue has been properly considered. PIT-tagged fallback salmon may be detected again if they re-ascend the dam; are these fish correctly accounted for in the estimates? Some fallback salmon may not re-ascend the dam; how are these fish treated in the SAR calculations, especially given that transported fish reportedly stray more than in-river fish?

> **Response:** *The final 2012 CSS Report includes an appendix (Appendix H) that has analyses of adult success between dams, D, and indices of straying for transported and in-river groups of Snake River spring/summer Chinook and steelhead. These analyses have been presented in previous CSS reports (e.g., Chapter 5 in 2011 CSS Report).*

Chapter 2. Using PIT-tag detections probabilities to estimate route-of-passage proportions at hydropower dams

The authors propose a method to estimate route selection from PIT tags without having to monitor each of the routes past the dam. The successful use of the method depends on monitoring a group of fish that passes a dam when no water is being spilled, as was the case in 2001. If there is no such data, then this method will not work. It is also making the strong assumption that the rate in 2001 is applicable to all years, but no assessment of the implication of this assumption was made. For example, no water was spilled because it was a low water year which in turn may have affected the choice of passage route. It also may be optimistic to think that that data from 2001 may still be applicable in higher water years.

> **Response:** *Data are available for zero spill conditions during 2001, 2004, and 2005 at Lower Granite, Little Goose and Lower Monumental dams and during 2001 at McNary and John Day dams. We explicitly stated that we "assume that FGE remains relatively constant across flow and spill conditions." In support of this assumption, we cited Moursund et al. (2006), who found that FGE did not vary across spill conditions which ranged between 0% and 80%. In the discussion section, we mention that when data are unavailable for estimating FGE using detection probabilities under zero spill conditions, an alternative approach would be to use telemetry or hydroacoustic estimates of FGE.*

The precision estimates are likely too optimistic because of the assumption that the different groups of fish all had the same fish guidance efficiency (FGE). The authors used the "average" rate over the different cohort. However, Figure 2.1 indicating the range of passage probabilities for hatchery and wild steelhead in 2001 appears too wide to be due to sampling variation. This excess variation should be accounted for in the estimation procedure. It would be useful to present a table specifying which species, year, group, and individual estimates were used to estimate the average overall FGE.

> **Response:** *The variability in detection probabilities may or may not be due to sampling variation. Our analysis has treated this variability as representing sampling variation. An examination of the flow and percent spill across the cohorts showed little variation in the operations at the dam. However, we did identify an effect of release cohort on detection probability, with lower detection probabilities for later releases. The later release cohorts also had lower survival, which reduced the number of tagged steelhead at McNary Dam and reduced the precision of the detection probability estimate. These effects, in combination with sampling variability, may explain the range of detection probabilities estimated for steelhead in 2001. We have provided tables summarizing the groups used to estimate the average FGE, along with the spill and flow conditions in tables 2.1 and 2.2.*

Chapter 3. Effects of the in-river environment on juvenile travel time, instantaneous mortality rates and survival

This is a well written and informative chapter. The synthesis at the end of the chapter in which some management actions are recommended based on the findings is particularly appreciated.

The effects of environmental variables on fish travel times (FTT), instantaneous mortality rates (Z) and survival rates (S) were modeled by using multi-model inference techniques to reduce model selection uncertainty. Models were ranked according to calculated Akaike information criterion (AIC) values, weights were calculated for each model, and model-averaged predictions were made. This methodology should minimize model-selection error, although it would be desirable to make more detailed information on the individual models accessible in an appendix or on the web.

> **Response:** *We have provided additional details on individual models in Appendices 3.1 and 3.2.*

The charts show that instantaneous mortality of most species increased rapidly with “day” of migration each year. A discussion about factors contributing to the increasing instantaneous mortality rate of each species as time progresses each season would be worthwhile. What is causing this increase in mortality? Is it related to physiology of the fish, increased predation, disease, or reduced feeding and growth? Do earlier releases of hatchery fish lead to greater in-river survival? To what extent is increased FTT over time within a given year related to water travel times (WTT), fish behavior and size? Are salmon smoltification indices consistent with expected levels at upper, mid, and lower river locations? The CSS analysis provides a good time series of key metrics, but it would be worthwhile to further explore key questions about factors affecting salmon migration and survival.

> **Response:** *We have provided a discussion of some potential mechanisms that may be causing the increase in instantaneous mortality over the season. Determining the exact cause(s) of mortality will be difficult, if not impossible.*

The authors present relative variable importance histograms for FTT and Z, but not survival (S). This would be worthwhile even if S is related to FTT and Z. These charts indicate the overall weighted contribution of the variable to the suite of key models based on AIC.

> **Response:** *We report the relative variable importance bar charts for FTT and Z because those were the models that were developed using multi-model inference techniques. We applied the predictions of those models to generate predictions for survival. Survival itself was not modeled using the multi-model approach (though the FTT and Z components of survival were), so we were not able to calculate relative variable importance values for survival.*

The relative variable importance charts are a good approach for summarizing the results and for highlighting the key variables in the models. Still, it would be worthwhile to show the top models in a table, either in Chapter 3 or an appendix. For example, how many models were within two or three AIC points, and therefore indicating little difference in the suitability of the top models? A potential drawback to the relative variable importance charts is that they did not appear to show whether the coefficient sign for a variable switched among the models; in complex multivariate models the coefficient can change, which is an indicator of collinearity. However, change in the sign of the variable could be incorporated into the metric, leading to a lower score when the sign is changed.

> **Response:** *We have provided additional details on individual models in Appendices 3.1 and 3.2. There were very few instances where the sign of the coefficient changed.*

The report states that reduced FTT of subyearling Chinook was related to the court ordered spill beginning in 2005. A discussion concerning why the court ordered spill seemed to have a greater effect on subyearling Chinook (e.g., Fig. 3.1, Table 3.2) compared with other species would be useful. Is this effect related to migration timing, or fish size, or something else?

Response: *We have provided graphs and a more thorough description of the changes in spill that resulted from the court-ordered spill program. Prior to 2005, there was no spill at Little Goose or Lower Monumental dams during the summer when subyearling Chinook salmon were migrating. The court-ordered spill program provided spill during the summer. This provision of spill had a dramatic effect on survival and fish travel time. There was not a dramatic difference for the other species because they migrate in the spring and have been provided with spill since the mid-1990s with a few exceptions (e.g., 2001, 2004 and 2005).*

The discussion addresses management actions that might lead to greater survival or faster travel time, for example, increase spill or reduce WTT. The discussion could have benefitted from using the quantitative models to predict the benefits of changing spill percentage and/or WTT while holding other variables constant. In that way managers could more fully appreciate the impact of altering these variables.

Response: *We have provided tables (Tables 3.4 – 3.7) and included a discussion on the expected effects of changes in WTT and percent spill for the purpose of informing managers on the impacts of altering these managed conditions.*

The discussion and some analyses in the results indicated that spill had a relatively large impact on subyearling Chinook salmon. However, the modeling effort (Fig. 3.5) revealed that the effect of spill on subyearling instantaneous mortality was similar to that of day, WTT, temperature, and surface spillways, indicating that a variety of factors affected subyearling Chinook salmon. See General Comments above for suggestions.

Response: *Several factors appeared to influence instantaneous mortality rates of subyearling Chinook salmon. However, spill was a very important factor that influenced fish travel times, with increases in spill resulting in much faster migration. The reduced migration delay appears to be the reason why survival rates for subyearling Chinook salmon have increased. See above response and the revised chapter for more details on the changes in spill that occurred with respect to subyearling Chinook salmon.*

The 2012 report states that improving detection probabilities at each dam would also be a good way to reduce uncertainty in the RIS-MCN and MCN-BON models. The ISAB concurs. It would be interesting to see how detection probability for both juveniles and adults varies by species.

Response: *We have begun assessing the detection probability data in Chapter 2 of this report.*

The discussion concludes that FTT and Z are reduced when WTT is lower and spill levels are higher and therefore that "*improvements to...survival are possible through management actions that reduce WTT and increase spill...*." These are strong hypotheses on the basis of data collected to date and modeling results summarized in Chapter 3, particularly for juvenile fish passage through the Snake River reaches of the hydropower system. See General Comments above for suggestions.

> **Response:** *We have provided tables (Tables 3.4 – 3.7) and included a discussion on the expected effects of changes in WTT and percent spill for the purpose of informing managers on the impacts of altering these managed conditions.*

The evidence is less supportive of the specific suggestion that "*there is opportunity to reduce fish travel time and increase survival through [the McNary pool to Bonneville reach] if these four projects were to operate at their minimum operating pools...adaptive management experiments, such as reducing WTT in the MCN-BON reach...could reveal...dramatic improvements for yearling and subyearling Chinook, steelhead, and sockeye*." Data sets are smaller and models incorporate more uncertainty for juvenile passage through the MCN-BON reach than for passage through the Snake River. Moreover, the models presented in Chapter 3 do not assign high relative importance values to the effects of WTT on Z of either steelhead or Chinook in the MCN-BON reach; temperature is the only highly ranked variable in the model for instantaneous mortality of steelhead in this reach. Water travel time is, however, a highly ranked variable (along with 4 to 5 other important variables) in FTT models for Columbia River passage. Currently available data are therefore at best weakly supportive of the notion that survival would be increased by drawdown of lower Columbia reservoirs. Adaptive management experiments are most easily justified for testing of strong hypotheses. Further consideration and justification is needed for the suggestion concerning adaptive management experiments to reduce WTT in the MCN-BON reach.

> **Response:** *We have provided tables (Tables 3.4 – 3.7) and included a discussion on the expected effects of changes in WTT and percent spill for the purpose of informing managers on the impacts of altering these managed conditions. Contrary to the assertion that the available data in the lower Columbia River are "at best weakly supportive," the results clearly support our original assertion.*

Modeling results indicate that the number of surface passage structures is correlated with decreased FTT and decreased Z for several of the study groups. Little is said about this observation in the Chapter 3 Discussion, but further elaboration would be welcome. A table summarizing the location and date of installation of surface passage structures would be useful in this chapter. Is the benefit derived from these structures likely to be fully realized from the existing installations and their operation, or is there scope for further improvement?

> **Response:** *Surface passage structures have been installed at most of the dams and we have quantified the number and timing of those installations in our modeling. However, they are typically installed in one or two spill bays out of the 10-20 spill bays at each dam. We do not know if additional installations would improve passage rates or not. Our results suggest that increases in spill percentages would improve migration rates and survival.*

Highly ranked variables in the FTT and Z models could have widely differing effects quantitatively. If and when does the CSS expect that it will be possible, assuming that the data set continues to grow for additional years, to quantitatively model the effects of alternative modes of hydropower system operation and of surface passage structures on FTT, Z, and survival? This could be a powerful tool to guide cost-effective expenditure of funds for passage improvements and adaptive management.

> **Response:** *The highest ranked models do not have widely differing effects in terms of expected changes in survival with changes in managed hydrosystem operations. We have provided tables (Tables 3.4 – 3.7) and included a discussion on the expected effects of changes in WTT and percent spill for the purpose of informing managers on the impacts of altering these managed conditions.*

How comparable are the arithmetic mean mortality rate, estimated by Equation 3.3, and the instantaneous mortality rate predicted by Equation 3.7? Are there any issues with comparing these two variables against each other as shown in Figure 3.2, 3.5, and Table 3.3?

> **Response:** *Equation 3.3 was used to estimate the instantaneous mortality rates, while equation 3.7 was used to quantify the effects of environmental factors on the instantaneous mortality rates using multiple regression. In equation 3.7, we use the individual estimates of Z as the dependent variable. If the environmental factors are able to capture a high degree of the variability in Z, then the estimates and the regression predictions will be similar. There are no issues in comparing the estimates with the predicted values for those estimates.*

It is customary to show the number of observations that are used in calculations. If not too confusing, showing the number of observations might make it easier to see why there is more variability in some reaches as compared to others.

Response: *We have added a column to Table 3.1 that lists the number of cohorts that were available for modeling survival rates.*

Some explanation is needed for the upper left figure in Figure 3.4 in which it appears that all of the variables have strong importance for characterizing FTT. The validity and reason for this result should be discussed.

Response: *The reason for this result is that all variables were in the top fitting model. Eliminating any one of the variables resulted in a substantial increase in the AIC score, indicating a much poorer fit when each variable was removed. See Appendix 3.1, where there is only one model listed because no other models were within 3 AIC points of this model.*

The development of the estimates uses a "statistics on statistics" approach whereby estimates from the mark-recapture model are further analyzed outside of the model. Incorporating individual travel times into the Cormack-Jolly-Seber (CJS) model is quite difficult because of the need to model the travel time between dams for fish not detected. For example, suppose that a fish is released at day 0 at dam 1, not detected at dam 2, and then detected at dam 3 on day 10. All that is known is that the fish must have passed dam 2 somewhere between day 0 and day 10. Presumably the travel time of other fish released at dam 1 and detected at dam 2 tells something about the travel time between dams 1 and 2, but this turns into a formidable estimation problem because of the need to integrate over the possible travel times when a fish is not detected at a dam. This approach would then allow direct estimation of the effect of travel time and other covariates on the survival probabilities. Muthukumarana et al. (2008) started work on this, but much more work is needed.

Response: *We have assumed that fish not detected at intermediate dams have a similar travel time as those fish that were detected at the intermediate dam. We use the arrival timing at each dam to estimate the environmental conditions that were experienced by fish passing each dam. We are familiar with the Muthukumarana et al. (2008) paper, but it appears that they are making a similar assumption that the unobserved fish behave in a similar fashion as the observed fish, so we are unclear whether their approach offers a solution to this issue or not.*

One of the dangers of the "statistics-on-statistics" approach is the ecological fallacy where relationships between averages (the average survival rate for a cohort of fish versus the average travel time for a cohort of fish) may not hold for individual fish. There could be confounding variables with the cohort, for example flow in the system, which spreads the averages out and gives rise to an apparent relationship, but this does not hold for individual fish within each cohort. A discussion of this potential problem should be presented in the chapter.

> **Response:** *All models represent simplifications of complex real-world phenomena. These simplifications are valuable because they improve understanding and help guide management decisions that have impacts on critically important species. It is a tautology that the survival rate for a population does not hold for any one individual- either it is alive or it is dead, it cannot be 73% alive. We agree that using a single, season-wide cohort could mask relationships that vary across the season. This is why we use the smallest cohorts possible to allow for estimating demographic responses and making associations with environmental conditions at short time scales. If there is a better approach to our modeling approach, we welcome suggestions for improvement.*

Chapter 4. Patterns in Annual Overall SARs

Chapter 4 explains that the SAR objectives of 2-6% are based on the original PATH analyses for Snake River spring/summer Chinook (Marmorek et al. 1998). These SAR objectives appear to have been applied to steelhead and fall Chinook without further modeling despite obvious differences in juvenile life history, especially the age and size at smolting. To achieve equivalent population viability, other factors being equal, SAR targets would need to be relatively higher for older, larger smolts (steelhead) and relatively lower for younger, smaller smolts (fall Chinook). A caveat to this effect is needed so that readers will not be misled about the relative status of fall Chinook and steelhead populations based on the magnitude of deviation from the SAR objectives.

The analyses in Chapter 4 lead to the important conclusion that overall SARs for Snake River wild spring/summer Chinook and wild steelhead fell well short of the NPCC SAR objectives of a 4% average and 2% minimum for recovery. On page 44 the authors state, "*The NPCC (2009) SAR objectives did not specify the points in the life cycle where Chinook smolt and adult numbers should be estimated … PATH analyses also did not identify specific SARs necessary for steelhead survival and recovery.*" This information should be specified and agreed upon in the region, perhaps in future Fish and Wildlife Program amendments. On page 45, lines 23-25 the authors also state, "*We have made preliminary comparisons of the overall SAR estimates 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*." This is an important programmatic issue, as above, NPCC and other SAR objectives for the CSS are apparently not clear. See Topics for Consideration by the Region above.

Response: *The CSS Oversight Committee recognizes that defining SAR objectives for persistence, and various recovery, rebuilding, and harvest objectives is an important programmatic issue. The time series of SARs, which the CSS is developing, from various populations throughout the Columbia River will be invaluable in addressing these long-term programmatic goals.*

The discussion concerning environmental correlates of annual patterns in survival in the 2012 CSS report relies heavily on methods and results reported in Petrosky and Shaller (2010) and Haeseker et al. (2011). The CSS report would be improved by including more detailed information on the methods and results of these two studies, as well as any updated analyses using new data.

Response: *We added more detail to methods for calculating S.oa and S.o1. New data and updated analyses concerning environmental correlates are being prepared for the 2013 CSS workshop on design of management experiments, which will be reported in the workshop report and 2013 annual report.*

Recent studies (e.g., Knudsen et al. 2009) and older studies indicate PIT-tagged salmon may shed tags or experience higher mortality. The run reconstruction (RR) analysis presented by CSS supports the concern that SARs based on PIT-tags may be biased low as evidenced by survival based on RR being consistently higher than that based on PIT-tags. The CSS also notes that RR may also have its own bias, for example RR estimates are not corrected for fallbacks. The issue of fallbacks is well-known, so it is not clear why RR estimates did not correct for fallback salmon. In the discussion, as recommended by the ISAB, the 2012 CSS report describes ongoing efforts to further evaluate potential tag effects of PIT-tags on salmon SAR estimates. CSS considers these studies to be a “high priority.” The ISAB agrees. The CSS report states that SARs based on PIT-tags and RR are highly correlated, perhaps providing some level of comfort in the results. However, closer examination of the data would reveal that percent differences in the annual SAR estimates based on the two approaches and variation in this difference from year to year can be quite high. Measurement error in SAR estimates associated with PIT-tags needs comprehensive examination and description in a report dedicated to this issue. PIT-tags are an extremely valuable tool, but investigators need to know the magnitude of introduced measurement error and what factors influence the error.

Response: *The ISAB highlights an important issue, which is somewhat beyond the scope of the CSS 2012 Annual Report. Window counts used in the RR represent the most consistent, long-term abundance data (at all projects) and are widely used in management (e.g., US v. Oregon). It is possible to correct RR window counts for some of* *the bias, however. PIT-tag detections provide a means to correct window counts for the extent of after-hours passage and fallback/re-ascension, but the numbers of fish that fall back and do not re-ascend cannot be determined. Adult age-structure sampling is now being used to correct window counts for true jack and adult proportions in the RR, rather than a simple reliance on length criteria.*

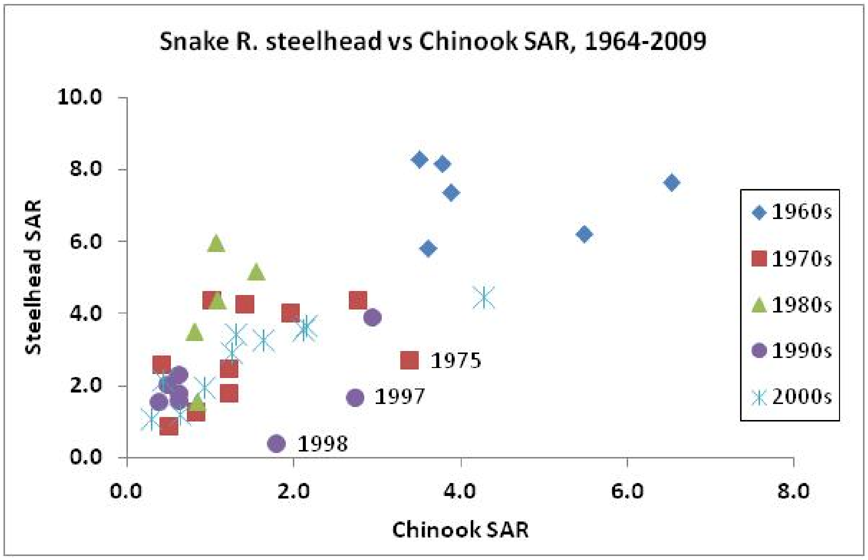
The SAR estimates appear to adequately exclude potential effects of mini-jack production in hatcheries. The text on page 49 states that the initiation point for counting PIT-tagged smolts is the first detection system (dam) below the release location (apparently the number of tagged fish is not used). Most mini-jacks probably do not emigrate downstream to the dam where they could be counted, and those mini-jacks that migrated through a dam might be detected going back upstream, and excluded from the analysis. Please clarify the approach to reduce potential bias caused by mini-jacks on SARs. Also identify the survival fraction of the PIT-tag release population from release to the first detection site (dam) and how it compares with other periods. This estimate would reflect mini-jacks and in-river mortality. The blood bioassay developed by NMFS to identify mini-jacks prior to release should be used to identify the proportion of mini-jacks each year and compared with mini-jack levels calculated from PIT-tag data.

Response: *The PTAGIS adult detector data include the date and time of all observations. None of the adult numerators used in SAR estimates for the CSS include adult detections that occurred during the year of out-migration. By definition, mini-jacks return during the year of the smolt out-migration and, thus, are excluded by this filter. The survival fraction of the PIT-tag release population at hatcheries to the first dam (S_1) are routinely calculated and provided in CSS website tables. For wild populations, the CSS relies on existing tributary or main stem SMP traps, and forms the starting cohort at the uppermost dam. The fall and spring survival fractions for wild populations are typically reported by the entities operating the traps (e.g., SMP, Idaho Supplementation Studies).*

The correlation between SARs for wild steelhead and wild spring/summer Chinook may be influenced by a few data points. It would be helpful to see scatterplots of the estimates with the brood year attached to each point to see if this is occurring.

For example, the correlation of 0.71 reported on page 54 appears to be based on the similar pattern of Figures 4.1 and 4.4. The correlation may be due to the high estimates of SAR in the early 1960s, but there may be less of a relationship in later years. Some thought should be given to how to present correlations in SARs among several runs other than pairwise scatterplots.

Response: *We plotted the Snake River wild spring/summer Chinook and steelhead SARs (LGR to Columbia River mouth) by decade (see below). The points that appeared to deviate most from the general relationship (based on inspection) were 1975, 1997 and 1998.*



The discussion of potential factors causing biases in estimates of SAR from PIT-tags (page 68) could be improved by presenting some rough estimates of effects. A goal would be to identify the most sensitive factors influencing bias. For example, assessing the impact of various levels of PIT-tag loss on the estimates and bias could be useful. If this has been done in the past please identify where.

Response: *The Chapter 4 discussion noted the collaboration of the CSS with ongoing double tagging experiments and other studies in the Basin, which should shed light on the amount of tag shedding/mortality and life-stages affected; the CSS plans to cite the results from these directed studies as they are presented.*

Chapter 5. Estimation of SARS, TIRS, and D for Snake River Subyearling Fall Chinook

The mini-jack issue is an important topic, and the information provided in Chapter 5 is appreciated. Clarification is needed concerning what is meant by targeting mini-jacks and excluding Snake River stocks. It is not clear why detection of juveniles in the system and their direction of movement would lead to a high bias of mini-jacks. Regardless, the discussion and explanation about why mini-jacks were excluded from age at maturation estimates is appreciated. Another possible confounding factor would be that most mini-jacks probably do not migrate down to a dam where they might be detected. Another method for estimating mini-jacks would be to use the bioassay developed by NMFS and applied to smolts prior to release.

The CSS puts considerable effort into investigating and estimating holdover probabilities for age-0 fall Chinook. Much of this discussion is obscure for readers not already familiar with the topic. It might help to (1) begin by explaining that the major concern is possible bias of estimates for the number of undetected juvenile migrants passing Lower Granite Dam (C_0) when calculating SARs. This explanation is presented, but it is not identified as the primary concern, (2) explain how C_0 estimates are made in this section of the report, and (3) explain how C_0 estimates may be biased, or not, by different types of holdover behavior, that is whether detected as subyearling migrant, as a subyearling migrant and again the following spring as a yearling migrant, only as a yearling migrant, or never detected. This information could be summarized in a simple table.

> **Response:** *We refer the reader to the first three paragraphs of the section of Chapter 5 entitled "Simulation to quantify potential holdover bias". That section spells out which holdovers would be of concern in causing bias to SAR estimates. Furthermore, Appendix A of the report includes an exhaustive discussion of the details of estimating the C0, C1, and T1 groups. The ISAB has requested in past reviews that those formulas and related tables be moved to appendices.*

The CSS report concludes (p. 115, lines 15-17) that "*based on TIRs (transport to in-river survival ratios) there appears to be no benefit to transport evident in the 2006 returns. Returns of more recent years are not complete but the pattern of little or no transport benefit appears to be holding.*" The limitations of the dataset and the preponderance of higher point estimates for survival of transported fish suggest that this conclusion is premature. Using data for the six study groups of age-0 Chinook released in 2006, in-river fish returned at a significantly higher rate for one group and transported fish at a higher rate for another group. For the seven groups released in 2008, transported fish returned at a higher rate for two groups. Although wide confidence limits preclude significant differences in most comparisons in these years, point estimates of survival are higher for transported than for in-river fish in 11 of the 13 comparisons. In addition, transportation has been thought of as a strategy for off-setting disastrously low in-river survival in extreme low-flow years, so particular attention should be given to the performance of transported fish in those years.

> **Response:** *We refer the reviewers to the TIR data presented in tables 5.15 to 5.17. In those tables there are only two significant differences in 2006, one TIR below 1.0 and*

one above 1.0; in 2008 there are two significant TIRs both above 1.0 but several others are not significantly different from 1.0; and finally, in 2009 there were two estimated TIRs above 1.0 and two estimates below 1.0 with none of them significant. These data suggest that transport benefit relative to in-river migration is a mixed bag, with some small indications of potential benefit (perhaps in 2008) but largely no significant benefit. Thus we would stand by our conclusion of little to no benefit.

A discussion of how TIRs would be changed if holdover SARs were also considered could be informative. Some studies have reported high return rates for holdover fish.

Response: *We do not know how holdover SARs would effect TIRs. We know that holdovers make SAR estimation exceedingly difficult. High return rates on holdover fish do not necessarily translate into high overall SARs, since mortality prior to that point, from subyearling to yearling could be quite high and therefore offset the perceived high SAR. Due to difficulties analyzing holdovers in SAR estimation, we had to avoid estimation for groups with a substantial number of holdovers.*

Chapter 6. Patterns in age at maturity for PIT-tagged spring/summer Chinook salmon and sockeye

Chapter 6 analyzes age-at-maturity data for 16 stocks of spring/summer Chinook salmon for juvenile migration years 2000-2009. Consistent differences are reported between stocks, accounting of 50% of overall variation. The conclusion that forecasting of adult returns from prior-year jack returns should be done on a stock-specific basis follows logically from this result. The examination of age at maturation is very useful and informative.

In addition to inter-stock differences in age-at-maturity, synchronized year-to-year changes over multiple-year periods are reported for some stocks, accounting for 32% of overall variation. This is a biologically interesting correlation, suggesting a strong influence of cyclic environmental factors most likely during the marine phase of the life cycle. Two papers are cited that hypothesize an effect of ocean conditions on age-at-maturity. If so, increased understanding of the ocean ecology of salmon could help to improve run-forecasting methodology.

It is unclear how missing data are dealt with in the statistical analyses and visual presentation: ten years of data are available for some hatcheries, but five or fewer years of data were available for five of the hatcheries (Figure 6.2, p. 120). Because age-at-maturity changed non-randomly over time, missing data for some years could bias estimates of mean age-at-maturity (Figure 6.3) and jack proportions (Figure 6.4). Although it is stated that "*the data and analyses ...in this chapter follow last year's report...We updated the analysis of variance...the logistic* *model was updated as well,*" more description of the statistical methods used in this chapter is needed.

> **Response:** *We have added more information on the methods for the analyses used in this chapter.*

The large proportions of jacks returning for some stocks raise many interesting questions that may be outside the scope of the CSS study. It would appear that the great majority of males return as either mini-jacks or jacks in some populations. What percentages of adult fish are males? Does a high percentage of prematurely maturing males (mini-jacks) result in a decreased percentage of jack returns?

> **Response:** *The ISAB presents some interesting questions regarding increased jack returns and the potential effects of mini-jack returns. However, the ISAB is correct that these questions are outside of the scope of the CSS.*

In Table 6.1, please identify the race of Chinook salmon (e.g., spring, summer, fall). Are all PIT-tagged Chinook and sockeye emigrating as yearlings?

> **Response:** *We have updated Table 6.1 to include race information for each of the Chinook stocks presented in this analysis. Yes, all Chinook and sockeye stocks presented in these analyses out-migrated as yearlings.*

Typically, age at maturation of Chinook varies with gender—females are older on average. There is some evidence that females have a lower survival rate, at least in Alaska, possibly due to older age and associated mortality risks. Is it possible to identify gender on at least a portion of these adults so that age at maturation can be compared by gender?

> **Response:** *The CSS Oversight Committee is unaware of any ways to determine the sex of returning PIT-tagged adults, unless they are all handled upon their detection.*

It is logical to expect that mean age at maturation will vary between stocks and between hatchery and wild Chinook. This variation and changes in jack abundance between stocks can confound forecasts that do not use stock-specific data. The report notes that an unknown factor(s) is causing age in maturation to vary synchronously among the stocks. There has been a tendency for age at maturation to decline over time, as shown in Fig. 6.2, indicating that the reproductive potential of individual Chinook is declining. The decline in age at maturation of Chinook salmon has been also observed in Alaska Chinook salmon and Atlantic salmon. Growth is known to be an important factor influencing salmon age at maturation, as well as age at smoltification, such that faster growth often leads to earlier maturation. Therefore, the investigators should consider length at age data as a factor that might explain earlier maturation as indicated by more jacks in recent years. However, it is possible that seasonal growth patterns, rather than cumulative growth quantified by length at age, may be a key factor. Another consideration is size-selective ocean harvest, which was an important factor in Atlantic salmon.

> **Response:** *As with the determination of sex, the CSS Oversight Committee is unaware of any methods to determine growth of returning PIT-tagged adults, particularly since very few are handled as adults for final measurement. Many of the CSS groups are tagged many months before release so size at tagging is not as useful. While we agree that these are interesting questions, they are outside the scope of the CSS.*

Appendix A: Survivals (Sr), SAR, TIR, and D for Snake River hatchery and wild spring/summer Chinook salmon, steelhead, and sockeye

This appendix contains interesting information in long list of figures and tables with essentially no text. The legibility of the main document has been improved by placing the lengthy section of figures and tables in the appendix.

Please clarify that mini-jacks were excluded by counting the smolt population at the first detector rather than at release.

> **Response:** *In the section titled Estimation of SARs and Ratios of SARs for Study Categories it is clearly stated that mini-jacks were excluded for steelhead and sockeye and that jacks and mini-jacks were excluded for Chinook. However, we have added a statement indicating that mini-jacks are excluded from the estimation of overall SARs (i.e., Chapter 4).*

It would be helpful to include a full "flow" diagram of the route of the fish, for example expand Figure A.1 to show the dams along the route, with the survival and detection parameters overlaid so that the rationale of the equations can be more readily seen. For example, different actions occur at different dams at the collector/detection stations and it is difficult to piece these together from the various equations.

> **Response:** *The CSS Oversight committee will explore adding a flow diagram for this section in future reports but are not able to construct this type diagram for the final report.*

The definition of C_0 should be more carefully stated. On page 126, C_0 is defined as the "PIT-tagged smolts that migrate through the hydrosystem without being bypassed at any of the Snake River collector dams." The phrase "that migrate through the hydrosystem" seems to imply that they fish actually survive to the mouth of the Columbia, but in fact, C_0 includes those smolt that die before reaching the mouth whose "virtual" bodies would not have been detected at subsequent dams, that is assuming that the dead fish still move through the system. This is why equation A.5 has the form it does, because it uses conditional detection probabilities, that is p_i is the probability of detecting a fish given that it is alive at dam i, in an unconditional fashion.

> **Response:** *The definition of the C_0 group was presented in the Glossary of Terms (page 126 of draft report). This definition has been modified to more clearly establish that the C_0 group included smolts that survived to reach the ocean and fish that may have died before reaching the ocean.*

The rational for using the expected counts starting on page 152 requires justification. Additional variability is introduced when the raw data is used, but the bootstrap confidence interval is supposed to capture this variability. The bootstrap confidence intervals are likely too narrow because of the use of the expected counts. This may make the test for equal SAR in equation A.13 too liberal.

> **Response:** *The rationale for using the expectation equations is explained on pages 151-152. There are no "expected counts". The numbers of undetected fish that pass through the spillway or turbines at the transportation projects (i.e., smolts in the C_0 category) are estimated by necessity. As explained on page 151, the number of smolts in the C_0 category was estimated by combining the Group T and Group R to estimate the number of smolts using equation A.2. The bootstrapping procedure accounts for the estimation uncertainty in the number of smolts in the C_0 category. The calculation of bootstrap confidence interval is described in the CSS Ten-Year Retrospective Report Appendix B, Analytical Methods: Statistical Framework and Equation of Study Parameters. On page B13 of that report, the procedure for generating bootstrap confidence intervals is described. Within each of 1,000 bootstrap iterations, estimates of all relevant study parameters, including estimates of the number of smolts in the C_0 category, are calculated. Because the bootstrapping procedure accounts for estimation uncertainty in the number of smolts in the C_0 and T_0 categories, we believe that the test for equal SARs (equation A.13) is appropriate and that the bootstrap confidence intervals properly reflect the uncertainty in that ratio. The expectation equations A.5 and A.6 are only*

utilized in cases where the C_0 group is estimated for the T or R group separately because these estimates are sensitive to reach survival estimates.

Similarly, clarification is needed to understand if bootstrapping accounted for the adjustment on a per mile basis for those groups where the missing portion of the total in-river survival rates was imputed.

Response: *The per-mile adjustment in the in-river survival rates are made prior to the bootstrapping. Bootstrapped SAR estimates incorporate these adjusted in-river survival estimates.*

More explanation is needed of how bird predation at the bypass outfall of LMN (presumably after PIT-tag detection at LMN) would bias the estimate of survival for the LGS-LMN reach, and how this bias relates to the remarkably low detection probabilities at LMN.

Response: *During transportation operations the default is for collected fish to be routed into raceways for loading into transportation barges. Therefore, very few fish are returned to the river, except for some PIT-tagged fish that are pre-assigned to be returned to the river. If birds are consuming fish at the bypass outfall as they exit the bypass, then bypassed PIT-tagged fish are likely to be consumed at a higher rate than undetected PIT-tagged fish that pass the project in other ways (e.g., spill, turbine). In CJS methodology, the survival estimate is a ratio of two populations (downstream/upstream). The population estimate at each dam relies in part on a ratio of fish that passed undetected at the dam but were subsequently detected downstream over fish that were detected at the dam and were subsequently detected downstream. If the detected fish have lower survival than the undetected fish, perhaps due to predation at the bypass outfall, then the estimated population at the dam would be bias high. If the LMN population is bias high then the reach survival would also be bias high.*

Specific Editorial Comments

Many of the tables and figures in this report use acronyms, abbreviations, and symbols that are not defined in the table heading or footnotes. Although many are defined in the glossary at the end of the report, for clarity it would be helpful to include definitions in the table heading, as well.

Response: *We have updated the glossary with additional terms (e.g., RIS is Rock Island Dam, RRE is Rocky Reach Dam, etc.). We added clarification about the report* *organization in the introduction (page 20, line 16 of review draft): "For the sake of brevity, abbreviations or acronyms are used to label the various PIT tag detection sites and river reaches of interest in many of the tables and figures. Because these terms are routinely used in CSS reports, as well as other regional PIT tag information reporting in the Columbia Basin, the reader should become familiar with them by consulting the Glossary and figures 1.2 and 1.3. All survival metrics are defined in text, and again in the interest of brevity, symbols or abbreviations are used within table and figure headings." The CSS will continue to work towards ensuring readability is as easy as possible.*

p. 4-5: What is meant by "complete return data"? Do complete return data include all ocean age groups or just the dominant age groups mentioned in the text for each species? There is no explanation of the age designation method, i.e., "1-salt, 2-salt, 3-salt" or Chinook salmon life history types, i.e., "ocean-type" and "stream-type." Perhaps these could be added to the glossary of terms. There is no mention of steelhead life history types (stream-maturing or summer-run vs. ocean-maturing or winter-run). How are PIT-tag detections of steelhead kelts (repeat-spawners) treated in the SAR estimates?

Response: *Complete return data means that adult returns from these migration years are completely finished and that we do not expect to see any more adults from these out-migration years in future years. We have revised the language in this section to avoid future confusion. The first sentence in page 5 states that the CSS study includes both ocean and stream-type Chinook. Age designation is based on the number of years spent in the ocean. For example, a 1-salt is a fish that returned one year after out-migration, a 2-salt fish returned 2 years after out-migration, etc. Steelhead kelts are only counted as a single adult return. The age designation for these fish based on the first adult detects. Subsequent adult detects of kelts are ignored.*

p. 5, 1st paragraph: "The number of individuals detected from a population of tagged fish decreases over time, allowing estimation of survival rates." The critical assumption seems to be that if a tagged fish is not detected then the tagged fish is dead, but this assumption is not stated. Perhaps this is a good place for a brief review and discussion of critical assumptions and uncertainties in survival estimates using PIT-tag data.

Response: *This chapter goes on to mention that Cormack-Jolly-Seber methods are used to estimate survival. These methods, their assumptions, and sources for more information are outlined in more detail in Appendix A.*

p. 5: Figure 1.1 is an informative figure, but it does not completely clarify the classifications and nomenclature used in the report. The use of different colors on the figure is more confusing than helpful. The “D” almost looks like a typo and the caption definition does not clarify. One needs to read much farther into the report to determine what “D” is. This is a key figure that could more effectively educate the reader about the different ways in which fish movement through the system is evaluated. One suggestion is to include the site abbreviations on the figure (e.g., Lower Granite (LGR), Lower Monumental (LMN), etc.). Further, could colors and dashed lines be used to distinguish different calculation mechanisms or to distinguish between calculations for wild versus hatchery fish? The fish show as two colors on the top of the figure, but are not distinguished by these colors on the figure. Could the path for transport fish be shown with a dashed line, for example, through the entire figure (all the way to return)?

> **Response:** *The CSS Oversight committee will explore ideas on how to make this figure more clear for future reports.*

p. 8, paragraph 1: *“Therefore we measure SARs against the regional management goal to maintain SARs between 2 and 6%, where....”* Please add that Lower Granite Dam is the reference site for enumeration of migrating juveniles and returning adults. This was done in the caption for Figure 1.1, but not in the text.

> **Response:** *Clarification was added to the text.*

p.10, line 34: Indicates that the probability of detecting PIT-tagged adults at LGR is nearly 100%. It would be useful to also summarize the typical range in detection probabilities for juveniles in this paragraph.

> **Response:** *Detection probabilities for juveniles at each of the different detections systems are highly variable and dependent on many factors (e.g., project, project operations, flows, location of detector, etc.). Describing detection probabilities at each of the projects would be complicated and likely confusing to the readers, particularly for an introductory section.*

p. 11, lines 1-2: Consider clarifying the statement *“Because TIR compares SARs starting from collector projects, it does not by itself provide a direct estimate of delayed mortality specific to transported fish”* by adding the parenthetical clause “(see below for description of use of the factor “D” as an estimate of transportation-related delayed mortality”).

> **Response:** *Suggested change was incorporated.*

p. 11, Line 39-40: Are these tagged fish assigned to treatment groups at random? If not, how are they assigned?

Response: *Inserted language to clarify that pre-assignment is done at random.*

p. 11, Line 43-45: Are these fish tagged but treated the same as untagged fish? Are they barged?

Response: *The T-group is more representative of the untagged population, as their fate (transported or not) depends on operations at the dams.*

p. 12, bottom of paragraph 4: When describing the assumptions regarding in-river survival and survival in barges, it would be informative to show in parentheses the range in assumed survival values. Given that delayed mortality estimates (D) are based in part on these assumed downstream migration/transport survival values (as a means to estimate survival beyond Bonneville), it is important that the bootstrapped confidence intervals incorporate this additional uncertainty.

Response: *D is a ratio. As mentioned on page 11, 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.*

p. 12: Clarification is needed in the first sentence of the last paragraph of the section on data generation. The last phrase of this sentence: *"…first from passage at LGR as smolts to their return as adults to LGR (TIR)*" was confusing. Consider rewording as "first using TIR for passage at LGR as smolts to these smolts' return as adults to LGR."

Response: *It is unclear where the confusion lies, as the quote in the above comment is not present in the referenced paragraph and line. Each of the metrics that the bootstrap estimates are clearly listed in this sentence. We did not incorporate the suggested change.*

p. 13, lines 29-31: "*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 2011. The sample sizes for each group with tags provided by the CSS from 1994-2011 are presented in the appendices at the end of this report.*" These appendices were not provided in the 2012 CSS draft report, and would have aided the ISAB's review. How does interannual variation in aggregate stock composition, for example in the Snake River spring/summer ESU that includes 28 independent populations and 5 major population groups, influence annual variation in survival estimates?

> **Response:** *The appendices are often not included in the draft report, due to time constraints. These tagging numbers can be found in Appendix B of this final 2012 Report. The 28 independent populations and 5 population groups are not managed separately. As discussed in previous response to overall comments, the CSS is exploring the potential of reporting Snake River wild Chinook and Steelhead SARs by smaller geographic groups (e.g. MPG) where there is adequate tag data. Wild fish SARs are reported as aggregate groups because tag numbers are generally too low to calculate survival and SAR for individual wild stocks. It is important to remember that the CSS strives to utilize existing mark groups and mark groups used for other studies to maximize efficiency and minimize cost to the degree possible. In the case of wild stocks, the low existing population numbers necessitate aggregation of groups, particularly when evaluating relative survival by route of passage.*

p. 15: "*Based on past estimates of SARs, sufficient numbers of smolts were tagged to ensure enough returning adults to compute statistically rigorous SAR estimates. Required samples sizes for SAR estimates are discussed in Appendix B of the CSS 2008 annual report*." A brief summary of sample size requirements would be useful.

> **Response:** *We do not feel that a summary of these analyses is necessary for this introductory section. The source that is cited in this statement provides the detailed analyses that were done for the 2008 analysis. Since this time, tagging numbers have been determined with these analyses in mind.*

p. 16-18, Tables 1.1 to 1.3: It would be useful to indicate grand totals for the number of fish tagged in the previous year (2011) or indicate % change.

> **Response:** *The final 2012 CSS Report has an appendix (Appendix B) that provides the numbers of PIT-tagged smolts that were released/analyzed for each of the CSS groups over the past 15 years.*

p. 22, Line 18-19: Evidence should be presented or cited that the detection probability through bypass systems is nearly 100%.

> **Response:** *This sentence on page 22, refers to the detection probability of a PIT tagged smolt that has entered a juvenile bypass system which has PIT tag detection capabilities. Evaluation of this detection probability occurs when the detection facilities are installed at the projects. These evaluations are conducted under the auspices of the US Army Corps of Engineers Anadromous Fish Passage Evaluations Program.*

p. 23, Line 27-28: Here the one best fitting model was used, but in Chapter 3 the estimates were model averaged. Usually the best fitting model is used if the Akaike weight is high (e.g., >0.8-0.9). Is this the case? If not, is there the possibility of model averaging over the multiple top models? Burnham and Anderson (2002) give guidelines for how many of the top models to average.

> **Response:** *This has been addressed in our previous response in this document to specific comments on Chapter 3.*

The methods used seem appropriate, but more information about the probabilities of detection should be given. In the Appendix, the methods used to estimate the detection probabilities are given, and Figure 2.1 shows the detection probabilities calculated and predicted, but more information on the linkage between these values and how they are applied in the equations in the Appendix is needed. For example, are all the detection probabilities shown in Figure 2.1 used or are the values aggregated for some calculations? Also, it seems that separate probabilities should be calculated for each of the detection facilities. Is the discussion on pages 23-24 of how detection probabilities were calculated at MCN an example and was the same method used for all other detection facilities? It is not clear if the values in Figure 2.1 are values only for MCN.

> **Response:** *We explain in chapter 2, that we use McNary Dam as a case study to describe the development of this methodology. Please refer to our previous response to comments on Chapter 2, in this document.*

p. 29: Consider changing the wording of lines 33-34 to "We calculated fish travel time as the number of days between release of a cohort at LGR until detection at MCN for each fish subsequently detected at MCN."

> **Response:** *The original wording for this sentence was retained for the final report.*

p. 32: It is mentioned that "average spill percentage" was calculated. More details are needed on how this is calculated. On page 33, it is mentioned that spill is one of the seven environmental factors evaluated. Is this "spill" the same as the "average spill percentage" mentioned on the previous page? Is this variable considered a continuous variable (i.e., if it's a percentage, it varies between 0 and 100%) or a binary variable (yes there is spill/no there is not). What variable is used here is important in terms of the management implications.

> **Response:** *Refer to our previous response to comments on Chapter 2 in this document. Chapter 2 is a description of an alternate methodology to describing the spill variable.*

p. 35: what is meant by “high degree of contrast” in the first sentence? Would “high degree of variability” be appropriate?

> **Response:** *We do not think that variability is the appropriate term, since we are evaluating the effect of environmental variables on juvenile survival and travel time. The environmental variables we are investigating have changed from year to year, and result in different levels of survivals and fish travel time.*

p. 35: The reference to Figures 3.4 and 3.5 in the first paragraph on page 35 is in error and is referring to other figures.

> **Response:** *Noted.*

p. 45: The NPCC 2-6% SAR objective for Chinook addresses the total adult return including jacks (i.e., 1-salt male Chinook). Although the CSS draft does indicate the complementary value of reporting SARs both including and excluding jacks, this reporting has not been consistent throughout the document.

> **Response:** *The CSS convention has been to exclude jacks in reporting of SARs by passage route, TIRs and D, consistent with the Basin’s management focus on adults. The CSS Oversight Committee believes we have been consistent in that regard in this and previous reports. Chapter 4 presents overall SARs both including and excluding jacks to address specifically the NPCC SAR objective. Numbers of jacks for the study groups are also reported in Appendix E of this report, the FPC website, and maintained in FPC data files.*

p. 48: It is not clear if the bootstrapping captured all of the uncertainty. Did the bootstrapping also apply to estimating the survival rates between dams based on the mark-recapture model that was used to obtain the T_0^* on page 48?

> **Response:** *Yes, the bootstrapping used to estimate uncertainty for T0* included bootstrap estimates of survival rates between dams. The closed form maximum likelihood estimators for Cormack-Jolly-Seber survival estimates were used for each iteration.*

p. 49: "*The method of deconstructing SARs into first year ocean survival rates used here is described in Petrosky and Schaller (2010) (Appendix D), and is similar to approaches used in STUFA (2000), Wilson (2003), and Zabel et al. (2006)*." A brief summary and justification of the method and a discussion of any differences in methods in the cited references would be useful.

Response: *We added some detail and explanation to the methods for calculating S.oa and S.o1. To clarify, the minor differences between methods in the cited studies were primarily related to data sources for passage survival and D.*

p. 47: "*point estimates are calculated from the population*…" Estimates are computed from samples. It is not clear if the use of the "population" refers to a specific stock.

Response: We *rephrased this statement to say "…point estimates are calculated from the sample for each population…''*

Figure 4.1: Why are there no SAR estimates from RR for wild Snake River spring/summer Chinook in years 1985-1993 (as suggested in caption and shown in Figure 4.4 for steelhead)?

Response: *There was no consistent marking program for hatchery spring/summer Chinook during 1985-1992, thus a reliable RR estimate of wild smolt yield was not possible for these smolt migration years. Hatchery steelhead smolts were distinguished at the dams from wild steelhead based on eroded dorsal fins in these years. Raymond (1988) estimated wild yearling Chinook smolt yield to the upper Snake River dam for 1964-1984 based on marking at hatcheries and recapture at dams. Beginning in 1993, hatchery spring/summer Chinook smolts were identifiable from natural-origin smolts at LGR based on adipose fin clips, other marks or tags (Petrosky et al. 2001). The CSS began to estimate PIT tag SARs for wild Chinook beginning in 1994.*

Figure 4.4: The 1999 LGR-Columbia River SAR for wild Snake River steelhead appears to be much lower than the corresponding LGR-GRA SAR in Figure 4.5 and Table 4.19. LGR-BOA SARs for 1997-1999 are missing from Table 4.19, so some explanation is needed for where the points plotted in Figure 4.4 came from.

Response: *There was a reference error in the data table for Figure 4.5; we corrected the discrepancy.*

p. 54: "*Estimated overall SARs (LGR-GRA) were higher for A-run hatchery steelhead than for B-run hatchery steelhead in 2008 and 2009 (Table 4.20)*." Is this result influenced by differences in ocean age composition of adult returns of the two runs (i.e., A-run fish are typically younger than B-run fish)? Does smolt outmigration timing differ between A- and B-run stocks?

Response: *Differences in adult salt-water ages would seemingly account for only part of the difference observed in SARs of hatchery A-run and B-run steelhead. SARs of hatchery A-run exceeded those of hatchery B-run in all passage categories, with Clearwater B-run showing a relatively poorer TIR response than other groups in these two years (Appendix*

A). However, the time series is very short for identifying patterns or causes of patterns with confidence.

Outmigration timing for wild and hatchery steelhead was summarized graphically in the CSS 2011 annual report (Figure 2.4). Generally, the Clearwater River hatchery B-run steelhead appeared to out-migrate past LGR earlier than other hatchery stocks.

p. 68: "*To date, a definitive control group has been lacking to quantify the potential post-marking mortality or tag shedding bias in PIT-tag SARs*." What are the criteria for a "definitive control group"?

Response: *By "definitive control group", we mean an unbiased estimate. We identified several sources of potential bias in the RR methods that may have affected RR SARs. The RR uses window counts, which probably have a positive bias due to fallback and re-ascension, which may be partially offset by negative bias due to passage during non-counting hours. As described earlier in our response, one can correct window counts (based on PIT tag detections) for fish that pass after hours or that fall back and re-ascend , but fish that fallback and don't re-ascend do not get accounted for. RR methods will contain some (small) positive bias from including out-of-basin strays in adult counts. Finally, RR methods contain some unknown fraction of unmarked hatchery smolts and adults that are counted as natural-origin; if the fractions differ between smolt and adult counts, the RR SAR estimate will contain bias. Parental based tagging (PBT) sampling at LGR for both juveniles and adults is beginning to address these specific misidentification issues. If both RR and PIT groups contain some SAR bias, it is difficult to isolate the bias in either group.*

p. 71, lines 1-2: It would be useful to suggest why the adjusted window counts of hatchery Chinook were 12-23% higher than the expanded PIT-tag estimates and to describe the implications of this discrepancy.

Response: *We suspect some of the difference is due to PIT-tag shedding or post-marking mortality, but with an unknown bias in all accounting measures (see above).*

Editorial: Chart axis labels "Migration year" should be relabeled as "Smolt Migration Year" to avoid confusion with adult migration year.

Response: *We have made the suggested correction to the chart labels.*

In general, the smolt migration years with highest SARS correspond to negative Pacific Decadal Oscillation (PDO) values, i.e., cool sea surface temperature (SST) periods in the Northeastern

Pacific, Gulf of Alaska, and southeastern Bering Sea. Could the PDO index be used as a tool to estimate SARs or to better manage the hydrosystem to increase SARs?

> ***Response:*** *Use of the PDO and other ocean indicators has clear promise in filtering environmental variability from effects of management actions, and in devising FCRPS management experiments with testable hypotheses (Marmorek et al. 2011 - CSS workshop report). The CSS Oversight Committee is currently working toward this goal, with plans for an experimental design workshop early in 2013.*

Does the CSS have any hypotheses as to why the 2008 smolt outmigration year was the best survival since 2000 for many Chinook and steelhead stocks?

> **Response:** *The observation of relatively high SARs for the 2008 outmigration appears to be consistent with the retrospective analyses of Petrosky and Schaller (2010) and Haeseker et al. (2012) and freshwater migration and ocean environmental variables. The PDO was the highest ranked (most negative) year during 1998-2011 (NWFSC Ocean Ecosystem Indicators), water travel time was relatively fast, and spill proportions and in-river survival rates were relatively high in 2008.*

p. 98, line 25: error in first variable in last expression? Presumably FN/N should be TN/N.

> **Response:** *We have made the correction to this equation.*

p. 100, lines 22-23: The procedure is not clear from this sentence.

> **Response:** *We modified the paragraph to clarify the idea. The paragraph now reads: The observed PIT-tagged holdover fish were used in simulations to determine the possible size of the juvenile holdover population that might have been present but undetected. Based on their migration timing, detection probability, and migration timing information simulations were run to calculate the amount of bias possible in PIT-tag subyearling fall Chinook release groups.*

p. 100, lines 33-36: The last part of this sentence is confusing; "*or passed LGR the following spring after the bypass and detection systems restarted.*" Does the restarting refer to BON or LGR?

> **Response:** *The sentence refers to Lower Granite Dam. There are two systems that both need to be operating to detect PIT-tagged fish. First the bypass system must be in operation and the PIT-tag detection system then must be turned on. So the reference to "systems" only refers to one dam.*

p. 102, lines 7-8: The definition of HO_u needs clarification, and it would also help to explain what the first term in the equation on line 4, $HO_u * (HO_{bon} / p_{bon})$, refers to in contrast to the second term which refers to the holdovers estimated from detections at BON after detection was restarted.

> **Response:** *This explanation was provided below the formula. HO_u = Unmonitored winter passage proportion (expressed as a proportion of all holdover passage, times the probability of passing LGR to BON prior to BON restart).*

p. 106, lines 27-28: Does the age convention used here for fall Chinook differ from other Pacific salmon? If not, sub-yearling (age 0+) smolts migrating downstream in 2006 would have hatched from eggs deposited in late 2005, and would reach age 5 in late 2010, rather than 2011 as seems to be indicated here. Same comment applies elsewhere in this chapter, for example page 110, lines 14-15 where the age convention appears to have been used inconsistently.

> **Response:** *As previously stated we have adopted the terminology for age of fish that has been used in previous CSS reports. For Chapter 5 we have adopted the convention used historically in CSS reports of referring to adult return age as ocean age such as "1-salt" or "years in ocean-salt", so that for subyearling fall Chinook jack returns would be "1-salt"; 2-salts would be adults returning after 2 years in the ocean etc…up to 5-salt returns.*

Tables 5.11 to 5.17: Why are SARs, TIRs, and Ds reported only without jacks, whereas previous tables report values with and without jacks, and all previous figures in Chapter 4 show results including jacks?

> **Response:** *Some comparisons were made with jacks as had been previously done with CSS analyses. However, the inclusion of jacks in TIR and D analyses for Chapter 5 is relatively new and some data were not available at the time of this report. We will provide jacks in future analyses of all of these metrics.*

p. 114: "*The method CSS developed for differentially identifying subyearling fall Chinook holdover probability worked well on a population level but did not work well for identifying individual fish within release groups*." Is the CSS exploring other methods that might succeed in identifying individual fish as holdovers? Can a method be developed to estimate SARS for groups with high percentages of holdovers?

> **Response:** *At this point we are not pursuing other methods of identifying potential holdover fish and we have not developed methods for estimating SARs for groups with high holdover rates.*

p. 115, last bullet of Conclusions: Perhaps it is more accurate to say that significant benefits from transport were evident in 2008, but no consistent benefits from transport were evident in 2006 and 2009.

> **Response:** *We stand by our conclusion that little or no benefit to transportation in the years we analyzed. However, we agree that by and large it appeared there was a benefit evident in 2008 while for 2006 and 2009 there appeared to be no evidence of benefit. We have reworded the last bullet to read "By study group, SARs were also quite low and based on TIRs there appears to be no benefit to transport evident in the 2006 returns. Returns for more recent years are not complete but there appeared to be a significant benefit for some transport groups 2008 while in 2009 the pattern of little or no transport benefit appears similar to 2006."*

p. 116, lines 12 and 16: The words "former and "latter" are switched.

> **Response:** *This typo has been corrected.*

p. 117, lines 12-16: The first sentence in this paragraph states that age-at-maturity was determined for sixteen stocks, but the third sentence makes reference to seventeen stocks. The reason for this (Table 6.1) is that two wild stocks were aggregated for analysis.

> **Response:** *We have changed the language in the third sentence to avoid confusion.*

p. 117: According to an aging scheme in common use, a S/S Chinook juvenile produced by, for example, the 2006 spawning run would migrate to sea in its second spring (2008) and be designated a yearling, with one freshwater annulus on the otolith (winter of '07-'08). If it returned in the spring of the following year (2009) it would be designated a "jack" (one-salt, with one freshwater annulus and one annulus from the winter at sea) and an age-3 spawner. The description on page 117 (lines 22 to 23) seems to use this scheme: "Chinook adult returns consisted of age-3, age-4, and age-5 fish. Age-3 fish are predominantly male and are termed jacks." However, the following paragraph (lines 28-29) then states: "jacks, 1-salts, and 2-salts are presented as age-4, age-5, and age-6, respectively." This terminology appears to be incorrect and does not match the earlier terminology. Age terminology should be clearly defined and used consistently.

> **Response:** *The language in lines 28-29 was a typo and has been corrected.*

p. 154, line 1: appears to be an error in the coding as codes 102 and 1002 appear twice.

> **Response:** *This was a typo and has been corrected.*

Table A.35: The TIR for Oxbow sockeye in 2009 appears to be significantly >1. Lower CI should be in bold font.

Response: *This has been corrected.*

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MEMORANDUM

TO: Ritchie Graves, NOAA

Michele DeHart

FROM: Michele DeHart

DATE: November 30, 2012

RE: Response to NOAA comments on Draft 2012 Comparative Survival Study Annual Report

Attached is the CSS Oversight Committee response to NOAA comments on the Draft 2012 Comparative Survival Study Annual Report. We have responded to each comment in the attached document. The original NOAA comment is followed by the response in italic font. We appreciate the time that NOAA invested in reviewing the draft report and providing helpful constructive comments.

NMFS Hydropower Division Technical Comments on the Draft CSS 2012 Report

October 15, 2012

1. We have concerns that without looking at the seasonal effects of transportation, a primary objective of this study is not being achieved, – the effectiveness of transportation as a management tool. The delayed start date of transportation for the spring-migrating fish (based on an acknowledgement that inriver migrants tend to return at higher rates than transported fish early in the season) makes the TIR as currently reported (a seasonal average) a less relevant comparison of transportation to in-river migrants. This is due to the fact that fish are transported for just part of the season, yet they are compared to an in-river group that has migrated over a longer time frame (the entire spring season). We do not object to presenting the seasonal average as it provides a linkage to past years' data. However, this metric is currently of little value in making an assessment of whether transport was effective over the time-frame it was used. Thus, we recommend that the report also include a TIR estimate which directly compares the returns of the inriver and transported groups when transport is being implemented.

   Response: *The primary and initial objective of the CSS was to evaluate route of passage and SAR based upon comparisons of transportation route of passage and the C_0 route of passage. A key objective of this study is to evaluate transportation on the basis of all routes of passage including the C_0 route of passage. The C_0 undetected passage which was not previously evaluated by NOAA Fisheries in previous evaluations of transportation only compared transported fish with fish migrating through the juvenile bypass system. Temporal evaluation of transportation cannot take place because the time of passage of the C_0 group is unknown. Recent analyses indicate that delayed mortality is associated with power house passage, which would create a downward bias in results when transportation evaluations are based upon comparison of the transported fish with the powerhouse bypassed fish. Evaluation of bypass compared to transported fish as would be required in temporal estimates of transportation benefits, overstates the benefit of transportation.*

2. The rationale for reporting SAR values of Upper Columbia groups based on MCN to BON was not clear. Reporting returns to Bonneville is informative, but Page 46 makes the statement that, "Due to limited detection capability upstream of MCN, most SAR data series are presented MCN-to-BON". Nearly 100% adult detection capability exists at

four projects upstream of McNary Dam: Priest Rapids, Rock Island, Rocky Reach, and Wells dams . We suggest also reporting SARs to Rock Island Dam, the lowermost dam above which nearly the entire Upper Columbia River ESUs must pass, as a means of adhering to the report's convention of reporting SARs to the uppermost dam.

Response: *We have modified a sentence on page 46 to clarify that the limitation to estimating SARs for Upper Columbia groups is due to lack of detection capability for juvenile out-migrants upstream of McNary Dam: "Due to limited detection capability <u>of juvenile out-migrants</u> upstream of MCN, most SAR data series are presented as MCN-to-BOA." Note also that the CSS will continue to work on this issue using smolt abundance estimates at RRE, as well as using FPC Smolt Monitoring Program tagging at Rock Island Dam for combined hatchery/wild groups of yearling Chinook, subyearling Chinook, and steelhead (see figures 4.11 and 4.12, and tables 4.33, and 4.36-4.39). For purposes of regional monitoring, the CSS estimates overall SARs for adults at BON for both Snake River and the other regional PIT-tag groups. We also plan to estimate SARs and confidence intervals to the uppermost dams with adult detection facilities in future reports.*

3. Mid-Columbia River SARs are reported only as JDA-to-BOA. While this is helpful, it would also be informative to have an estimate of the JDA-to-JDA SARs. The absence of an adult PIT tag detector at JDA makes this somewhat challenging. However, a loss per mile estimate could be applied to the adults, similar to how the report uses juvenile survival estimates based on a survival per mile estimate. Since adult survival is reduced by both harvest and hydro effects as they migrate through the river, applying such a loss estimate for adults would better represent the reports convention of "Reporting SARs to the upmost dam". Using adult detections in the John Day River plus those of any overshoots (especially for steelhead) detected at McNary dam, should provide sufficient information to generate a JDA to JDA SAR estimate.

Response: *As noted in the comment, no adult PIT tag detection capability exists at John Day Dam, thus no adult PIT tag data are available at John Day Dam. For purposes of regional monitoring, the CSS estimates overall SARs for adults at BON for both Snake River and the other regional PIT tag groups. Complete PIT tag detection capability at BON for adults has been available since the 2002 adult return. Note the CSS convention for Chapter 4 is not simply "*Reporting SARs to the upmost dam*" - SARs for all populations are reported at the first uppermost mainstem PIT tag detection site encountered by juvenile out-migrants to adults ascending the Bonneville Dam adult fish ways. We also plan to estimate SARs and confidence intervals to the uppermost dams with detection facilities in future reports. For the overall SARs presented in Chapter 4,* *the CSS does not use "*a loss per mile estimate … similar to how the report uses juvenile survival estimates…" *and it does not plan to use other than actual adult detections to estimate overall SARs. Information to generate a JDA to JDA SAR estimate for steelhead is insufficient, because the detection probability in the John Day River is unknown and detection capability for "any overshoots" that swim back downstream through McNary Dam is insufficient.*

4. It appears that S.oa (Tables 4.40 and 4.41) are being calculated as SAR (lgr to lgr) / System Survival. Unfortunately, when System Survival > 1.00 (due primarily to D estimates > 1.00) this estimate is illogical. We suggest that when D (and System Survival) are > 1.00; the relative survival of the inriver migrants should be discounted, instead of a benefit accruing to transported fish. This will ensure that system survival estimates < 1.00 (which is logical) and that S.oa estimates are NOT unduly influenced by expectations that transported fish doubled in a number in years like 2001 (and 2002 and 2004 for wild steelhead).

   Response: *The methods of calculating S.oa and S.o1 are consistent with past literature cited in Chapter 4. We added language to clarify this point. The estimates of system survival put the effects of transportation (as estimated by D) on the transported group into in-river equivalents upon estuary entry. 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 of transported fish is mostly expressed 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. 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 1998), and assigns all ocean survival rate variability to the S.o1 life-stage (Zabel et al. 2006; Petrosky and Schaller 2010).*

5. Comments on Chapter 5, which reports on fall Chinook.

- The estimation procedure to select which release groups fit the CJS model seemed overly complicated and given it is a work in progress, its presentation might best be placed in an appendix. However, given the influence of hold-overs on results and the fact they don't fit the CJS model assumptions it raises the question whether the CJS model is the best way to analyze this data? Some sensitivity analysis (what if the number of hold overs was 2X, 5X, etc. the estimates) on what effect this would have on the CJS estimates would better illustrate the point and convince the reader that the CJS results are reasonable.

Response: *The detail provided was necessary in-order to follow-up on the analytical approach that was under development in the 2010 report. It was important to come to some resolution on the method which was introduced as a possible way to separate fish with high holdover probability. The fact that it did not work was why results of the analysis were abbreviated in the report.*
The simulations done in the later sections of the Chapter did provide some sensitivity analysis including a range of possible effects on SAR estimates. The groups we used in the SAR analysis were groups of fish with very few to no holdovers present such that SARs were virtually unaffected. Those groups with high holdover proportions such as wild Clearwater marks and surrogates were not used because of the potential impact on SAR estimation.

- It was our understanding this "consensus study" was supposed to include a collaborative analytical effort involving the authors of this report as well as NMFS, the Corps, and other stakeholders to avoid "dueling analyses and reporting". Has the original plan of a broad collaborative effort changed? An update on the status of the consensus analytical effort would be helpful.

Response: *The Fall Chinook analyses are included in the CSS Annual Report in response to a request from the Oregon Department of Fish and Wildlife. The CSS analyses are provided to the Fall Chinook Planning Team for their review and consideration. The CSS analyses and Annual Report are the result of the collaborative effort of Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Idaho Department of Fish and Game, the US Fish and Wildlife Service and the Columbia River Inter-tribal Fish Commission. Representation on the CSS Oversight Committee overlaps representation on the Fall Chinook Planning team. The CSS analyses do not supplant the Fall Chinook planning team but rather provides technical input to the Fall Chinook Planning Team. The scientific process is strengthened by multiple analytical approaches and reporting of those approaches. The scientific process breaks down when only one view, one analytical approach, one method are allowed to go forward. The Fall Chinook*

Planning team efforts can only be strengthened by the consideration and inclusion of CSS analyses.

- The conclusion made on page 115 that "The pattern of little or no transport benefit [for fall Chinook] appears to be holding", does not appear to be supported by the data presented in the report. The TIRs in Table 5.16 were all positive, with two groups showing significantly higher TIRs. We suggest that a more reasonable conclusion is that transport benefits are not consistent between groups or years and that returns from 2010 and subsequent outmigrations will be informative because the dam configuration improvements to benefit inriver migrants were largely completed by then.

  Response: *We have modified the concluding bullet to read "By study group, SARs were also quite low and based on TIRs there appears to be no benefit to transport evident in the 2006 returns. Returns for more recent years are not complete but there appeared to be a significant benefit for some transport groups 2008 while in 2009 the pattern of little or no transport benefit appears similar to 2006."*

- The fall Chinook SAR data is presented as a seasonal average. It would be informative to determine whether the effect of transportation varies through the season. Are there sufficient numbers of adult returns to estimate SARs for more than one period in some years?

  Response: *There is no way to calculate SARs through the season using the CSS methodology. CSS method does not use C1 fish to calculate in-river SARs for comparison to transport (e.g. TIR) since it has been shown that bypassing fish can lead to delayed mortality and decreased adult returns.*

Lastly, the report concludes on page 115 that "Overall Smolt-to-adult return rates for Snake River subyearling fall Chinook were very low in the years we have analyzed." We assume that you mean relative to the Council's 2-6% SAR target or to Snake River spring/summer Chinook or steelhead SARs. However, SARs of subyearling migrants are <u>expected</u> to be lower than those for larger yearling migrants. We urge you to also compare S.R. fall Chinook SARs to those of other subyearling migrants from other interior bright fall Chinook ESUs (unlisted Deschutes River or Upper Columbia River fall Chinook) as a more meaningful comparison.

> **Response:** *We agree that the reference to the Council's 2 to 6% target are not appropriate for fall Chinook and have removed reference to those. We also agree that estimation of SARs for Deschutes River and Upper Columbia River fall Chinook would be*

useful and we will explore the possibility of providing SARs for other fall Chinook groups in future CSS reports.

References from Responses to ISAB and NOAA:

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Appendix H

Snake River Adult Success Rates for Transported and In-river Outmigrants and for the Run as a Whole

Quantifying the efficacy of transportation is one of the foundational goals of the CSS. The estimation of SARs from smolts at 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 (BON) and Lower Granite dams (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-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 outmigrating 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 smolt-to-adult survival rates (SARs) based on adult detections at Lower Granite Dam (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 outmigration 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 outmigration 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 outmigrants (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 drop out 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 2011 report to include migration years 2000-2010 for CSS Snake River groups.

The CSS was requested to add 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 outmigration 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 outmigration type are aligned with the year of the smolt outmigration 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 2010. 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 been installed in the fish ladders at BON, MCN, ICH, 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 1-salt and 2-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: (i) adults potentially could swim over the weir crests and not pass through the orifices where the detection equipment is installed; (ii) adults pass in the navigational locks; (iii) 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 precision for these estimates BON efficiency was calculated using the pooled transported and in-river adults. Detectability at BON of adults 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:

$$Adult.success.rate = \frac{LGR_{count}}{\left(BON_{count} \div BON_{efficiency}\right)} \qquad \text{[H.1]}$$

which can be re-arranged as:

$$Adult.success.rate = \frac{LGR_{count}}{BON_{count}} \times BON_{efficiency} \qquad \text{[H.2]}$$

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 outmigration 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., $Success_{(TX \text{ or } T0)}/Success_{Cx}$), 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 program R (R Development Core Team 2010). The non-parametric bootstrapping approach of Efron and Tibshirani (1993) was employed where first the point estimates are calculated from the population, and then the data are re-sampled with replacement to create 1,000 simulated populations. Specifically, a dataset of individual fish released for each group of interest (e.g., 2001 Rapid River spring Chinook) was assembled. Each dataset 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 dataset even if there were zero adult detections at any site. Each dataset was randomly re-sampled 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 H.1 and H.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 2003-2010 without confidence intervals is presented in this report.

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 2-salt and 3-salt. Age 4-salts were not included because only two returns of PIT-tagged Snake River wild Chinook occurred from 2003-2010 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 outmigration. 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 H.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 outmigration 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.

$$\textbf{Adult Success by ReturnYear} = \frac{\sum LGR_{2-salt} + LGR_{3-salt}}{\sum BON_{2-salt} + BON_{3-salt}} \qquad [H.3]$$

Calendar years prior to 2009 include returning adults from outmigrating 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 outmigration (Chapter 1; Figure 1.4). 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 outmigration 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 outmigration) for the 2008 calendar year were calculated as:

$$
\begin{aligned}
NT_{3-salt} &= Pop \times Transport\ SAR \times PROP(3-salt) \times PROP(Transport) \\
NC0_{3-salt} &= Pop \times C0\ SAR \times PROP(3-salt) \times PROP(C_0) \\
NC1_{3-salt} &= Pop \times C1\ SAR \times PROP(3-salt) \times PROP(C_1) \\
& and, \\
WT_{3-salt} &= \frac{NT_{3-salt}}{\sum all\ N's}\ ,\ WC0_{3-salt} = \frac{NC0_{3-salt}}{\sum all\ N's}\ ,\ WC1_{3-salt} = \frac{NC1_{3-salt}}{\sum all\ N's} \\
& where,
\end{aligned}
$$

$$
\begin{aligned}
&Pop && = Estimated\ smolt\ population\ at\ LGR \\
&Transport\ SAR && = Transport\ SAR\ from\ LGR_{SMOLT}\ to\ BON_{ADULT} \\
&C0\ SAR && = C_0\ SAR\ from\ LGR_{SMOLT}\ to\ BON_{ADULT} \\
&C1\ SAR && = C_1\ SAR\ from\ LGR_{SMOLT}\ to\ BON_{ADULT} \\
&PROP(3\text{-}salt) && = Overall\ proportion\ of\ \mathbf{3}\text{-}salt's \\
&PROP(Transport) && = Run-at-large\ population\ proportion\ of\ transported \\
&PROP(C_1) && = Run-at-large\ population\ proportion\ of\ C_0 \\
&PROP(C_0) && = Run-at-large\ population\ proportion\ of\ C_1
\end{aligned}
\qquad [H.4]
$$

The above weighting factors were similarly calculated for 2-salts from the 2006 outmigration. 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:

$$
\begin{aligned}
\textbf{Adult Success by Return Year} = &\left\{\frac{\sum LGR_{2-salt\_transported}}{\sum BON_{2-salt\_transported}} \times WT_{2-salt}\right\} + \left\{\frac{\sum LGR_{3-salt\_transported}}{\sum BON_{3-salt\_transported}} \times WT_{3-salt}\right\} \text{-} \\
&\left\{\frac{\sum LGR_{2-salt\_C1}}{\sum BON_{2-salt\_C1}} \times WC1_{2-salt}\right\} + \left\{\frac{\sum LGR_{3-salt\_C1}}{\sum BON_{3-salt\_C1}} \times WC1_{3-salt}\right\} + \qquad [H.5] \\
&\left\{\frac{\sum LGR_{2-salt\_C0}}{\sum BON_{2-salt\_C0}} \times WC0_{2-salt}\right\} + \left\{\frac{\sum LGR_{3-salt\_C0}}{\sum BON_{3-salt\_C0}} \times WC0_{3-salt}\right\}
\end{aligned}
$$

The calculations in years both with and without pre-assignment assume that the proportions of 2-salts and 3-salts is the same across all study categories (C_1, C_0, transported) from a single migration year. This assumption seems reasonable from comparisons of age at return across study categories (Chapter 5; CSS 2010 annual report).

Results

Table H.1 Counts of adults at LGR and BON for all Snake River CSS groups for the juvenile outmigration years 2000-2010. Total adults are shown for fish with two different routes of passage as emigrating juveniles (transported [T0 before 2006, TX thereafter] and in-river groups [CX]). The BON efficiency used for success rates is calculated from the pooled (TX + CX) 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/ Migr Yr[A]	LGR-TX	BON-TX	LGR-CX	BON-CX	BON efficiency (TX + CX)
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	360	400	98.5%
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%
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%

Rear-type/ species/ Migr Yr[A]	LGR-TX	BON-TX	LGR-CX	BON-CX	BON efficiency (TX + CX)
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%
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	80	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	62	106	359	498	99.3%
HST-SAL-B run	70	112	99	128	99.0%
WST	94	143	123	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)	98.9%	Geom (CH)	97.3%

Rear-type/ species/ Migr Yr[A]	LGR-TX	BON-TX	LGR-CX	BON-CX	BON efficiency (TX + CX)
2010					
HCH-CATH	20	26	51	74	99.0%
HCH-CLWH	30	50	205	260	98.6%
HCH-DWOR	21	42	199	262	99.6%
HCH-IMNA	25	31	78	90	97.4%
HCH-MCCA	36	45	109	142	95.3%
HCH-PAHH	4	4	1	2	95.9%
HCH-RAPH	34	54	139	206	98.1%
HCH-SAWT	12	15	27	32	98.7%
WCH	62	89	158	183	100.0%
HSK-OXBH	N/A[B]	N/A[B]	25	46	94.3%
HSK-SAWT	N/A[B]	N/A[B]	24	44	97.5%
Geom(SK)	95.9%			Geom (CH)	98.1%

[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), Hell's 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 possible.

Table H.2 Adult success rates for all CSS groups for the juvenile outmigration years 2000-2010. Adult success rate for the transported (T0 before 2006, TX thereafter) and in-river groups (CX), 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 T0	Success Cx	Success ratio T0/ Cx
2000	HCH	CATH	NA	NA	NA
	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 - 0.91)	**0.95 (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)**
	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)
	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)

Mig. Year	Rear-type / Species[A]	Hatchery Group[A]	Success T0	Success Cx	Success ratio T0/ Cx
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 (0.71 - 0.87)	0.89 (0.76 - 1.06)
	HCH	CLWH	0.62 (0.54 - 0.71)	0.73 (0.68 - 0.77)	**0.86 (0.73 - 0.99)**
	HCH	DWOR	0.66 (0.55 - 0.77)	0.75 (0.69 - 0.82)	0.87 (0.72 - 1.05)
	HCH	IMNA	0.63 (0.56 - 0.71)	0.60 (0.52 - 0.68)	1.05 (0.87 - 1.26)
	HCH	MCCA	0.59 (0.51 - 0.68)	0.54 (0.47 - 0.61)	1.10 (0.91 - 1.34)
	HCH	PAHH	0.56 (0.25 - 0.83)	0.62 (0.53 - 0.71)	0.89 (0.39 - 1.41)
	HCH	RAPH	0.71 (0.66 - 0.76)	0.70 (0.65 - 0.74)	1.02 (0.92 - 1.12)
	HCH	SAWT	0.86 (0.69 - 1.00)	0.91 (0.67 - 1.21)	0.94 (0.62 - 1.34)
	WCH		0.74 (0.68 - 0.80)	0.72 (0.69 - 0.76)	1.03 (0.93 - 1.13)
	HST	GRN A Run	0.58 (0.51 - 0.63)	0.76 (0.72 - 0.80)	**0.76 (0.67 - 0.85)**
	HST	HCD A Run	0.60 (0.53 - 0.66)	0.72 (0.64 - 0.79)	**0.83 (0.72 - 0.97)**
	HST	IMN A Run	0.59 (0.53 - 0.65)	0.72 (0.67 - 0.77)	**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 (0.50 - 0.66)	0.72 (0.68 - 0.75)	**0.81 (0.69 - 0.93)**
	HST	SAL B Run	0.62 (0.54 - 0.69)	0.77 (0.70 - 0.83)	**0.81 (0.70 - 0.93)**
	WST		0.65 (0.59 - 0.72)	0.75 (0.69 - 0.81)	**0.88 (0.77 - 0.99)**
	HSK	OXHB	0.66 (0.52 - 0.80)	0.61 (0.48 - 0.74)	1.07 (0.80 - 1.46)
	HSK	SAWT	0.65 (0.59 - 0.71)	0.61 (0.56 - 0.66)	1.07 (0.95 - 1.21)
2010	HCH	CATH	0.75 (0.60 - 0.88)	0.67 (0.58 - 0.76)	1.12 (0.88 - 1.40)
	HCH	CLWH	0.57 (0.46 - 0.70)	0.75 (0.71 - 0.79)	**0.76 (0.60 - 0.94)**
	HCH	DWOR	0.48 (0.35 - 0.61)	0.73 (0.68 - 0.77)	**0.66 (0.48 - 0.85)**
	HCH	IMNA	0.79 (0.67 - 0.90)	0.85 (0.79 - 0.91)	0.93 (0.77 - 1.09)
	HCH	MCCA	0.79 (0.68 - 0.90)	0.76 (0.70 - 0.81)	1.04 (0.87 - 1.21)
	HCH	PAHH	1.00 (0.47 - 1.00)[B]	0.50 (0.03 - 0.97)[B]	NSD[B]
	HCH	RAPH	0.59 (0.49 - 0.71)	0.64 (0.58 - 0.69)	0.93 (0.75 - 1.13)
	HCH	SAWT	0.78 (0.61 - 0.95)	0.82 (0.71 - 0.93)	0.95 (0.72 - 1.23)
	WCH		0.69 (0.61 - 0.78)	0.86 (0.82 - 0.90)	**0.81 (0.71 - 0.92)**
	HSK	OXHB	N/A[C]	0.54 (0.42 - 0.67)	N/A[C]
	HSK	SAWT	N/A[C]	0.52 (0.40 - 0.64)	N/A[C]

[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), Hell's 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 H.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.

Table H.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. Wild steelhead estimates include 1-salt, 2-salt, and 3-salt adults.

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	0.704
2010	0.814	0.777
2011	0.664	N/A*

***To be updated in 2013 CSS Annual Report**