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

2009 Annual Report

BPA Contract #19960200

Prepared by

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Executive Summary

This report covers the 10th complete brood year return of adults from PIT-tagged fish. These adult returns are from the 1997-2007 juvenile migrations of hatchery Chinook and the 1994-2007 juvenile migrations of wild Chinook. Also included are adult returns from 1997-2006 steelhead juvenile migrations that originate from wild steelhead on the lower Clearwater River and wild and hatchery steelhead from other tagging operations.

The primary purpose of this report is to update the time series of smolt-to-adult survival rate data and related parameters with additional years of data. This report completes the 3-salt returns from migration year 2005 for wild and hatchery Chinook and steelhead to Lower Granite Dam. For wild and hatchery Chinook, this report also provides 3-salt returns from migration year 2006 and 2-salt returns from migration year 2007 through a cutoff date of August 4, 2009. For wild and hatchery steelhead, it provides completed 2-salt returns for wild and hatchery steelhead that out migrated in 2006.

An additional objective for this year's CSS annual report was to begin to compare PIT tag SARs with SARs estimated from run reconstruction for Snake River spring/summer Chinook as recommended by the ISAB/ISRP (2009). The 2009 activity focused on estimation of Lower Granite Dam wild smolt numbers and their associated variance.

Significant changes in downstream passage conditions for Chinook and steelhead have occurred since the beginning of the CSS study. These changes in passage conditions are reflected in the survival rate and related parameter data and resulting CSS analysis. The 2007 outmigration conditions were characterized by very low flows during the spring migration period in the Snake River, similar to the low-flow conditions in 2001, 2004 and 2005. However, spill for fish passage was provided in 2007 during these low river flows, a notable difference from any year in the historic record. Under the high-spill, low-flow conditions within the Snake River in 2007, juvenile spring/summer Chinook and steelhead exhibited relatively high survival and fast travel times. Spring flows in 2007 were near the Biological Opinion flow targets of 237 kcfs in the lower and middle Columbia River, but unlike previous years, spill was provided 24 hours per day at most projects.

Overall, results presented in the CSS indicate that SARs of transported wild Chinook and steelhead have not met the levels of survival necessary to achieve the Northwest Power and Conservation Council SAR objectives. Similarly, SARs of in-river wild Chinook and steelhead have not met the Council's SAR objectives, but analyses indicate that improvements in survival at the juvenile stage could be achieved through reductions in water transit time and/or increased spill levels. Further, there is evidence that the relative SARs of transported and in-river migrants are a function of in-river survival and that transportation increases steelhead straying rates while reducing adult upstream migration success of both Chinook and steelhead. The effects of transportation and in-river migration conditions on Snake River sockeye are currently unclear, but efforts to PIT-tag sufficient numbers of sockeye began in 2009 and initial adult returns will occur in 2010. Given the complex interactions among management actions and the intended and unintended biological responses within and across ESUs, a comprehensive decision analysis that considers the array of benefits and harms for alternative management options would be informative and valuable for the region, in an effort to consistently achieve regional management objectives.

Synopsis of Key Findings

- Consistent with findings of the Ten-year Retrospective Summary Report, juvenile travel time, instantaneous mortality rates and survival rates are all strongly influenced by managed river conditions including spill and flow. Notably, juvenile spring/summer Chinook and steelhead exhibited relatively high survival and fast travel times in the Snake River under the low-flow, high-spill conditions of 2007.
- Snake River water transit times and temperatures were nearly identical in 2007 and 2005, but spill was provided in 2007 while it was not provided in 2005. On average, LGR-MCN reach survival rates were 11 percentage points higher for wild Chinook and 12 percentage points higher for wild and hatchery steelhead in 2007 compared to 2005. In addition, LGR-MCN fish travel times averaged 4.4 days faster for Chinook and 1.3 days faster for steelhead in 2007 than in 2005. These results indicate that spill in 2007 increased juvenile survival and decreased fish travel time over what would likely have occurred if a no-spill, maximized transportation strategy had been implemented.
- Overall PIT-tag SARs for 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. In addition, transportation SARs for wild Chinook and steelhead also fell short of the NPCC objectives.
- Run-reconstruction SARs were also below the 4% average and 2% minimum objectives for recovery. Run-reconstruction SARs showed greater levels of uncertainty when uncertainty in the collection sample was incorporated compared to previous estimates. Even higher uncertainty in run-reconstruction SARs is likely when uncertainty in adult return estimation is included.
- TIRs of both wild Chinook and wild steelhead demonstrated considerable variability across study years and appeared to be associated with in-river survival rates. Expected values of TIRs decreased significantly with increases in reach survival for juvenile Chinook and steelhead. The results from 2007 suggest that the provision of spill may lower TIRs by increasing reach survival, even under low-flow conditions. However, incorporating variation in sample size in analyzing the entire CSS data set (while not incorporating the influence of in-river survival on the estimation of central tendency for TIRs) resulted in the central tendency being greater than one for TIRs of wild steelhead, over the years analyzed. The evidence indicated that the central tendency of TIRs of wild Chinook were not statistically different from one, over the years analyzed.
- Incorporating variation in sample size in analyzing the entire CSS data set

demonstrated that average *D* values for wild Chinook were statistically less than one, providing evidence of delayed mortality for transported wild Chinook. The evidence also indicated that wild steelhead *D* values on average were not statistically different from one, a result that is inconclusive as to whether transported wild steelhead express delayed mortality.

- Comparisons of the C_0 versus C_1 SARs indicate that bypassed fish appear to have a lower SAR than undetected in-river migrants. The magnitude of those differences varied across years.
- Adult upstream migration success from BON to LGR appeared to be negatively affected by transportation during the juvenile outmigration. Overall, the success rate for adults that were transported as juveniles was approximately 9% lower than the success rate for adults that out-migrated in-river.
- Straying rates during the adult migration were higher for individuals that were transported as juveniles versus those that out-migrated in-river. This was statistically significant for Snake River hatchery Chinook and Snake River wild and hatchery steelhead, but not for wild Chinook.

Chapter 1 -- Introduction

The Comparative Survival Study (CSS; BPA Project 199602000) began in 1996 with the objective of establishing a long term dataset of the survival rate of annual 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 and transporting them downstream in barges and trucks and releasing them downstream of Bonneville Dam was compensating for the effect of the Federal Columbia River Power System (FCRPS) on survival of Snake Basin spring/summer Chinook salmon migrating through the hydrosystem.

The completion of this annual report for the CSS signifies the 13th outmigration year of hatchery spring/summer Chinook salmon marked with Passive Integrated Transponder (PIT) tags as part of the CSS. Its' also the 10th complete brood year return as adults of those PIT-tagged fish, covering adult returns from 1997-2007 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 1994-2007 wild Chinook juvenile migrations). The CSS tags 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 1997-2006 wild and hatchery steelhead migrations.

The primary purpose of this 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 10-yr retrospective analysis 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). This report completes the 3-salt returns from migration year 2005 for wild and hatchery Chinook and steelhead (all returns are to Lower Granite Dam). For wild and hatchery Chinook, this report also provides 3-salt returns from migration year 2006 and 2-salt returns from migration year 2007 through a cutoff date of 04 August 2009. For wild and hatchery steelhead, it provides completed 2-salt returns for wild and hatchery steelhead that outmigrated in 2006 (any 3-salt returns of PIT-tagged steelhead are few, but will occur after July 1, 2009).

All of the Chinook salmon evaluated in the CSS study exhibit a stream-type life history. 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. Reductions in the number of individuals detected as the tagged fish grow older provide estimates of survival. This allows comparisons of survival 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) as illustrated in Figure 1.1.

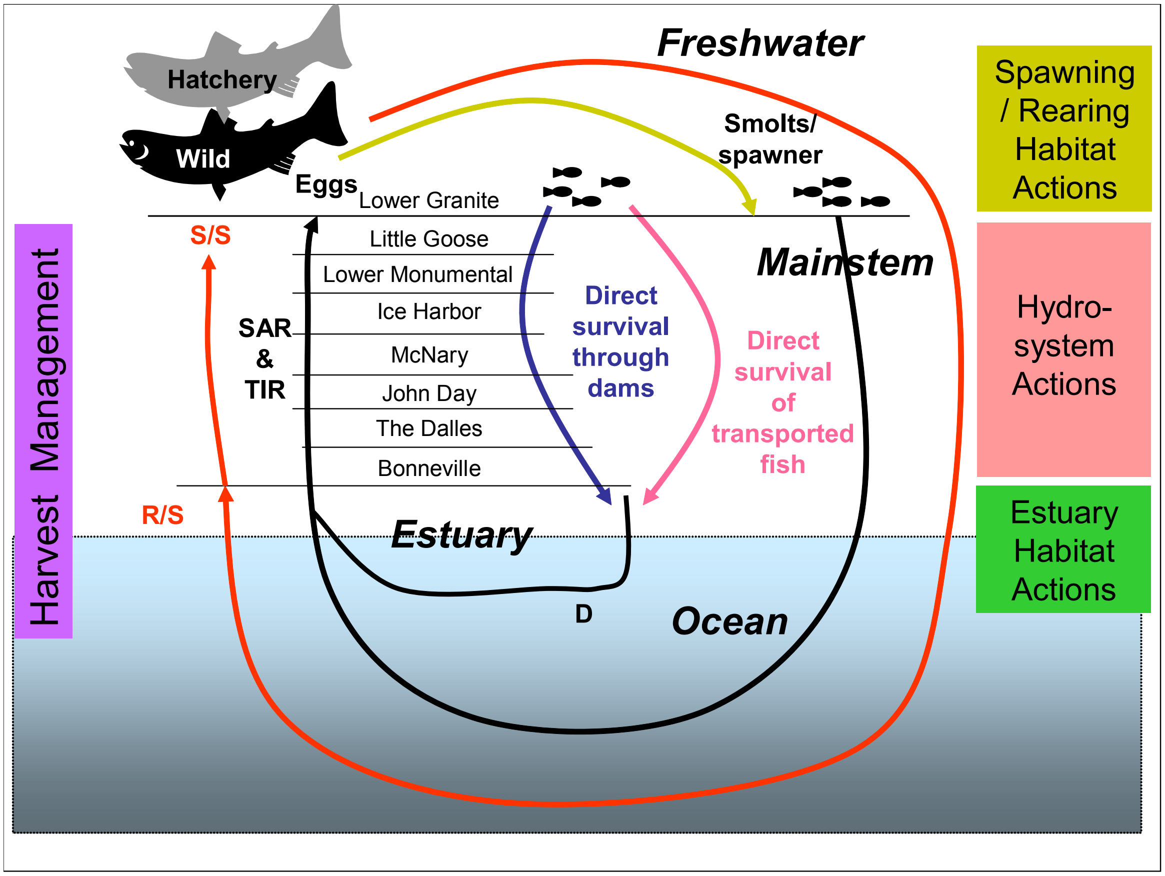


Figure 1-1. Salmonid life cycle in the Snake River and lower Columbia River basins (Source: Marmorek et al. 2004).

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 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. The location of all tagging sites is identified in Figures 1.2 and 1.3. 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
BPA: http://www.efw.bpa.gov/searchpublications/index.aspx?projid .

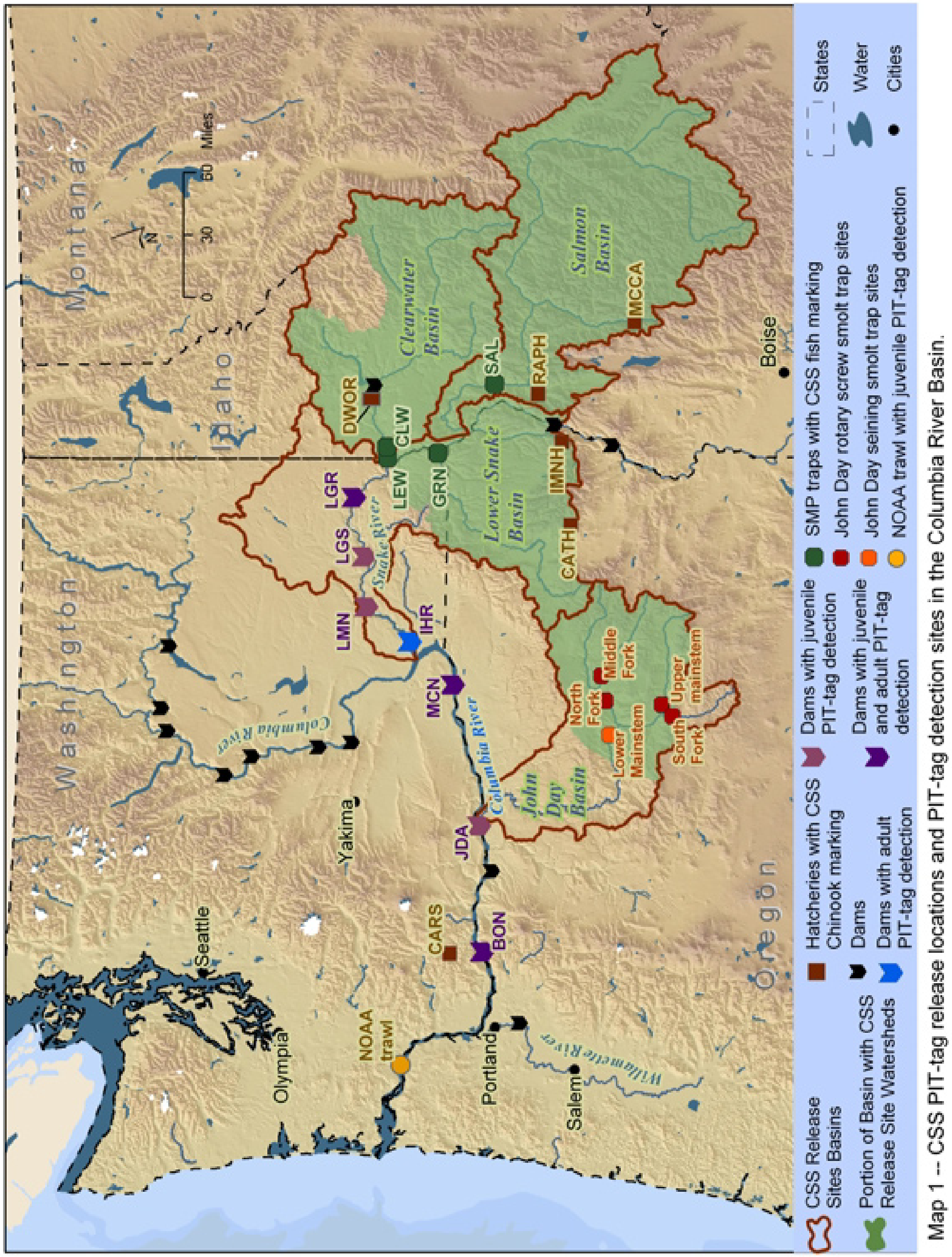


Figure 1-2. CSS PIT tag release locations and PIT-tag detection sites in the Columbia River Basin.

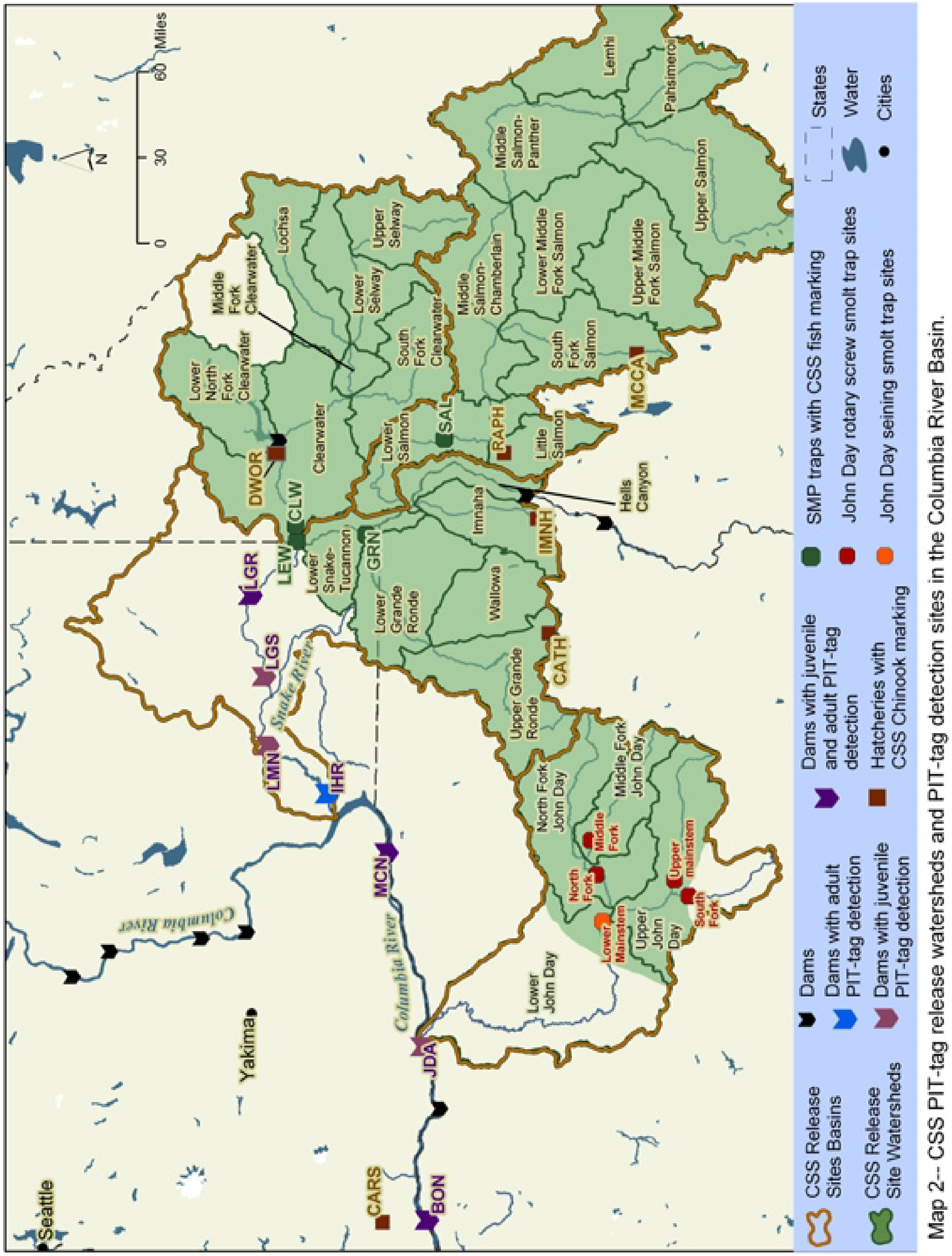


Figure 1-3. CSS PIT-tag release watersheds and PIT-tag detection sites in the Columbia River Basin.

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 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.

Regionally 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 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 against the regional management goal to maintain SARs between 2-6%, 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 outmigration 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), 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 each fish, and lower impacts due to trapping and handling occur where automated detection stations exist.

Within the Columbia and Snake River mainstems PIT-tag detectors at the dams 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). Given sufficient numbers of fish among release groups and appropriate distribution across subbasins, ESUs, hatchery vs. wild, and outmigration season, survival rates of subgroups of fish with unique life history experience, or aggregate groups with common life history experiences, can be estimated at discrete or combined life-stages throughout their life cycle. The CSS PIT-tagging design and application allows the use of the Cormack-Jolly-Seber (CJS) method with multiple mark-recapture information to estimate survival of the total number of fish estimated to approach the upper most dam (Lower Granite Dam), thus representing the conditions that the majority of fish migrating through the hydrosystem experience.

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, through the use of PIT tagging efforts, to address several of the basin wide monitoring needs and to provide these demographic data and other responses for Snake River and Columbia River wild and hatchery salmon and steelhead populations. The CSS is designed with the goal of obtaining annual estimates of smolt-to-adult survival rates (SARs) for Snake River hatchery and wild spring/summer Chinook and steelhead. Estimation of the overall, aggregate SAR of fish that are transported and those that migrate entirely in-river is key to evaluation of avoidance of jeopardy as well as progress towards recovery goals.

Monitoring survival rates in this way over the life-cycle can help identify where survival bottlenecks are occurring, which is critical input for informed management decisions (Good et al. 2007). The objective of the CSS was and is to build a long-term database monitoring smolt-to-adult return rates and passage characteristics of specific wild and hatchery groups of Chinook and steelhead throughout the Columbia River Basin. 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 will make use of mark groups from other research to meet CSS requirements in order to reduce costs and handling of fish. The CSS is also appropriate for and examines environmental factors associated with life-cycle survival rates and evaluates the hypothesized mechanisms for variations in those rates.

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 Lower Granite Dam (LGR) and returning as adults back to LGR (LGR-LGR SARs). 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, or "delayed", mortality (i.e., to smolts after passing BON) caused as a result of passage through the hydrosystem. However, because TIR compares SARs starting from collector projects, it does not by itself provide a direct estimate of any delayed mortality specific to transported fish.

Related to TIR is "D", the ratio between SARs of transported fish and in-river fish from downstream of Bonneville Dam (BON) as smolts back to LGR (BON-LGR SARs) as adults. Estimates of *D* isolate mortality occurring during juvenile salmon passage between Lower Granite and Bonneville dams from that occurring afterwards during time in the ocean and upon returning upriver as adults to Lower Granite Dam for transported smolts. When *D* is equal to one indicates that there is no difference in survival rate after hydrosystem passage; $D < 1$ indicates transported smolts die at a higher rate after passing BON than smolts that have migrated through the hydrosystem; $D > 1$ indicates transported fish have higher survival after passing BON. 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: tagged fish that are detected at Snake River collector dams (i.e., Lower Granite [LGR], Little Goose [LGS], or Lower Monumental [LMN]) and transported (T0); tagged fish collected at Snake River dams and returned to the river (C1), or tagged fish never collected or transported (C0) at the Snake River dams. These SARs and the ratios derived from them in this report are estimated for the entire migration year. The SARs developed for each of these study categories will be weighted by the proportion of the run-at-large (untagged and tagged fish) represented by these categories to provide overall annual SARs. Because no transported smolts and only a small number of in-river smolts are enumerated at BON, the BON-LGR SAR is estimated from the LGR-LGR SAR, adjusted by annual in-river survival rate estimates (through the hydrosystem) and assumed average direct transport survival rate from empirical studies.

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 in 2007 and 2008. The start of transportation at LGS and LMN was delayed further to account for smolt travel time between projects, ranging from 4 to 12 days later than LGR depending on year. This change in operations affects 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 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 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 the Transport-With-Spill group [TWS] 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 the Bypass-With-Spill Group [BWS] in this report) follows the default return-to-river routing at each collector dam throughout the season. For example, on entering the bypass facilities at the transportation sites two things can happen. If transportation is taking place, TWS group fish are transported and BWS group fish are bypassed. If transportation is not taking place, both groups are bypassed. Smolts in the two study groups created would experience different passage routes through the hydrosystem whenever transportation was occurring. In the future, these two groups will provide the opportunity to compare estimated SARs between transport and non-transportation management scenarios.

Combining Groups TWS and BWS provides a composite group comparable to what has been used in the CSS in all migration years through 2005. For the analyses work in this report, we use the composite group to estimate CJS reach survival rates, SARs, TIRs, and D as in past years. The estimated smolt numbers and adult return data for Group TWS provides a direct estimation of the annual overall SARs beginning with the 2006 migrants. We compare these direct estimates with annual overall SARs computed using the original methods for the 2006 and 2007 yearling Chinook migration years and the 2006 steelhead migration year in this report.

To evaluate different aspects of the effectiveness of transportation relative to in-river migration, annual SAR ratios between T0 and C0 fish are compared, first from passage at Lower Granite Dam 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. With the new pre-assigned groups of smolts, comparison of a year's existing management protocol (a mixture of spill, early season bypass, and later season transport) may be made with an approach that exists without transportation. This comparison will providing an additional dimension in the evaluation of the effectiveness of transportation relative to in-river migration.

Coordination and pre-assignments during 2009

Wherever possible the CSS will make use of mark groups from other research and coordinate with other marking programs to meet CSS requirements in order to reduce costs and handling of fish. To that end the CSS has had 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 2009 migration year are outlined in Appendix C (these smolts will be analyzed in future reports). In addition to the present mark groups, in 2010 the CSS proposes to continue coordination efforts to affect cost savings and avoid redundancy as recommended by the ISAB/ISRP reviews (2007 and 2009). Collaborations in recent years include 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 (See Appendix C for details). The CSS has also recently collaborated with Idaho Power Company (IPC), and historically coordinated with the Smolt Monitoring Project (SMP) (Appendix C.) The CSS will 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.

Historic in-river conditions

The environmental conditions experienced by out-migrating juvenile yearling Chinook and steelhead have varied considerably over the 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) had lower spill. During 2007, conditions were particularly unique. Low flows were accompanied by high spring spill percentages and low transportation percentages. The transportation program underwent a change in operations during 2006. Transportation was delayed at LGR until April 20 and May 1 in 2006 and 2007 respectively. This was combined with an increased spill percentage, and resulted in a lower proportion of smolts being transported. The transportation percentage in 2001, 2004, and 2005 were three years with the highest transportation percentages of CSS PIT-tagged wild fish. 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 undoubtedly contributed to a lower percentage of wild smolts transported in 2007 than other low flow years.

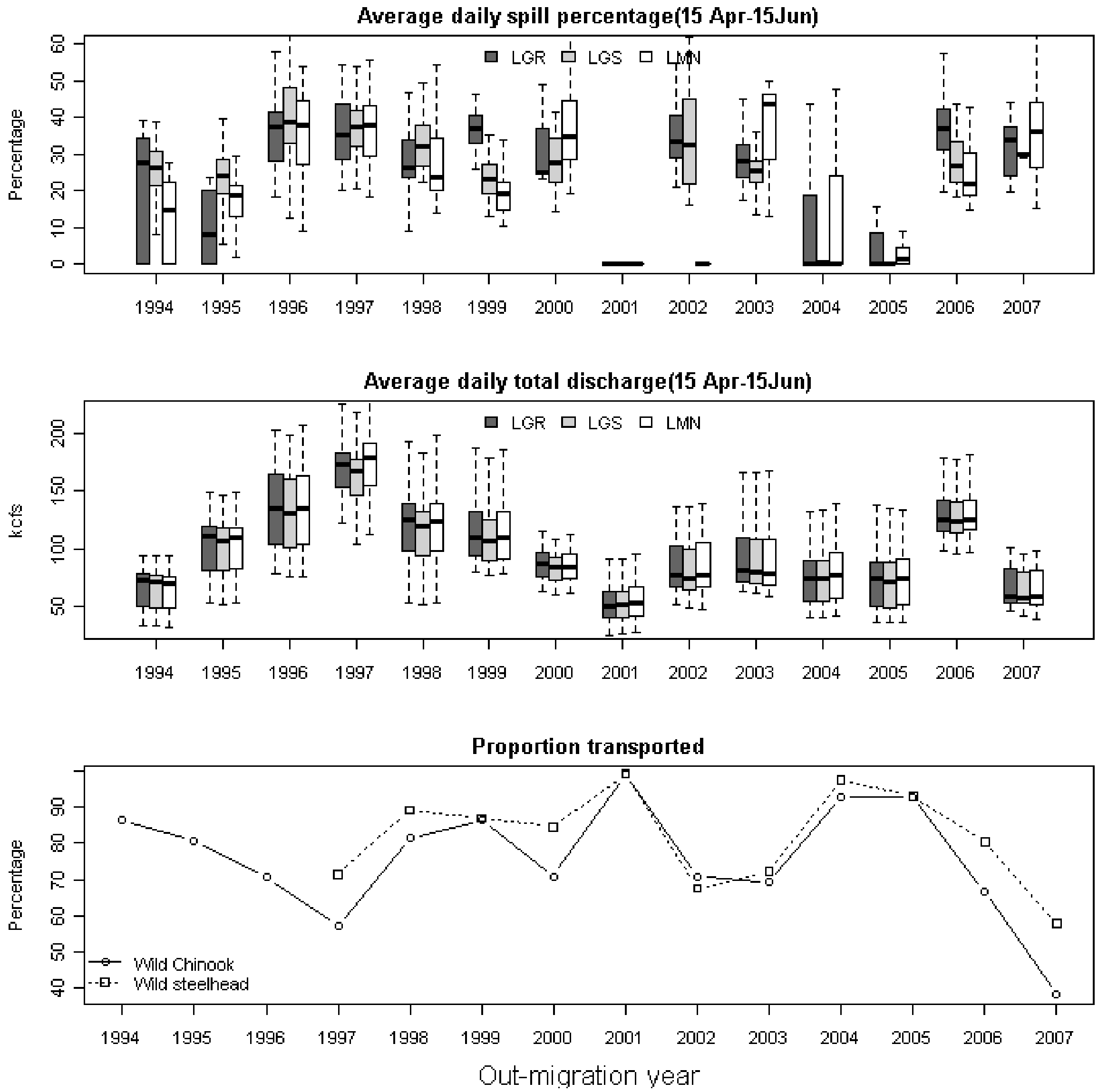


Figure 1-4. The top, middle, and bottom panels are summaries of spill percentage, flow, and the proportion transported over the historical context of the CSS. Spill percentages and flow are shown for the three primary transportation dams. The proportion transported is shown for the wild Snake River stocks involved in the CSS as expressed by population proportion of T0 fish from Table 7.8 and Table 7.12 (except for the 2007 wild steelhead estimate which is a preliminary estimate).

Chapter 2 -- Methods

Tagging

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 they are generally retained and function throughout the life of the fish. Wild and hatchery Chinook and steelhead used in the CSS analyses were obtained from all available marking efforts in the Snake River basin 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 2007 (number and origin of PIT-tagged wild Chinook analyzed is in Table B-1). 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 2006 (number and origin of PIT-tagged wild steelhead analyzed is in Table B-4). 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 2006 (number and origin of PIT-tagged hatchery steelhead analyzed is in Table B-5). 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.

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 (number and origin of PIT-tagged hatchery Chinook analyzed is in Table B-2 and B-3). Hatcheries that accounted for a major portion of Chinook production in their respective drainages were selected. Since study inception, the CSS has PIT-tagged juvenile Chinook at McCall, Rapid River, Dworshak, and Lookingglass hatcheries. Two Chinook stocks are tagged at Lookingglass Hatchery: a Catherine Creek stock released in the Grand Ronde River drainage and an Imnaha River stock released into the Imnaha River. This former stock became available to the CSS in 2001 after the Lookingglass Hatchery complex changed its operation to rearing only Grande Ronde River basin endemic stocks.

Based on past estimates of SARs, sufficient numbers of smolts were tagged to ensure enough returning adults to compute statistically rigorous SAR estimates. All attempts were made to ensure that the PIT-tagged fish are representative of their untagged cohorts. 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. Pre-release tag loss and mortality of PIT-tagged fish were monitored, and the tagging files were transferred to the regional PTAGIS database in Portland, OR. The study requires that prior to pre-assigning groups, PIT-tagged fish are not necessarily routed or diverted at collector projects in the proportions that non-tagged fish are; consequently adjustments are made (described below) in estimation to more closely represent the experience of run-of-the-river (non-tagged) fish.

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 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. Therefore we use only these release groups to compose the C_0 group (fish that remained in-river throughout their migration) in this analysis; fish collected and marked at LGR do not have a similar experience (explained in more detail below).

Estimation Overview

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 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, LGS, LMN, McNary (MCN), John Day (JDA), and BON (Figures 1-2 and 1-3). Upon arrival at LGR, LGS and LMN, smolts can go 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 fish 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, fish without PIT-tags that enter the collection facility are generally put in trucks or barges and transported to below BON. Prior to 2006, 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 that would then follow the same route as un-tagged fish or, if not submitted, would follow the default return to river route. In addition, PIT-tag detections are 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 in recent years allowing for additional analyses.

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 ($SAR_{LGR\text{-}to\text{-}LGR}$); survival from smolt outbound arrival at BON to LGR as adults ($SAR_{BON\text{-}to\text{-}LGR}$); 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 is re-sampled with replacement to create 1000 simulated populations. These 1000 iterations are used to produce a distribution of values that describe the mean and variance associated with the point estimate. From the set of 1000 iterations, non-parametric 80%, 90%, and 95% confidence intervals were computed for each parameter of interest. 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 (failure to reject a false null hypothesis) and Type II (failure to accept a true alternative hypothesis) errors in comparisons among study groups of fish for the various parameters of interest.

Estimation of in-river survival rates

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 (Cormack 1964; Jolly 1965; Seber 1965). 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, describes the direct impacts of the hydrosystem on the in-river population of smolts, and 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 an overall multi-reach survival estimate, we allow individual reach survival estimates to exceed 100%. However, an estimate of survival rate for a specific reach was considered unreliable when its coefficient of variation exceeded 25%.

When fewer than six individual reach survival estimates were available, the product of the useable estimates was extrapolated to estimate SR. The total number of reaches for which survival was estimable was a function of the number of smolts in the initial release and recovery effort available in that year. Prior to 1998, there was limited PIT-tag detection capability at JDA and TWX. 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 have been possible in most cases. Estimation of S_R with fewer than 6 individual estimates was calculated as follows. First, the product of the survival estimates over the longest reach possible was converted to survival per mile. This was then expanded to the number of miles between LGR and BON. However, because per mile survival rates thus generated were generally lower for the Snake River than for the lower Columbia River, direct estimates of in-river survival over the longest reach possible were preferable

Estimation of smolts in study categories

For convenience, we made comparisons between SARs of groups of smolts with different hydrosystem experiences from a common start and end point. Thus, LGR-to-LGR SARs were estimated for all groups even including smolts not detected at LGR. The population of PIT-tagged study fish arriving at LGR was partitioned into three categories of smolts 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, respectively.

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. Smolts transported at LGR represented a larger group than the sum of smolts actually transported at all projects, because some smolts died while migrating in-river from LGR to either LGS or LMN. A proportion of those that died relative to the fraction of transported fish among total fish that survive migration past these collector dams (i.e. transported or in-river) were summed with fish that are actually transported to make up the total group of fish that were "destined" for transportation (LGR equivalents). Therefore, an estimated survival rate was needed to convert actual transport numbers at LGS and LMN into their LGR equivalents starting number. The actual transport numbers at LGR, LGS, and LMN are in Table B-22 for wild Chinook, Table B-24 for hatchery Chinook, Table B-27 for wild steelhead, and Table B-29 for hatchery steelhead. The PIT-tagged fish destined for transportation at LGR, LGS, and LMN together formed Category T_0. Using the definitions presented in the following text box, the formula for estimating the number of fish in Category T_0 was

$$T_0 = X_{12} + \frac{X_{102}}{S_2} + \frac{X_{1002}}{S_2 * S_3} \qquad [2.1]$$

Symbol Definitions:

R = number of PIT-tagged fish released
n2 (or X12) = number of smolts transported at LGR
n3 (or X102) = number first-detected and transported at LGS
n4 (or X1002) = number first-detected and transported at LMN

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

m12 = number of fish first detected at LGR
m13 = number of fish first detected at LGS
m14 = number of fish first detected at LMN
m15 = number of fish first detected at MCN
m16 = number of fish first detected at JDA
m17 = number of fish first detected at BON
m18 = number of fish first detected at TWX

d2 = number of fish removed at LGR (includes all transported fish, site-specific mortalities, and unknown disposition fish)
d3 = number of fish removed at LGS regardless of prior capture history (includes all transported fish, site-specific mortalities, and unknown disposition fish)
d4 = number of fish removed at LMN regardless of prior capture history (includes all transported fish, site-specific mortalities, unknown disposition fish, and fish accidentally removed for use in NMFS survival study at IHR)
d0 = site-specific removals at dams below LMN of fish not detected previously at a Snake River Dam estimated in LGR-equivalents.
d1 = site-specific removals at dams below LMN of fish previously detected at a Snake River Dam estimated in LGR-equivalents.
Note: beginning in migration year 2003, d0 and d1 now contain site-specific removals that have been expanded by their corresponding estimated survival rate from LGR. Prior years used a fixed expansion rate of 50% survival rate for all removals below LMN.

d5.0 = removals of C_0 type fish at MCN
d6.0 = removals of C_0 type fish at JDA
d7.0 = removals of C_0 type fish at BON
d5.1 = removals of C_1 type fish at MCN
d6.1 = removals of C_1 type fish at JDA
d7.1 = removals of C_1 type fish at BON

AT_{LGR} = adult tally of smolts transported at LGR, capture history “12”
AT_{LGS} = adult tally of smolts transported at LGS, capture history “102”
AT_{LMN} = adult tally of smolts transported at LMN, capture history “1002”
AC_0 = adult tally of smolts migrating in-river with no detections at Snake River dams
AC_1 = adult tally of smolts migrating in-river with ≥1 detections at Snake River dams

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 covered in this report, 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) (equivalently, dividing the number of smolts detected at LGR by the CJS estimate of seasonal LGR collection efficiency) 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 (i.e., not return-to-river) at sites below LMN had to be taken into account. Using symbols defined in the text box, the formula for estimating the expected number of fish in Category C_0 is

$$C_0 = R * S_1 - \left(m_{12} + \frac{m_{13}}{S_2} + \frac{m_{14}}{S_2 * S_3} \right) - d_0 \qquad [2.2]$$

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. The C_1 category exists 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 of passing through Snake River dam bypass/collection systems on subsequent survival, and in investigating non-transport operations. Using symbols defined in the text box, the formula for estimating the expected number of fish in Category C_1 is:

$$C_1 = (m_{12} - d_2) + \left(\frac{(m_{13} - d_3)}{S_2} \right) + \left(\frac{(m_{14} - d_4)}{S_2 * S_3} \right) - d_1 \qquad [2.3]$$

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. Additionally the C_0 smolts that did exist passed mostly through turbines without 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). Returning adults of steelhead and Chinook that had no detections 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, C_1 data were used instead of C_0 data in the computation of SAR, TIR, and *D* parameters (described below) and therefore is 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_O category (see Chapter 7; Tables 7-7, 7-8, 7-13, 7-14). If the number of C_0 PIT-tagged smolts is too low, the SAR estimates could be unreliable. Therefore, we combined the C_0 and C_1 estimates for PIT-tagged steelhead in 2004 and both Chinook and steelhead in 2005 in order to create the in-river groups used to estimate the SARs, TIR, and *D*.

Estimation of SARs and Ratios of SARs for Study Categories

LGR has been the primary upriver evaluation site for many objectives of the CSS. Adults detected at LGR 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 count is the sum of the 1 to 3-ocean returns (only fish returning in the same year as their smolt outmigration, called minis, are excluded). The number of returning adults at LGR by age is in Table 7-11 for wild steelhead and Table 7-12 for hatchery steelhead. The adults Chinook count is the sum of the 2 to 4-ocean returns. Chinook jacks and mini-jacks (1-ocean or less, precocial males) are excluded from SARs due to the limited contribution to spawning of these age classes. The number of returning adults (and jacks) at LGR by age is in Table 7-4 for wild Chinook and Table 7-5 for hatchery Chinook.

SARs are calculated by study category with the adult tally in the numerator and estimated smolt numbers in denominator. The SAR(T_0) has been referred to as $SAR_2(T_0)$ in reports prior to the 10-year summary report. The formulas are:

$$SAR(T_0) = \frac{\{AT_{LGR} + AT_{LGS} + AT_{LMN}\}}{T_0} \tag{2.4}$$

$$SAR(C_0) = \frac{\{AC_0\}}{C_0} \tag{2.5}$$

$$SAR(C_1) = \frac{\{AC_1\}}{C_1} \tag{2.6}$$

The difference between SAR(T_0) and SAR(C_0) was characterized as the ratio of these SARs and denoted as the TIR (transport: in-river ratio):

$$TIR = \frac{SAR(T_0)}{SAR(C_0)} \tag{2.7}$$

The statistical test of whether SAR(T_0) is significantly (α =0.05) greater than SAR(C_0) is conducted by evaluating whether TIR is significantly greater than 1. We use the criteria that the lower limit of the non-parametric 90% confidence interval of TIR must exceed 1 (i.e., below this lower limit threshold occurs 5% of the TIR estimates in rank order from the distribution of bootstrap iterations). This provides a statistical one-tailed (α=0.05) test of H_0 TIR $\leq$1 versus H_A TIR>1.

Estimation of *D*

A parameter that evaluates the differential delayed effects of transportation in relation to in-river outmigrants is *D*. *D* is the ratio of SARs of transported smolts (T_0) and in-river outmigrants (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; *D* is effectively:

$$D = \frac{SAR_{BON-LGR}(T_0)}{SAR_{BON-LGR}(C_0)} \tag{2.8}$$

The total number of smolts passing BON was not observed directly. However, *D* can be estimated by removing the portion of the $SAR_{LGR\text{-}to\text{-}LGR}$ that contains the LGR to BON juvenile hydrosystem survival. So, the parameters S_T and S_R were divided out of their respective $SAR_{LGR\text{-}to\text{-}LGR}$ values to estimate the $SAR_{BON\text{-}LGR}$ for each study group. The resulting estimate of *D* was calculated as:

$$D = \frac{\left(\dfrac{SAR(T_0)}{S_T}\right)}{\left(\dfrac{SAR(C_0)}{S_R}\right)} \qquad [2.9]$$

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 was simply $SAR(C_0)/S_R$, where S_R was 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.

In the numerator of *D* (transportation portion), the quotient is $SAR(T_0)/S_T$, where S_T reflects an adjustment of the project-specific proportions of the transported PIT-tagged fish to mimic the proportions of untagged fish transported at the different projects. 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 resulting formula for estimating S_T utilizes estimates of the total number 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 untagged fish. The S_T estimate is:

$$S_T = (0.98) * \frac{(t_2 + t_3 + t_4)}{\left(t_2 + \dfrac{t_3}{S_2} + \dfrac{t_4}{S_2 * S_3}\right)} \qquad [2.10]$$

where the t_j is the estimate of the fraction of PIT-tagged fish that would have been transported at each dam if all PIT-tagged fish had been routed to transport at the same rate as the untagged fish. The estimates of S_T have ranged between 0.88 and 0.98 for Chinook and steelhead across the years evaluated in the report. Values of t_j are found in Tables B-22 for wild Chinook, B-24 for hatchery Chinook, B-27 for wild steelhead, and B-29 for hatchery steelhead.

A statistical test of whether *D* is significantly (α =0.05) greater than 1 was conducted in the same manner as was done with TIR. We use the criteria that the lower limit of the non-parametric 90% confidence interval of D must exceed 1 (i.e., below this lower limit threshold occurs 5% of the D estimates in rank order from the distribution of bootstrap iterations). This provides a statistical one-tailed (α=0.05) test of H_0 $D \leq 1$ versus H_A $D > 1$.

Estimation of overall annual SARs (pre-2006 migration years)

Annual estimates of $SAR_{LGR\text{-}to\text{-}LGR}$ reflective of the run-at-large for wild steelhead, hatchery steelhead, wild Chinook, and hatchery Chinook that outmigrated in 1997 to 2005 are computed 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, we estimated 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. This estimation uses run-at-large collection and transportation data for these dams from the FPC Smolt Monitoring Program. The total estimated number transported across the three Snake River collector dams in LGR equivalents equals $T_0^* = t_2+t_3/S_2+t_4/(S_2S_3)$. 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, 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:

$$\begin{aligned} SAR_{Annual} &= w\left(T_0^*\right) * SAR\left(T_0\right) \\ &+ w\left(C_0^*\right) * SAR\left(C_0\right) \\ &+ w\left(C_1^*\right) * SAR\left(C_1\right) \end{aligned} \qquad [2.11]$$

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 migration year 2006 and beyond

With the new approach of pre-assignment into the Groups TWS and BWS, the estimation of annual overall SARs become much simpler. The Group TWS reflects the untagged fish passage experience under a given year's fish passage management scenario. Therefore, estimation of the annual overall SAR is simply the number of returning adults in this group 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 TWS group's release number by the estimated S_1 (survival rate from release to LGR tailrace) obtained from running the CJS model on the combined TWS and BWS groups. The Group BWS has its migrants bypassed if collected at a dam throughout the season. Combining Groups TWS and BWS provides the original release group from which the standard T_0, C_0, and C_1 study categories may be obtained for migration year 2006. The overall SAR for Group TWS migrants does not require a weighting of group-specific SARs; its overall SAR is directly estimated as the number of returning adults divided by the total population (i.e., detected and estimated undetected PIT-tag population) at LGR.

Chapter 3

Juvenile survival, arrival time, travel time, and the in-river environment

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 (see chapter 4 and 6), 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, Mid Columbia, John Day and Lower Columbia river systems.

The first portion of this chapter presents annual demographic metrics by hatchery and by the smallest basin possible (in the case of wild groups). The second portion of this chapter updates the multiple regression models of fish travel time, instantaneous mortality rates and survival rates from chapter 2 of the 10-year report (Schaller et al. 2007). 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 Chinook salmon and steelhead to conditions experienced within the hydrosystem. These analyses distill many of the descriptive elements from the first section of this chapter into a comprehensive analysis. These analyses provide an example of how the CSS PIT-tag results could be used in a predictive fashion to characterize the effects of management actions on fish travel times and in-river juvenile survival rates, while directly accounting for measurement uncertainty and environmental variability.

Methods

PIT-tagged fish and the annual estimates

In this chapter, we define the hydrosystem as the overall reach between Lower Granite Dam 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 hydrosystem into two reaches for summarizing fish travel time, emigration rate, and survival: LGR-MCN and MCN-BON. We used PIT tag detections at LGR and BON to express juvenile out-migration timing for groups of marked smolts in the upper and lower hydrosystem. We define fish migration rate as the rate at which fish migrate through these reaches, expressed in kilometers per day. We define fish travel time (FTT) time spent migrating the LGR-MCN or MCN-BON reach and expressed this in days. 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 operating below BON (Cormack 1964, Jolly 1965, Seber 1965, Burnham et al. 1987).

The first portion of this chapter provides the long-term information about specific groups of fish, organized by management-oriented groups similar to past CSS reports (*e.g.* Dworshak hatchery Chinook, John Day River wild Chinook, etc.). We describe those groups of fish as members of a species from a particular hatchery, or watershed in annual blocks of time.

Specifically, we analyzed these annual parameters and measurements: out-migration timing, LGR-MCN reach survival and fish migration rate, and MCN-BON reach survival and fish migration rate. The Snake River wild Chinook group analyzed in the CSS can be separated into four major basins, the Salmon, Imnaha, Grande Ronde, and Clearwater Rivers; this group was subdivided by these basins for both arrival timing and fish migration rate. All years of juvenile PIT-tag detection at LGR for Snake River groups analyzed in the CSS are presented here (1994-2007). Bonneville Dam arrival timing, MCN-BON survival and fish migration rates for Lower and Mid Columbia River stocks and Snake River stocks that can be compared are shown for the years 2000-2007. These juvenile migration years correspond with the beginning of Bonneville adult detections in 2002 and across years with few cases where expansion-by-mile calculations were needed for juvenile survival from MCN-BON.

For Snake River groups, the LGR-MCN reach survivals are the product of LGR-LGS, LGS-LMN, and LMN-MCN reach survivals shown in Appendix A. The MCN-BON reach survival is then LGR-BON reach survival (Sr) divided by LGR-MCN reach survival. For the Columbia River groups, the closed form CJS estimators were used to generate bootstrapped reach survivals over the reach of interest using program R version 2.9.1 (R Development Core Team 2009). When presenting median annual fish migration rates, we followed Conover's recommendations for approximating confidence intervals around a quantile to calculate 90% confidence intervals around the estimate (Conover 1999).

Multiple regression model parameters

The goal of the multiple regression models in the second portion of this chapter is to evaluate finer-scale analyses of the relationships between survival and specific operational actions or environmental features during the juvenile outmigration. For this reason, we developed and summarize within-year (weekly or multi-weekly) travel time and survival rate estimates for juvenile yearling Chinook and steelhead across years of the CSS. Yearling Chinook and steelhead 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 on 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. 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 groups of fish. 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 detected at MCN. Because the distribution of fish travel times was often right-skewed, we used the median to characterize the central tendency of the fish travel time distributions. We used bootstrapping to estimate the variance of the median FTT_i for each weekly cohort (Efron and Tibshirani 1993). The bootstrapping procedure consisted of resampling the distribution of observed travel times, with replacement, 2,000 times and calculating the median FTT for each bootstrap sample. The variance of the 2,000 bootstrap samples of the median FTT constituted our estimate of the variance of median FTT_i for each weekly release cohort i. In preliminary plots of the data, we noticed exponential associations and heteroscedasticity between some of the environmental variables and median FTT_i. In order to linearize these associations, stabilize the variances, and better approximate normality for the subsequent regressions (Netter and Wasserman 1987), we also calculated median $\log_e(FTT_i)$ and used the same bootstrapping procedure described above to estimate the variance of median $\log_e(FTT_i)$. We implemented the same approach for both yearling Chinook and steelhead, for both the LGR-MCN and MCN-BON reaches.

For yearling Chinook, we calculated median 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 median FTT_i for six weekly cohorts from April 26 through June 5. For steelhead, we calculated median FTT_i for six weekly cohorts from April 17 through May 28 in the LGR-MCN reach. In the MCN-BON reach, we calculated median 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

For each species and Chinook rearing type in the LGR-MCN reach, we estimated the survival rates for each weekly cohort. 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. 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 weekly survival rate estimates in the LGR-MCN reach was 7% for wild yearling Chinook, 6% for hatchery yearling Chinook, and 13% for steelhead (combined hatchery and wild). In the MCN-BON reach, the average CV across the survival rate estimates was 13% for yearling Chinook (hatchery and wild combined, two-week cohorts) and 28% for steelhead (hatchery and wild combined, three-week cohorts). Each release cohort was identified by the Julian day of the midpoint of the cohort.

Similar to the observations on fish travel time, we noticed some exponential associations and heteroscedasticity in preliminary plots of the survival data against environmental variables. In order to linearize these associations, stabilize the variances, and better approximate normality for the subsequent regressions, we also calculated $\log_e(\hat{S})$. By definition, using a log-transformation of $\hat{S}$ assumes that $\hat{S}$ is lognormally distributed. There is both empirical evidence and a theoretical basis for assuming that a lognormal distribution is a reasonable approximation for characterizing variability in survival rates (Peterman 1981, Hilborn and Walters 1992:264-266). In addition, the log-transformation can greatly reduce the high degree of correlation between $\hat{S}$ and var($\hat{S}$) (Burnham et al. 1987:211-212). For lognormally distributed random variables, the variance of $\log_e(x)$ is (Blumenfeld 2001):

$$\mathrm{var}[\log_e(x)] = \log_e(1+[cv(x)]^2) \quad . \qquad [3.1]$$

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, Ricker (1975) provides a numerical characterization of survival, also known as the exponential law of population decline (Quinn and Deriso 1999):

$$S = \frac{N_t}{N_0} = e^{-Z} \quad , \qquad [3.2]$$

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. 3.2 is the solution to the differential equation

$$\frac{\partial N}{\partial t} = -ZN \quad , \qquad [3.3]$$

and the instantaneous mortality rate Z is interpreted as the rate of exponential population decline. Eqn. 3.2 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. 3.2, Z can be estimated as

$$\hat{Z} = \frac{-\log_e(\hat{S})}{t} \quad . \qquad [3.4]$$

In our application, we calculated instantaneous mortality rates (in units of d^{-1}) for each survival cohort using Eqn. 3.4. We used the CJS estimates of survival for each cohort ($\hat{S}_i$) in the numerator and used the median $F\hat{T}T_i$ in the denominator of Eqn. 3.4. While individuals in each release cohort have variable individual *FTT's*, we used the median $F\hat{T}T_i$'s in the denominator of Eqn. 3.4 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 median $F\hat{T}T_i$ estimates, we estimated the cohort-level instantaneous mortality rates ($\hat{Z}_i$) using Eqn. 3.4.

Both $-\log_e(\hat{S}_i)$ and median $F\hat{T}T_i$ 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):

$$\operatorname{var}(\hat{Z}_i) = \operatorname{var}\left(\frac{x}{y}\right) \cong \left(\frac{x}{y}\right)^2 \left(\frac{\sigma_x^2}{x^2} + \frac{\sigma_y^2}{y^2} - \frac{2cor(x,y)\cdot\sqrt{\sigma_x^2\sigma_y^2}}{xy}\right), \qquad [3.5]$$

substituting $-\log_e(\hat{S}_i)$ for x and median $F\hat{T}T_i$ for y, with variances estimated using Eqn. 3.1 and bootstrapping, respectively.

<u>Environmental variables</u>

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 flow, flow^{-1}, water travel time, spill percentage, temperature (based on tailwater total dissolved gas monitoring data, downloaded from the COE website (http://www.nd-wc.usace.army.mil/perl/dataquery.pl) and turbidity values (also downloaded from the COE website) as indicators of conditions each group experienced while passing through the reach. Water travel 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 flow, $flow^{-1}$, spill percentage, temperature and turbidity, whereas for water travel time the sub-reach values were summed for a reach water travel time. In addition to these environmental predictor variables, we also used Julian date as a predictor variable to help capture seasonal effects not represented by 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).

Variable selection and model building

We used linear regression techniques to evaluate the associations between the environmental variables and median FTT and instantaneous mortality (Z). Because preliminary bivariate plots indicated that median $F\hat{T}T_i's$ may be exponential functions of the environmental variables, we modeled median $\log_e(F\hat{T}T_i)$ as the dependent variables. The $\log_e$ transformations were also implemented to help reduce heteroscedasticity and to better approximate normality in the regressions. These regressions were of the form:

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

where $\beta_0, \beta_1,..., \beta_n$ are estimated parameters used to describe the relationship between environmental variables $X_1, X_2,\ldots, X_n$ and median FTT, and $\varepsilon_i \sim N(0,\sigma^2)$. It was unclear whether $\hat{Z}_i$ should be log-transformed, therefore we evaluated modeling both $\hat{Z}_i$ and $\log_e(\hat{Z}_i)$ as the dependent variables. Our determination of whether to model $\hat{Z}_i$ or $\log_e(\hat{Z}_i)$ as the dependent variable was based on the method that maximized the r^2 values for the predictions on the arithmetic scale. These regressions were of the form:

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

With Eqn. 3.7, we attempt to characterize how instantaneous mortality rates may reflect environmental and/or seasonal conditions experienced during migration through the reaches.

To account for potential differences in the precision of the dependent variable estimates, we evaluated both weighted and unweighted regressions. There were substantial differences among the variance estimates for the $\hat{Z}_i$ across cohorts and years, but the median $F\hat{T}T_i's$ were generally quite precise (CV's typically less than 2%). For the weighted regressions we weighted by the inverse-CV. As with the decision to model $\hat{Z}_i$ or $\log_e(\hat{Z}_i)$ as the dependent variable, our selection of weighting scheme was based on the approach that maximized the r^2 values for the predictions on the arithmetic scale.

In Schaller et al. (2007), extensive analyses were conducted to identify the environmental factors and relationship forms for characterizing variation in median FTT and instantaneous mortality rates (Z) based on data collected during 1998-2006. In this report, we utilized those same sets of environmental variables and equation forms that were identified in Schaller et al. (2007), updating those results with data collected during the 2007 juvenile migration year.

<u>Survival modeling approaches</u>

Our approach for modeling survival rates utilized the exponential mortality model (Eqn. 3.2), allowing the instantaneous mortality rates Z_i and the median $F\hat{T}T_i's$ to vary in response to environmental factors. Using our best-fit models for predicting Z^*_i and FTT^*_i (Eqns. 3.6 and 3.7), predicted survival rates were estimated 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 median 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

Annual summaries of out-migration timing, fish migration rate, and reach survival

<u>Annual out-migration timing</u>

The annual timing of detections for PIT-tagged groups from the four major drainages in the Snake River Basin at LGR (1994-2007) are summarized with boxplots in Figure 3-1, Figure 3-2, and Figure 3-3. PIT tagged wild Chinook typically arrive at LGR in early April and most of those from the Salmon, Imnaha, and Grand Ronde Rivers passed by the end of June (Figure 3-1). The Imnaha River group was frequently the first to arrive at LGR, followed by the Salmon and Grand Ronde River groups, and the Clearwater River was routinely last except for 2007. The Clearwater River group also had a more protracted emigration period than the other three groups and extended into July or occasionally August.

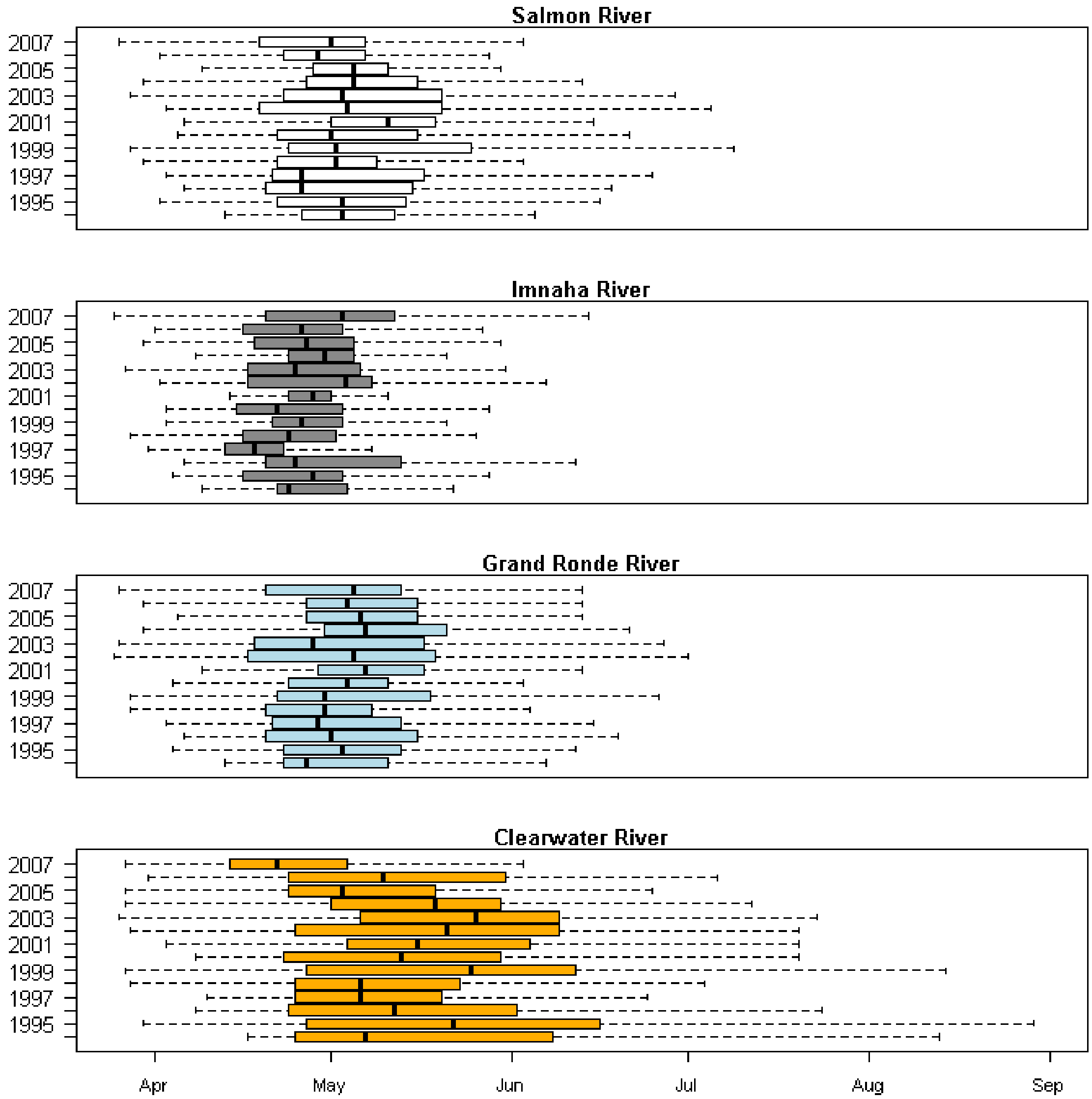


Figure 3-1 Boxplots of Lower Granite Dam detections for Snake River Basin wild Chinook analyzed in the CSS. Each panel represents PIT tagged smolts marked in a major drainage within the Snake River Basin. Each box encompasses the first and third quartiles of the data (the inter-quartile range), the line inside each box corresponds to the median, and the whiskers correspond to the least and greatest observations within the first quartile minus, and the third quartile plus, 1.5 times the inter-quartile range; outliers are not plotted.

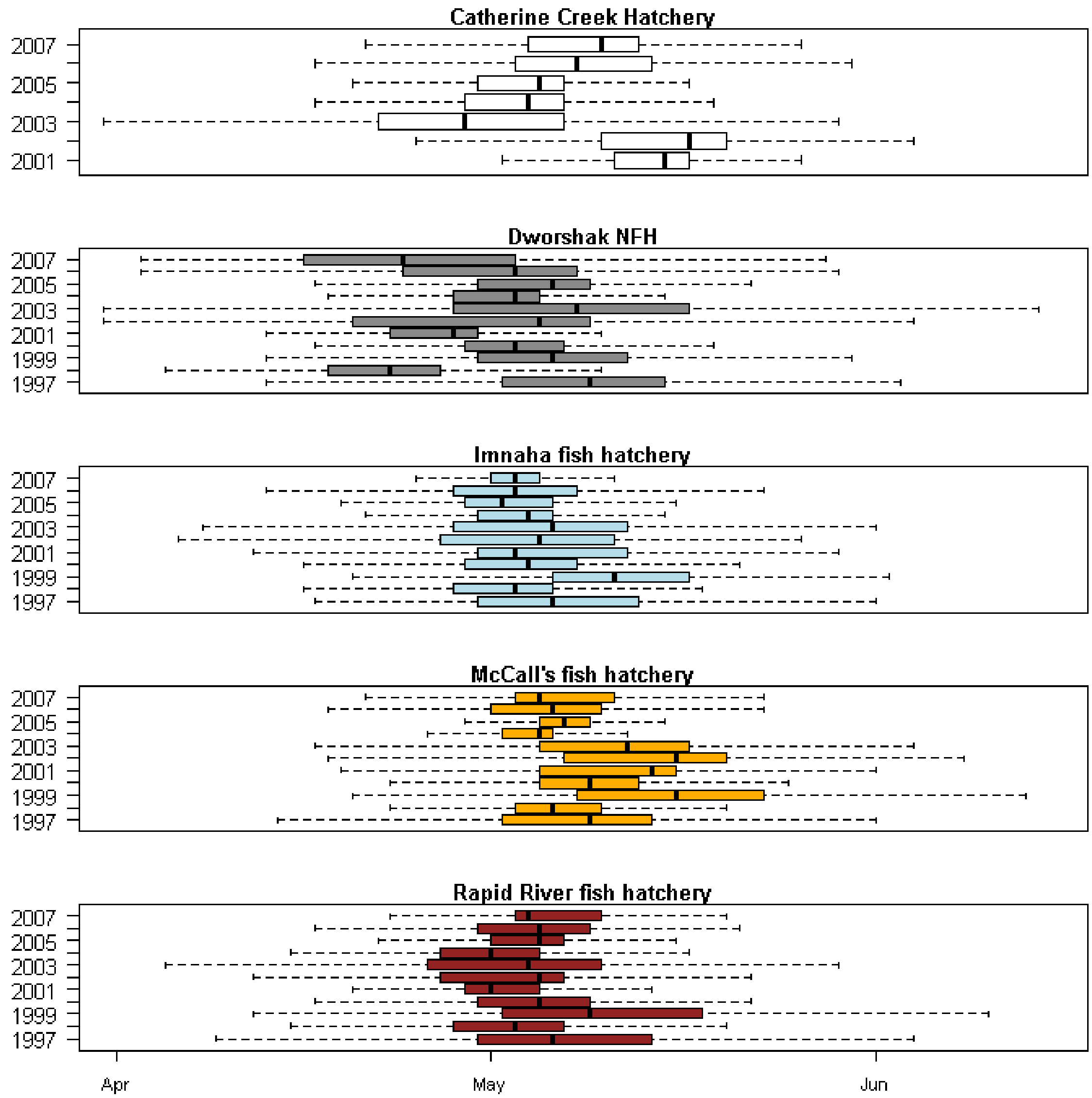


Figure 3-2 Boxplots of Lower Granite detections for Snake River Basin hatchery Chinook analyzed in the CSS. Each panel represents a particular hatchery. See Figure 3.1 for a description of boxplots.

Yearling Chinook were PIT-tagged for the CSS at specific hatcheries within the four drainages above Lower Granite Dam including the Clearwater, Salmon, Imnaha, and Grande Ronde rivers. Both spring and summer stocks were included. The CSS has PIT-tagged and/or analyzed juvenile Chinook at McCall, Rapid River, Dworshak, and Imnaha River hatcheries since 1997. The Catherine Creek hatchery became available for use in the CSS during 2001. Smolts from both the Imnaha River hatchery (Imnaha stock Chinook) and the Catherine Creek hatchery (Grande Ronde River stock) are tagged at Lookingglass hatchery.

The majority of the PIT tagged hatchery Chinook groups emigrating from the Snake River arrived at LGR within a more narrow temporal window than for wild fish (Figure 3-2). Passage at LGR began later in April and few fish were still passing in June for the five historical CSS hatcheries. The Dworshak hatchery PIT tagged fish were often the first to arrive at LGR followed by Imnaha and Rapid River groups; Catherine Creek or McCall's hatchery groups were often the last to pass LGR. The Dworshak group also had the most protracted emigration of the Chinook hatchery groups. Hatchery and wild steelhead passed LGR earlier than most Chinook groups (Figure 3-3) but perhaps were most similar in timing to the Dworshak hatchery Chinook. Hatchery steelhead generally passed LGR later than the wild steelhead group.

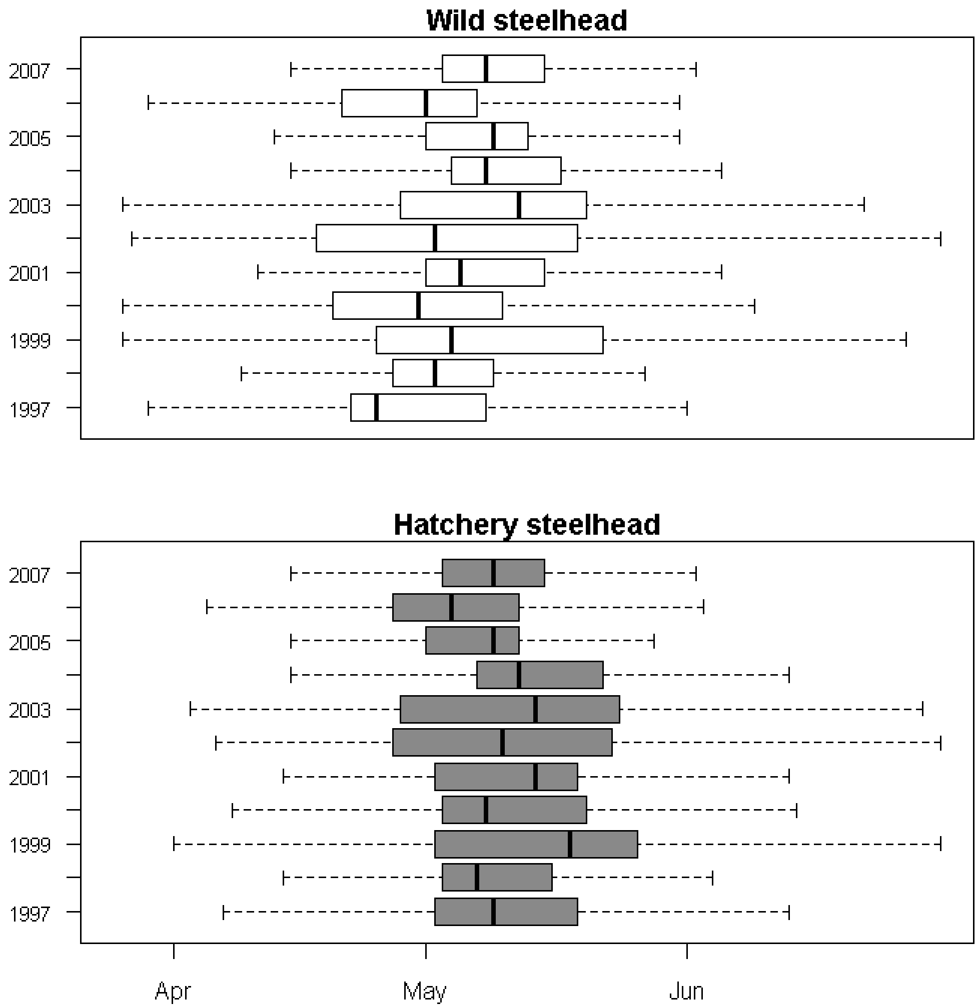


Figure 3-3 Boxplots of Lower Granite detections for Snake River Basin steelhead analyzed in the CSS. The top and bottom panels represent wild and hatchery steelhead respectively. See Figure 3.1 for a description of boxplots.

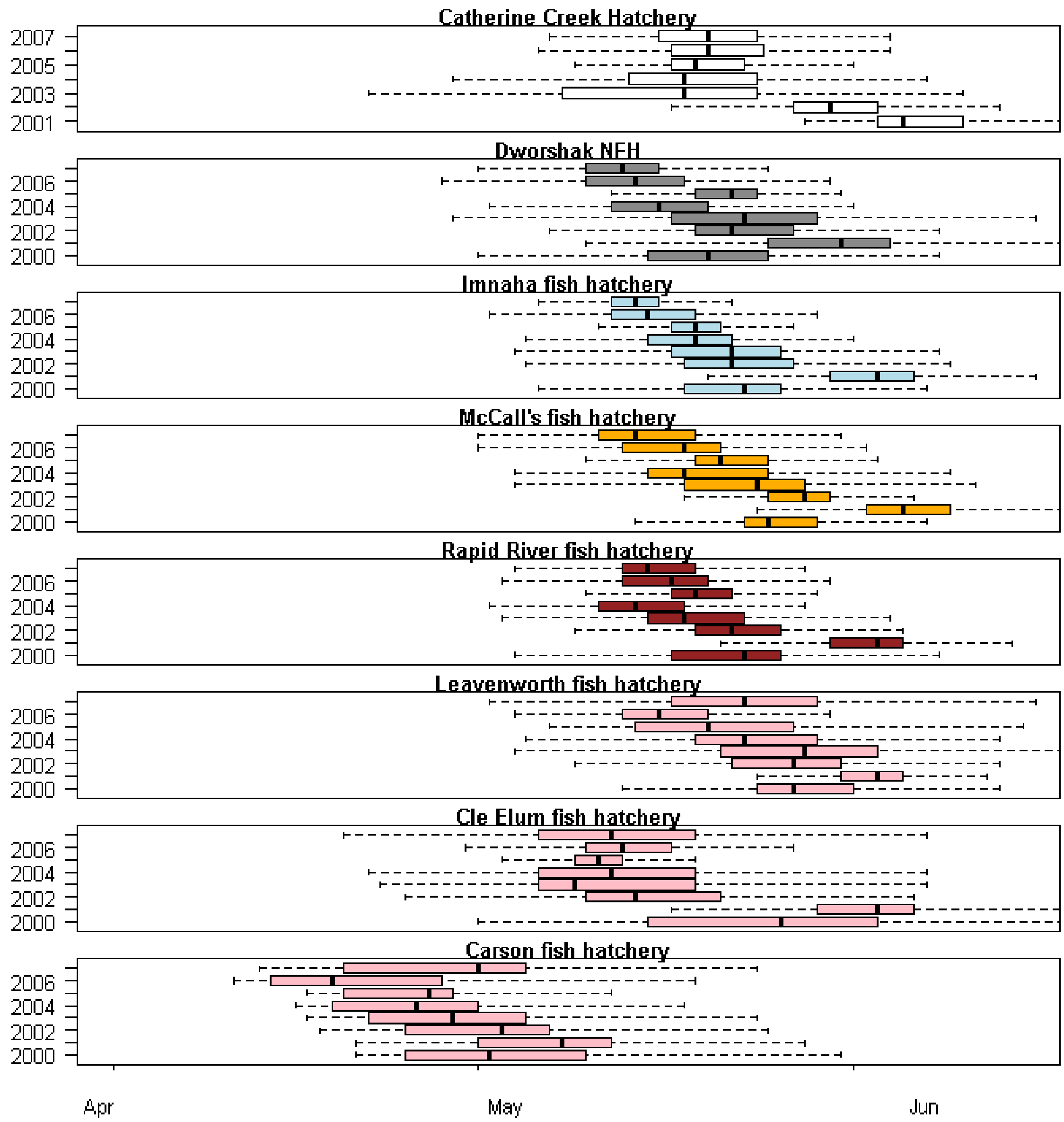


Figure 3-4 Boxplots of Bonneville Dam detections for Snake River Basin and lower river hatchery Chinook analyzed in the CSS. See Figure 3.1 for a description of boxplots.

The annual timing of detections for PIT-tagged groups at BON (2000-2007) is summarized in boxplots in Figure 3-4, Figure 3-5, and Figure 3-6. The Snake River hatchery groups followed the same general ordering at BON as at LGR with Dworshak being first and Catherine Creek being last. Of the Columbia River groups, Leavnworth hatchery was the most similar to Snake River groups in BON arrival timing. Carson hatchery fish were the earliest to arrive followed by Cle Elum hatchery PIT tagged fish.

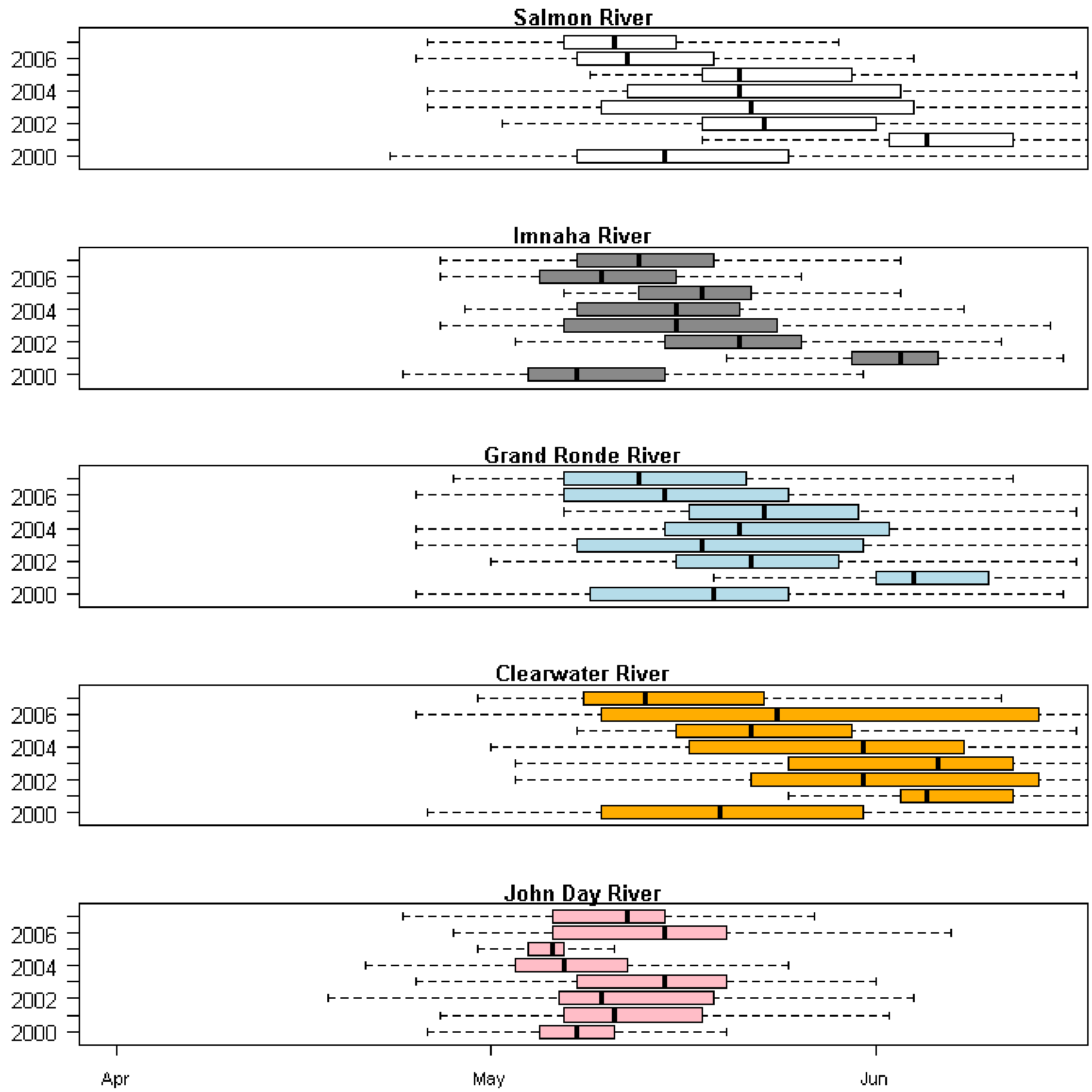


Figure 3-5 Boxplots of Bonneville Dam detections for Snake River Basin and lower river wild Chinook analyzed in the CSS. The top four panels each represent PIT tagged smolts marked in a major drainage within the Snake River Basin. See Figure 3.1 for a description of boxplots.

Displayed in Figure 3-5 are BON detections of PIT tagged wild Chinook originating from four Snake River basins and the John Day River. Most of the wild Snake River PIT tagged Chinook passed BON at a later date and had a more protracted emigration than those originating from the John Day River. The Snake River Chinook groups followed a similar order of appearance as at LGR with Imnaha River first, followed by the Grand Ronde and Salmon Rivers, with the Clearwater River arriving last. For steelhead, the BON arrival timing was qualitatively similar to the observations at LGR, with hatchery and wild steelhead passing BON earlier than most Chinook groups (Figure 3-6). Hatchery steelhead generally passed BON later than wild steelhead.

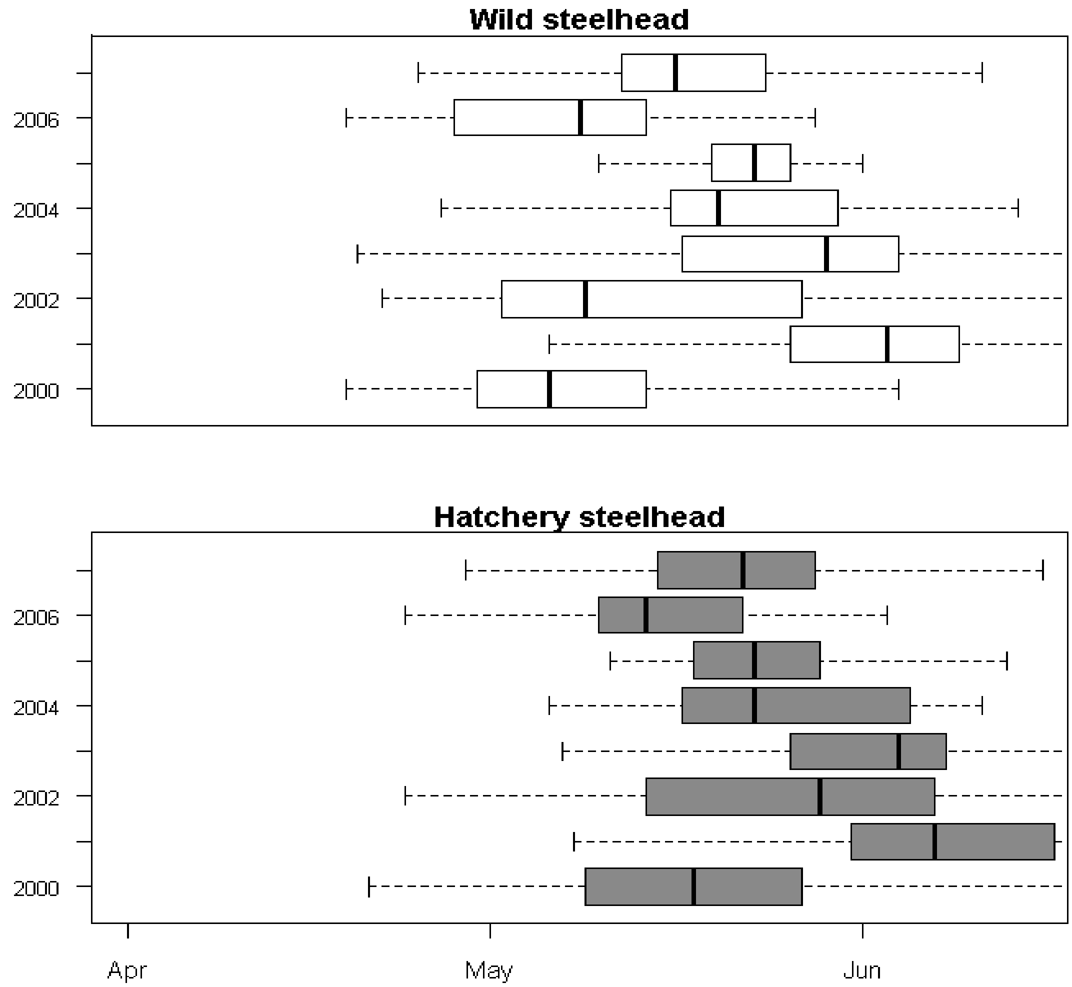


Figure 3- 6 Boxplots of Bonneville detections for Snake River Basin steelhead analyzed in the CSS. The top and bottom panels represent wild and hatchery steelhead respectively. See Figure 3.1 for a description of boxplots.

Annual fish migration rate

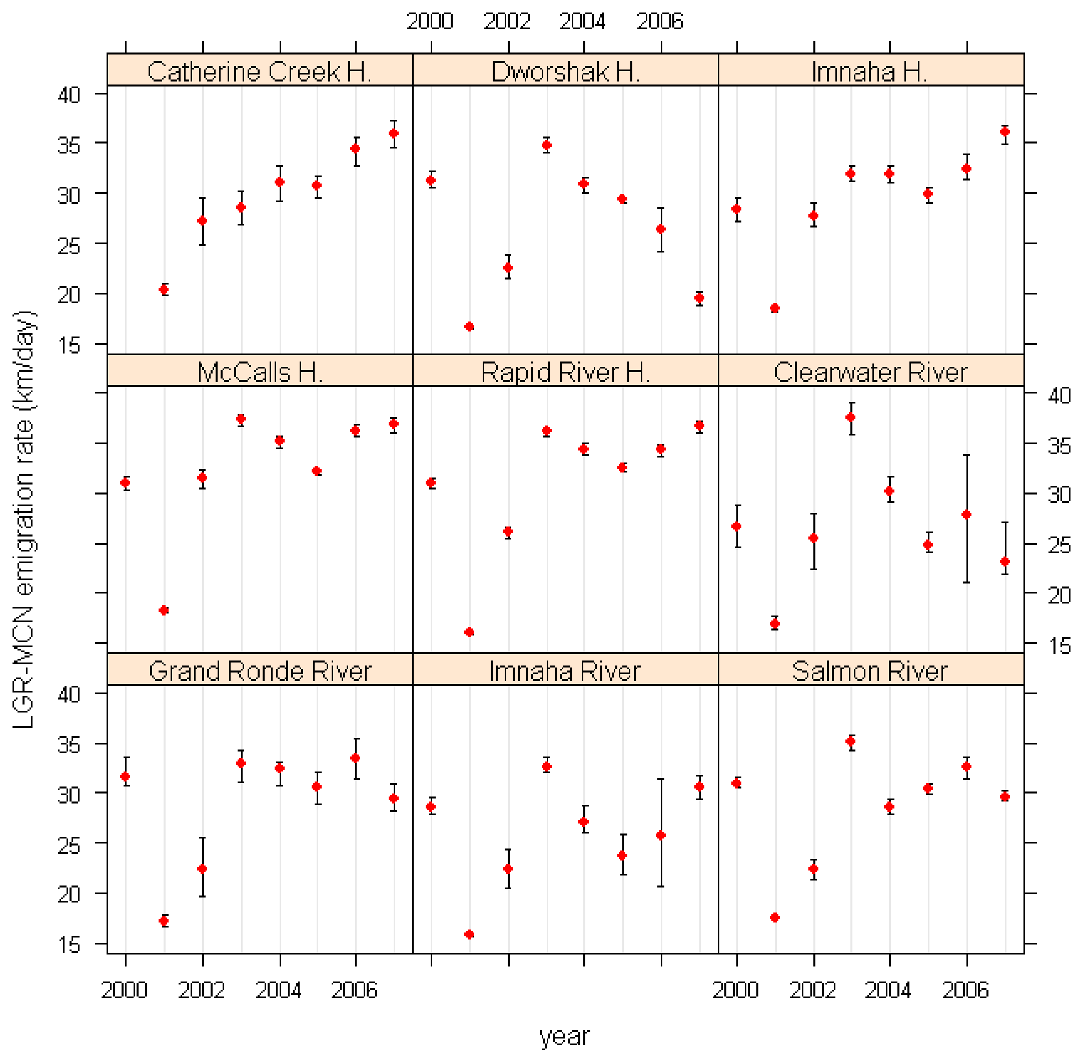


Figure 3-7 Median fish migration rate from LGR to MCN in km/day for Snake River Chinook from five hatcheries (Catherine Creek, Dworshak, Imnaha, McCalls, and Rapid River) and wild Chinook from four drainages (Clearwater River, Grand Ronde River, Imnaha River, and Salmon River). Bars are 90% confidence intervals.

Annual fish migration rate expressed in km/day from LGR to MCN for the Snake River Chinook groups is shown in Figure 3-7. In many years, the hatchery Chinook groups emigrated at a faster rate than the wild fish. Fish migration rates in the lower hydrosystem (MCN to BON) for the wild groups are shown in Figure 3-8. Generally, the lower river rates are higher than in the upper hydrosystem. Also because of smaller sample sizes, the estimate in the MCN-BON reach is less precise than for the LGR-MCN reach.

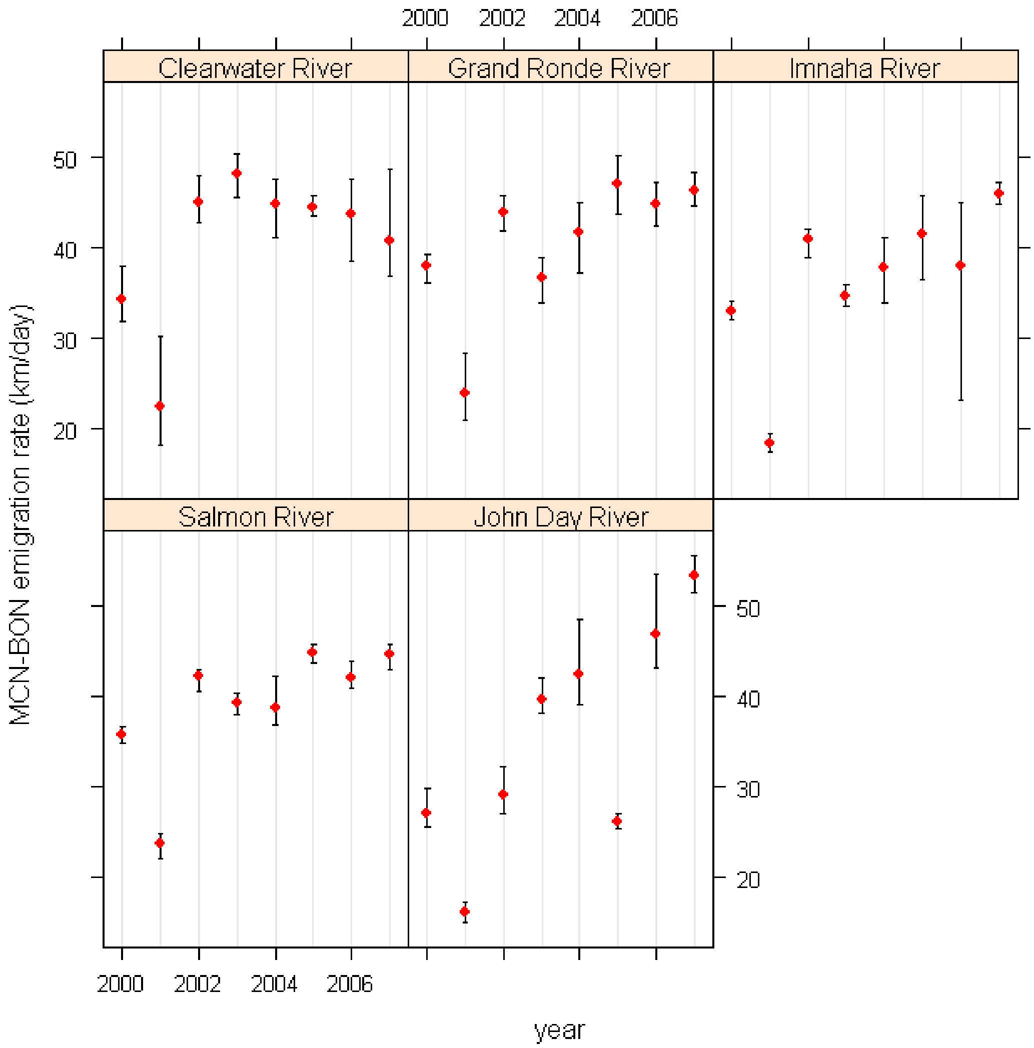


Figure 3-8 Median fish migration rate from MCN to BON in km/day for Snake River wild Chinook from four drainages and wild Chinook from the John Day River for the JDA to BON reach. Bars are 90% confidence intervals.

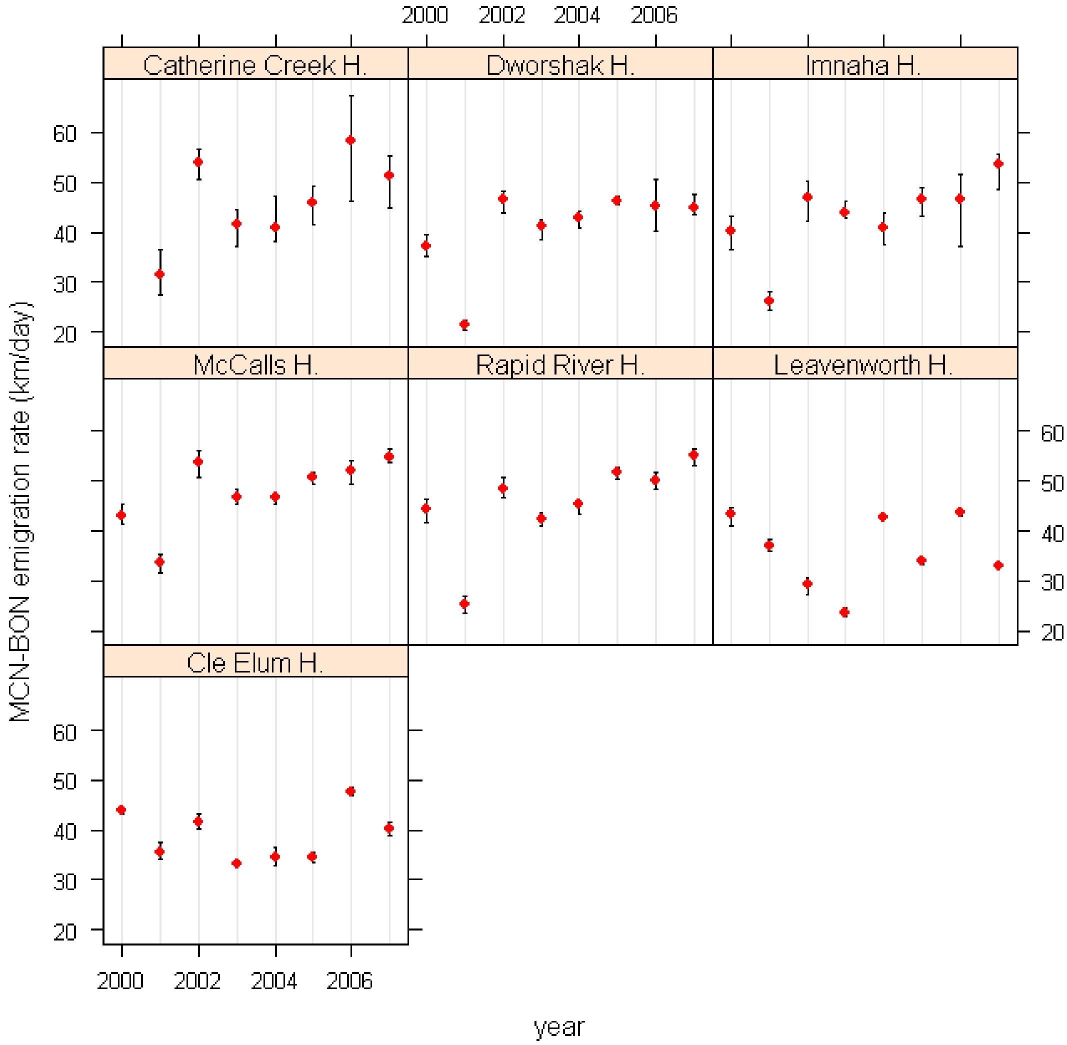


Figure 3- 9 Median fish migration rate from MCN to BON in km/day for Snake River Chinook from five hatcheries and Mid Columbia River Chinook from two hatcheries. Bars are 90% confidence intervals.

Median fish migration rates in the lower hydrosystem for the hatchery groups (Figure 3-9) were higher than for the upper hydrosystem. Also, hatchery Chinook groups emigrated faster than wild Chinook groups in the lower hydrosystem (Figure 3-9 & 3-8). Snake River-originating hatchery Chinook generally emigrated at a higher rate than Columbia River-originating hatchery grous.

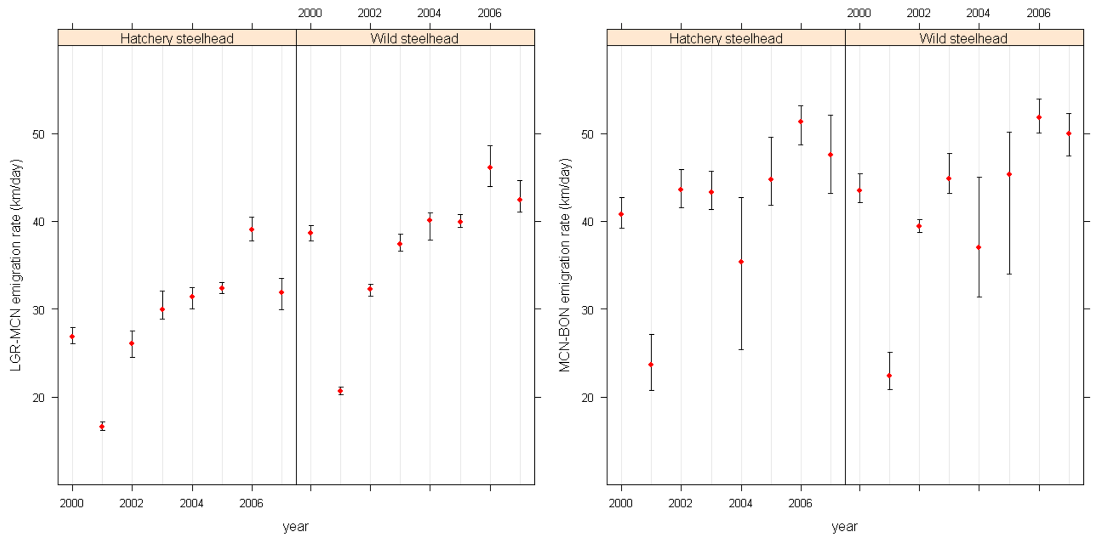


Figure 3-10 Median fish migration rate in km/day for Snake River hatchery and wild steelhead; the LGR to MCN and the MCN to BON reaches are plotted in the left and right panels respectively. Bars are 90% confidence intervals.

Wild steelhead typically emigrated at a faster rate than hatchery steelhead (Figure 3-10). This observation was opposite that of Chinook, which had higher rates for hatchery than wild. As for other groups, the fish migration rate for steelhead was higher in the lower river and the same year effects were apparent.

Annual survival

The estimated in-river survival from LGR tailrace to BON tailrace (termed S_R) for PIT-tagged wild Chinook and five groups of CSS PIT-tagged hatchery Chinook migrating had considerable annual variability, but the S_R of both wild populations and hatchery populations tracked closely across years from 1998 to 2007 (Figure 3-11). In the 14-yr time series for wild Chinook and the 11-yr time series for hatchery Chinook, a major drop in in-river survival relative to adjacent years occurred in 2001 (a drought year throughout the Northwest) and 2004, which were both years with low flows in the Snake River basin and no spill at the Snake River collector dams. The same pattern of very low LGR-BON survival (S_R) in 2001 and 2004 was also observed for both PIT-tagged wild and hatchery steelhead (Figure 3-12). Across years, steelhead survival from LGR to BON was generally lower than Chinook survival. For wild and hatchery steelhead in 2001, the estimated S_R was much lower than their Chinook counterparts and included both dead and holdover steelhead as mortalities. The actual values of S_R plotted above for both wild and hatchery Chinook and steelhead are found at the end of Chapter 4 in even numbered tables between Table 4-6 and 4-20.

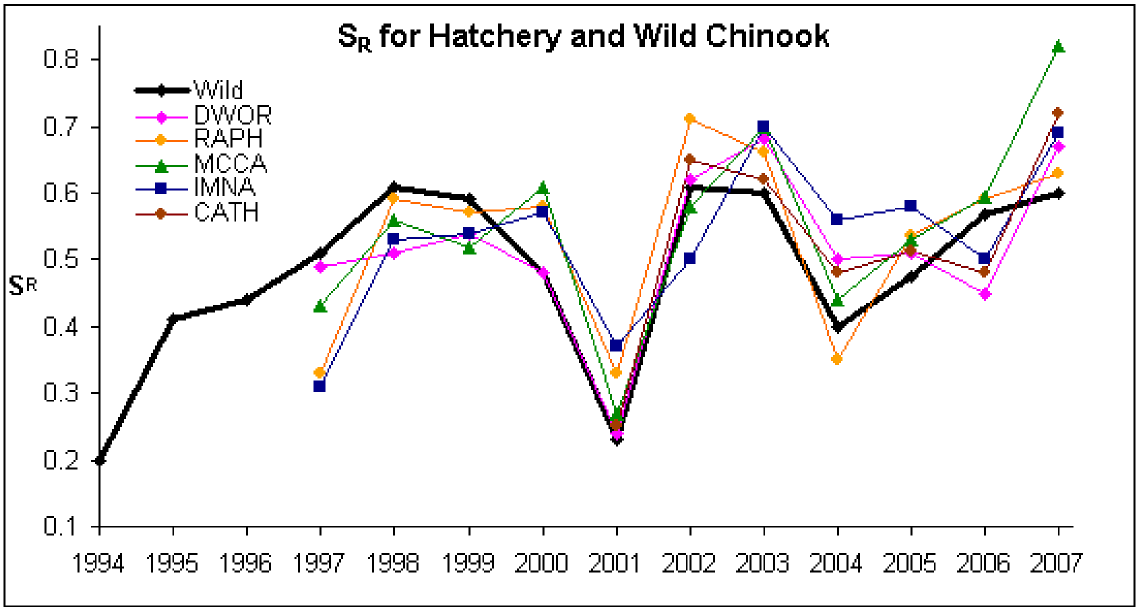


Figure 3-11 Trend in in-river survival (S_R) for PIT-tagged Snake River wild and hatchery spring/summer Chinook in migration years 1994 to 2007.

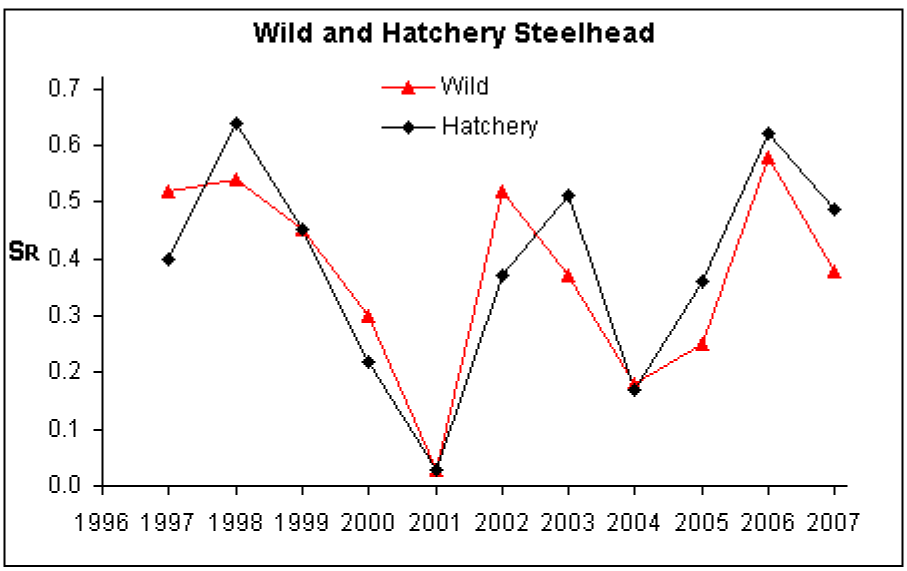


Figure 3-12 Trend in in-river survival (S_R) for PIT-tagged Snake River hatchery and wild steelhead for migration years 1997 to 2007.

Further partition of these survival rates into the LGR-MCN reach and MCN-BON reach are plotted in the following figures. The values of individual in-river survival rates between each monitored reach from LGR to BON are presented in Appendix A Tables A-21 to A-28.

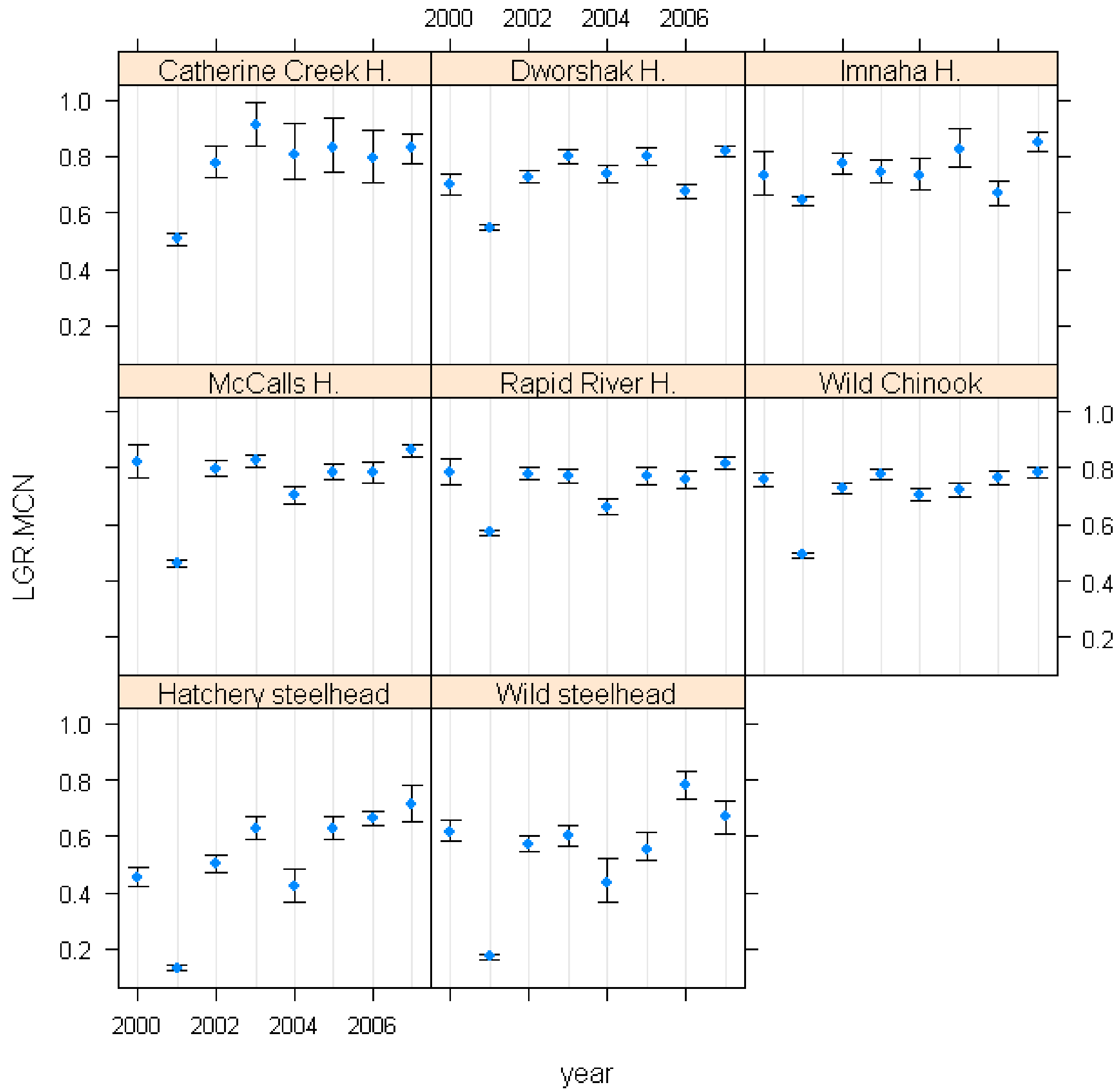


Figure 3-13 Annual estimates of reach survivals from LGR to MCN for five Snake River Chinook hatcheries, wild Chinook, hatchery steelhead and wild steelhead (2000-2007). Estimates were calculated using the CJS model; confidence intervals are 90% non-parametric bootstrapped intervals.

Survival estimates from LGR to MCN and MCN to BON are displayed in Figure 3-13 and 3-14. For Snake River originating groups in the upper hydrosystem, hatchery Chinook survive at a higher rate than wild Chinook, wild steelhead often survive at a higher rate than hatchery steelhead, and Chinook groups survive at a higher rate than steelhead groups. In the lower hydrosystem, there is more variability surrounding the survival estimates.

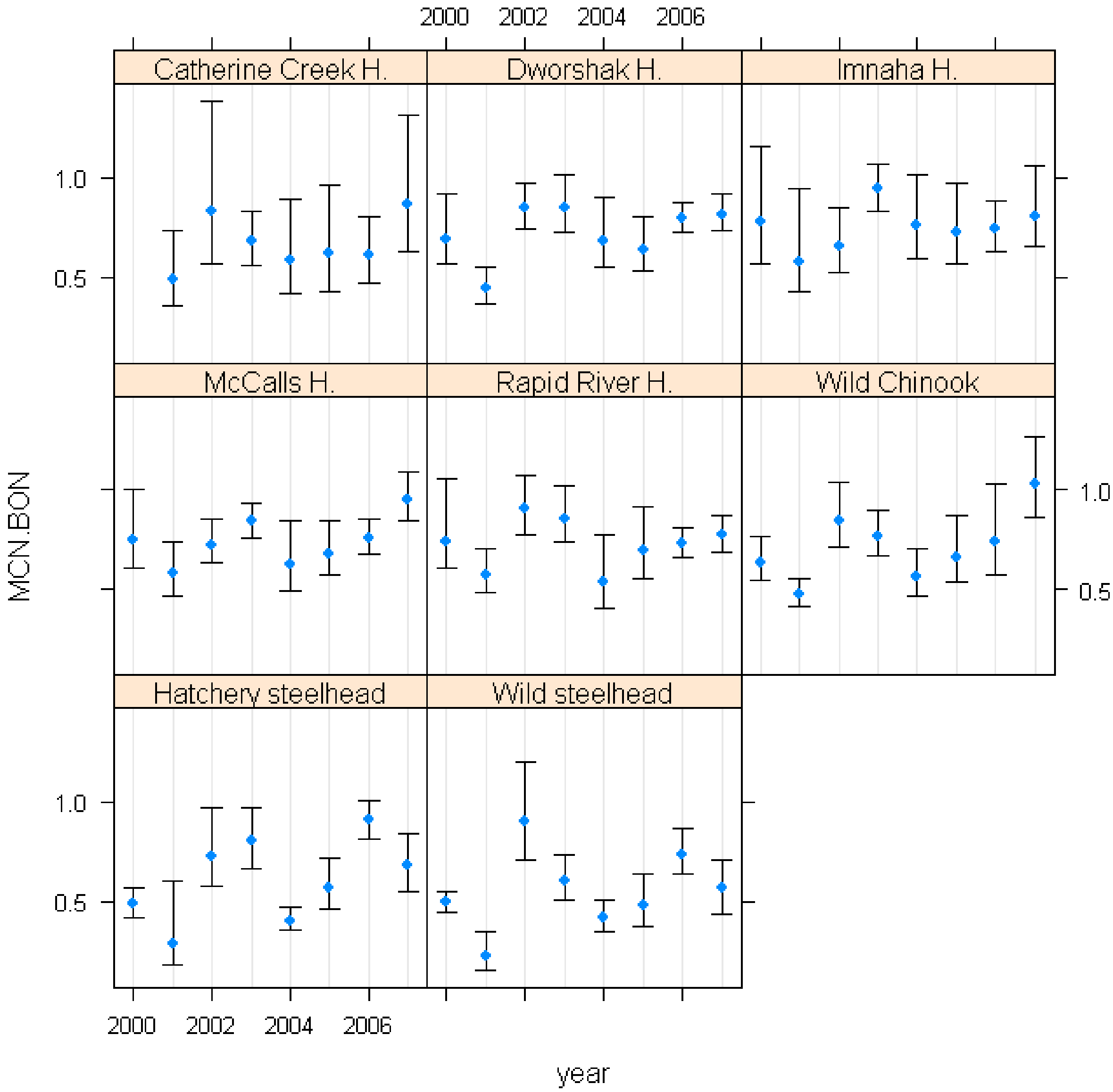


Figure 3-14 Annual estimates of reach survivals from MCN to BON for five Snake River Chinook hatcheries, wild Chinook, hatchery steelhead and wild steelhead (2000-2007). Estimates were calculated using the CJS model; confidence intervals are 90% non-parametric bootstrapped intervals.

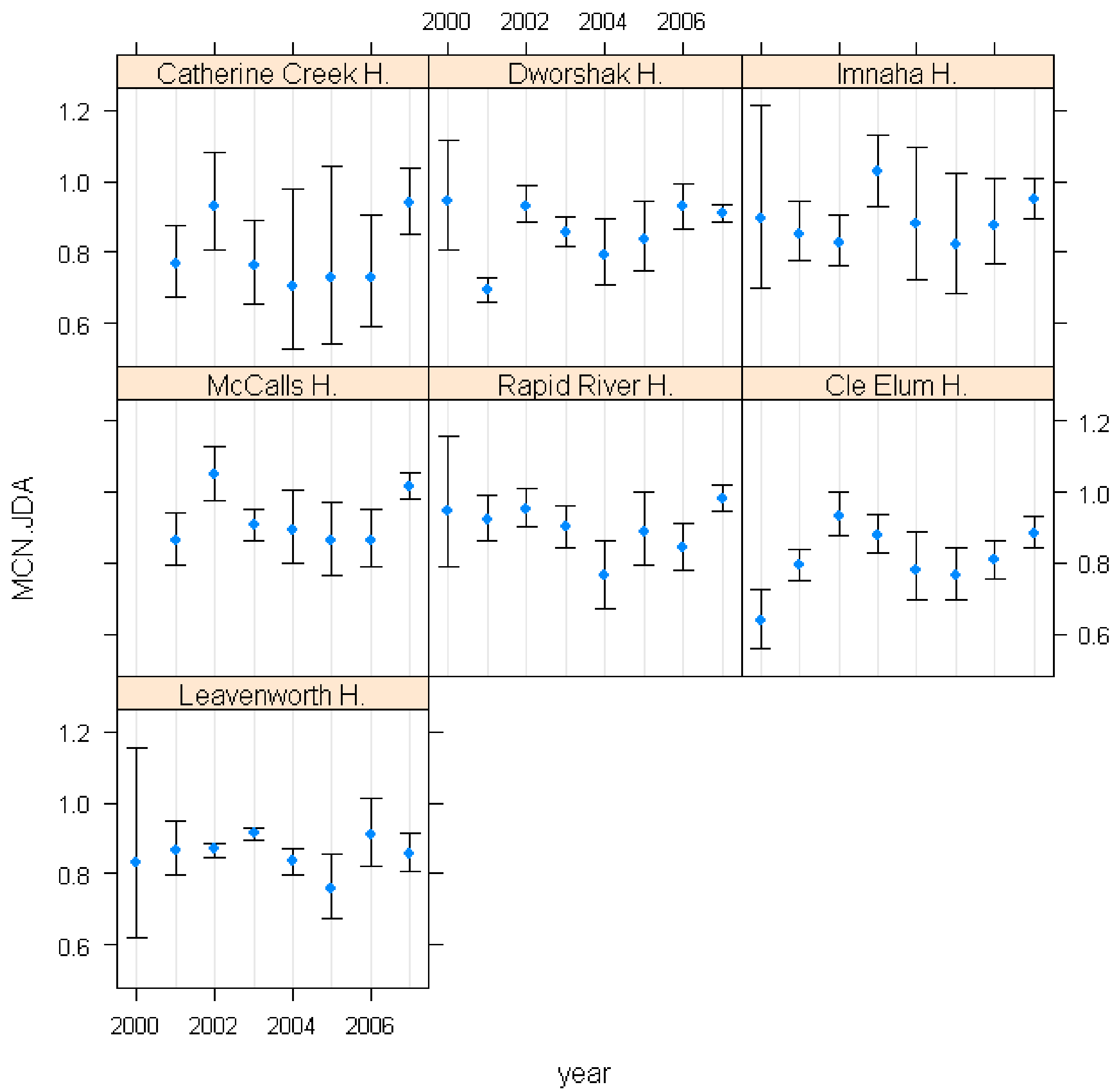


Figure 3-15 Annual estimates of reach survivals from MCN to JDA for five Snake River Chinook hatcheries, and two mid Columbia River Chinook hatcheries (2000-2007). Estimates were calculated using the CJS model; confidence intervals are 90% non-parametric bootstrapped intervals.

Survival estimates through the entire lower reach (MCN to BON) were not stable for the Cle Elum and Leavenworth hatchery Chinook groups. However, we were able to estimate survival in the MCN to JDA reach and these are compared with those for Snake River originating hatchery Chinook groups within the MCN to JDA reach (Figure 3-15). Point estimates for Snake River groups were typically higher than for Columbia River groups within the same year.

The environmental conditions experienced by emigrating smolts varied over the years 2000-2007 (Figure 1-4). The 2001 and 2007 migration years had the lowest flows while 2006 was the highest. Of interest here, the drought year of 2001 coincided with the lowest emigration rates (in km/day), the latest arrival dates at BON and the lowest survival of nearly all smolts emigrating through the hydrosystem. The later arrival dates at BON for the Snake River groups are not apparent in the arrival dates for these same smolts at LGR (Figure 3-1), suggesting that these reduced migration rates and later BON timing effects were not in place prior to smolts entering the hydrosystem.

During 2006, flows and spill were higher than previous years and across nearly all groups shown here, fish migration rates (km/day) were high, arrival times at BON were early and survival through the upper and lower hydrosystem was high. The 2007 migration year had similar flows to 2001 at the transportation dams, but a much higher spill percentage (2001 had essentially zero spill). However in contrast to 2001, during 2007 emigrating smolts from the Snake, Columbia, and John Day River groups did not arrive at BON on a marked later date. The 2007 median date of passage at BON was one of the earliest for most hatchery Chinook groups (Figure 3-4). In general during 2007, fish migration rates (km/day) were high, arrival times at BON were early and survival was high.

Results from the multiple regression model

The multiple regression model shown here adds one year of data to the model analyses previously presented in Chapter 2 of the 10-year report (Schaller et al 2007). Similar to the 10-year report analyses, these models were capable of capturing a high proportion of the variation in median $F\hat{T}T_i$, $\hat{Z}_i$ and $\hat{S}_i$.

Estimates of median $F\hat{T}T_i$, $\hat{S}_i$, and $\hat{Z}_i$ of cohorts of juvenile yearling Chinook and steelhead along with predicted values for these parameters are shown in Figures 3-16, 3-18, and 3-20 (LGR-MCN reach) and Figures 3-17, 3-19, and 3-21 (MCN-BON reach). The equations used to predict these parameters are shown in tables 3.1, 3.2, and 3.3. Median $F\hat{T}T_i$, $\hat{S}_i$, and $\hat{Z}_i$ varied considerably over the period of 1998-2007 in the LGR-MCN each, both within- and across-years (Figures 3-16, 3-18, 3-20). While there were some special cases, median $F\hat{T}T_i$ 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 Chinook and steelhead, and by up to 32 percentage points for hatchery Chinook. Across all years and cohorts, estimates of $\hat{S}_i$ varied by up to 64 percentage points for 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 1998-2007 timeframe. For both wild Chinook and steelhead in 2007, observed survival rates were generally higher than model predictions.

In the MCN-BON reach, cohorts of yearling Chinook and steelhead demonstrated within-year median $F\hat{T}T_i$, $\hat{S}_i$, and $\hat{Z}_i$ patterns similar to those observed in the LGR-MCN reach, varying considerably both within- and across-years (Figures 3-17, 3-19, and 3-21). For both species, median $F\hat{T}T_i$, generally decreased over the migration season; exceptions to this are steelhead in 1999, 2000, 2006, and 2007 which maintained a low median $F\hat{T}T_i$, throughout the season (Figure 3-19). Yearling Chinook in 2001 demonstrated the largest within-year variation in median $F\hat{T}T_i$, ranging from 20 days early in the season to 6 days late in the season (Figure 3.17). 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 3-19 and 3-21). For both Chinook steelhead, $\hat{Z}_i$ generally increased over the season. Steelhead $\hat{S}_i$ generally decreased over the season, but no general patterns were evident for Chinook $\hat{S}_i$.

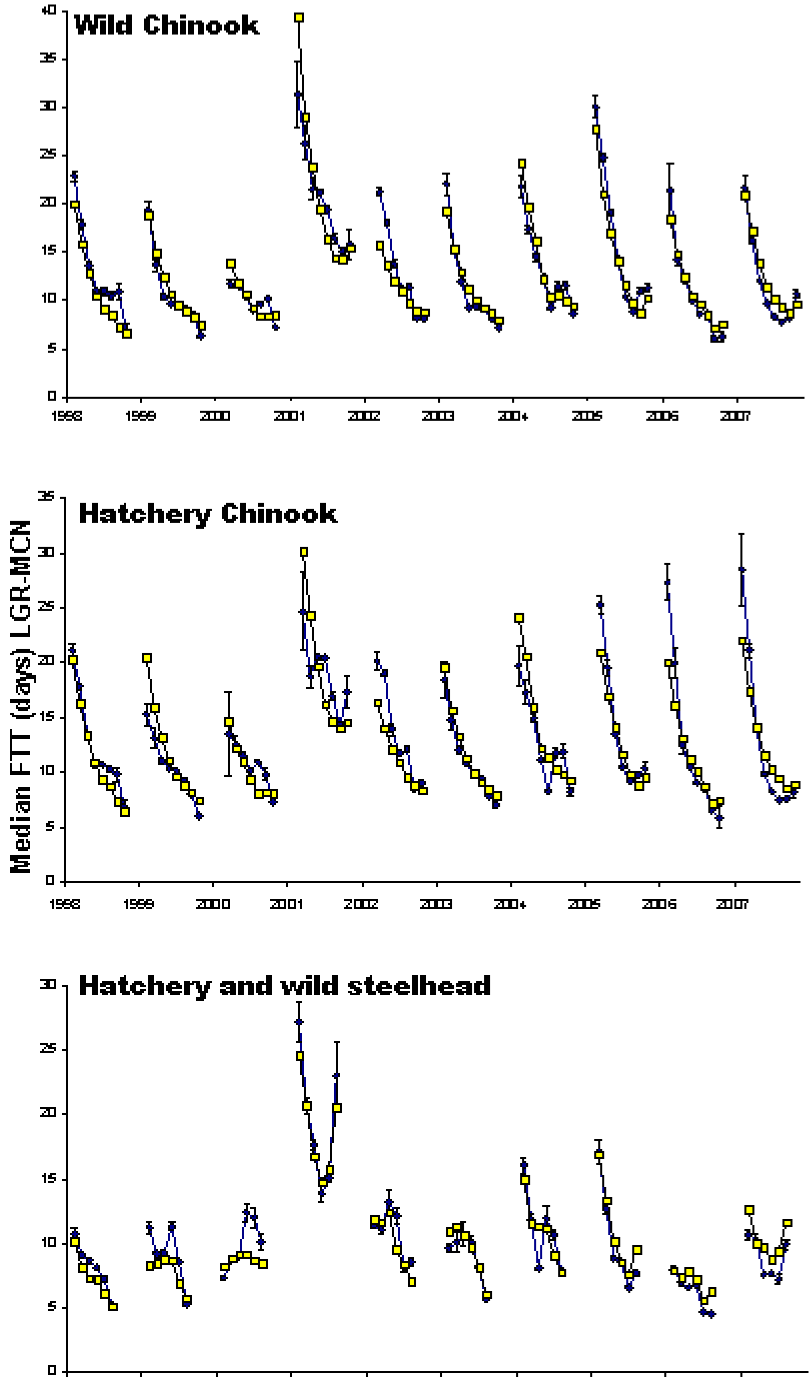


Figure 3-16 Estimates of median FTT in days (closed diamonds) and predicted median FTT in days (open squares) for weekly release groups of wild Chinook (upper panel), hatchery Chinook (middle panel) and combined hatchery and wild steelhead (lower panel) in the LGR-MCN reach, 1998-2007. Error bars represent the 95% confidence limits on the median FTT.

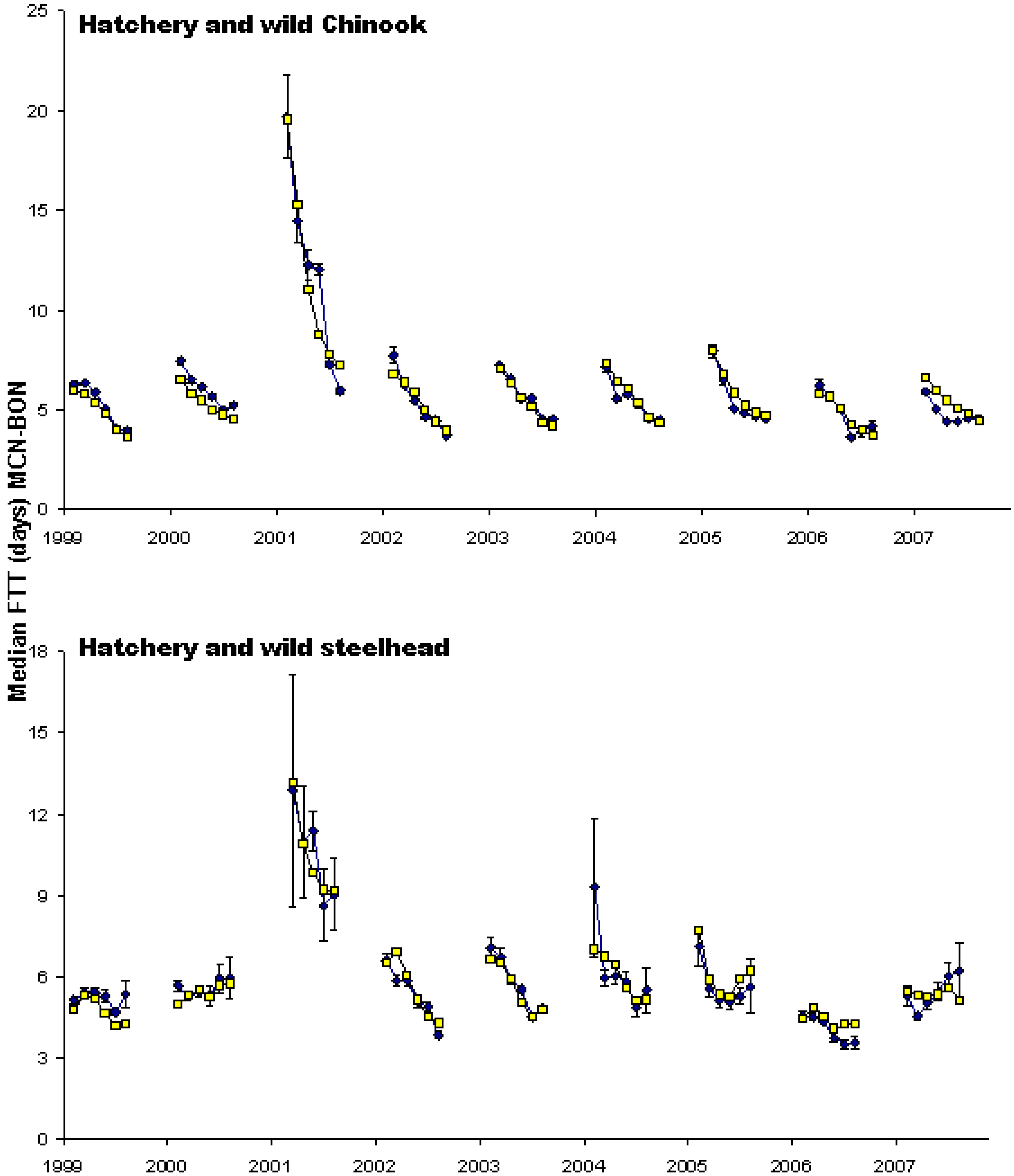


Figure 3-17 Estimates of median FTT in day s (closed diamonds) and predicted median FTT in days (open squares) for weekly release groups of combined hatchery and wild Chinook (upper panel) and combined hatchery and wild steelhead (lower panel) in the MCN-BON reach, 1999-2007. Error bars represent the 95% confidence limits on the median FTT.

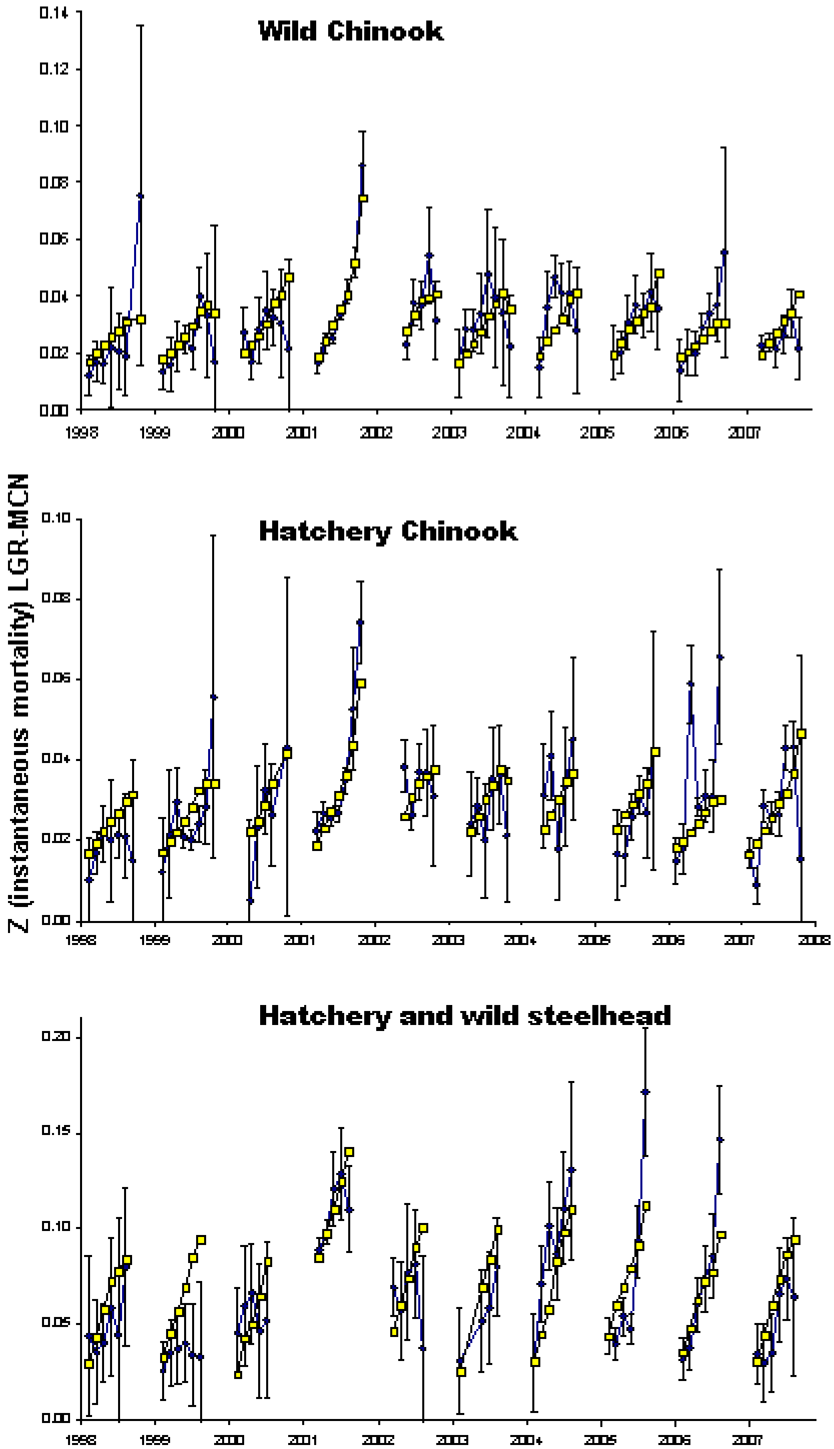


Figure 3-18 Estimates of instantaneous mortality rates (Z, closed diamonds) and predicted Z (open squares) for weekly release groups of wild Chinook (upper panel), hatchery Chinook (middle panel) and combined hatchery and wild steelhead (lower panel) in the LGR-MCN reach, 1998-2007. Error bars represent the 95% confidence limits on Z.

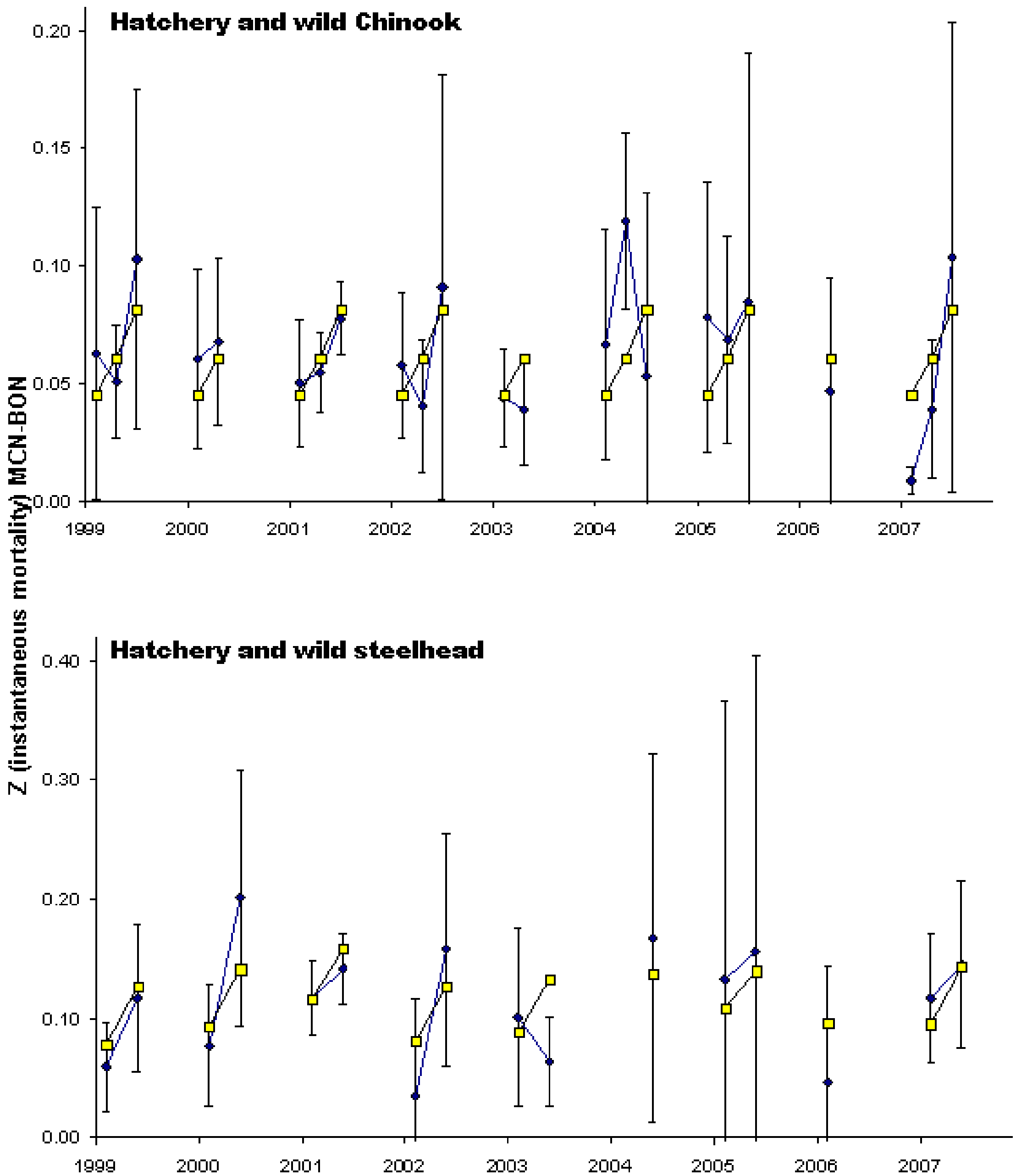


Figure 3-19 Estimates of instantaneous mortality rates (Z, closed diamonds) and predicted Z (open squares) for two-week release groups of combined hatchery and wild Chinook (upper panel) and for three-week release groups of combined hatchery and wild steelhead (lower panel) in the MCN-BON reach, 1999-2007. Error bars represent the 95% confidence limits on Z.

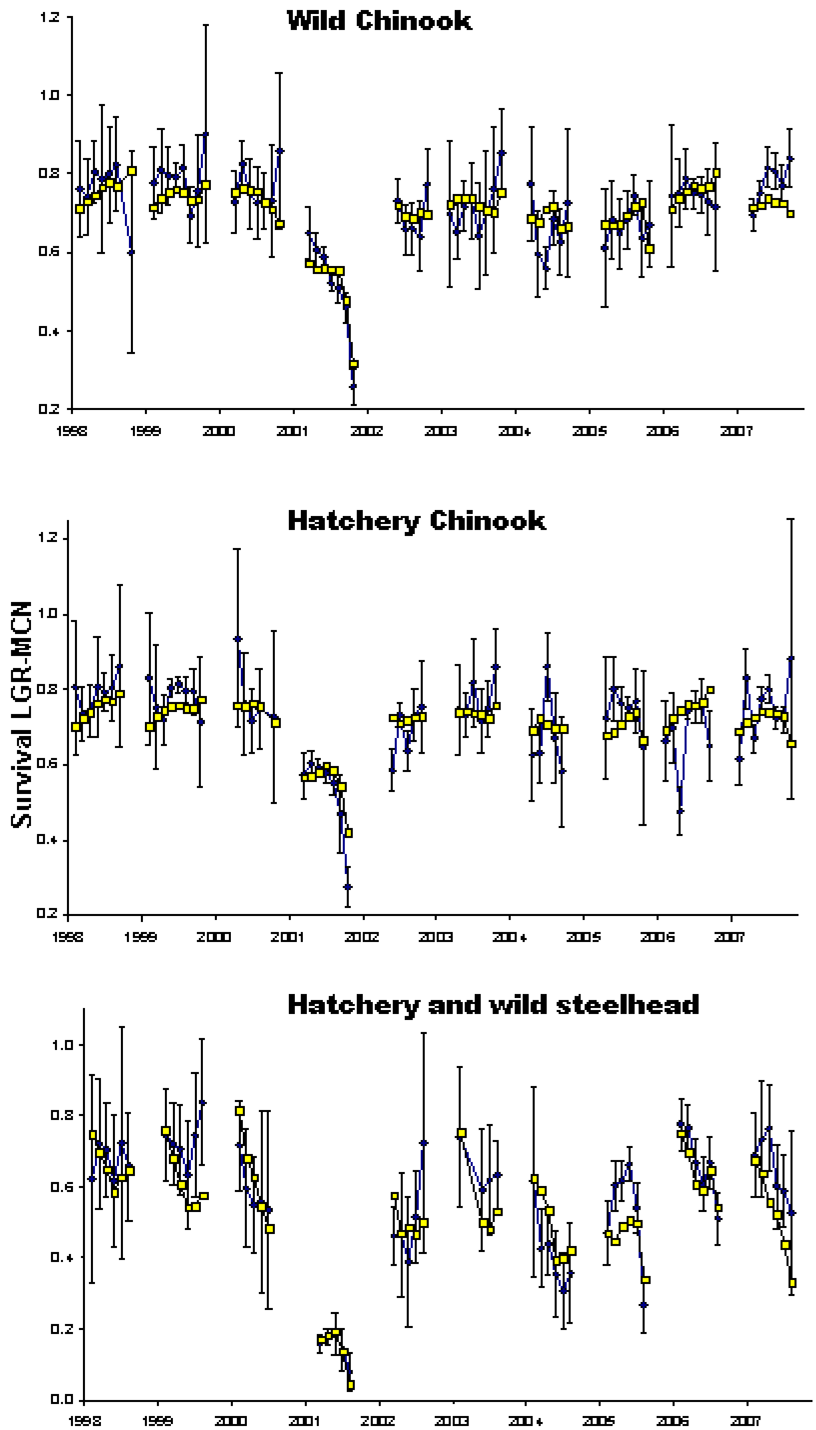


Figure 3-20 Estimates of in-river survival rates(closed diamonds) and predicted survival rates (open squares) for weekly release groups of wild Chinook (upper panel), hatchery Chinook (middle panel) and combined hatchery and wild steelhead (lower panel) in the LGR-MCN reach, 1998-2007. Error bars represent the 95% confidence limits on the survival rates.

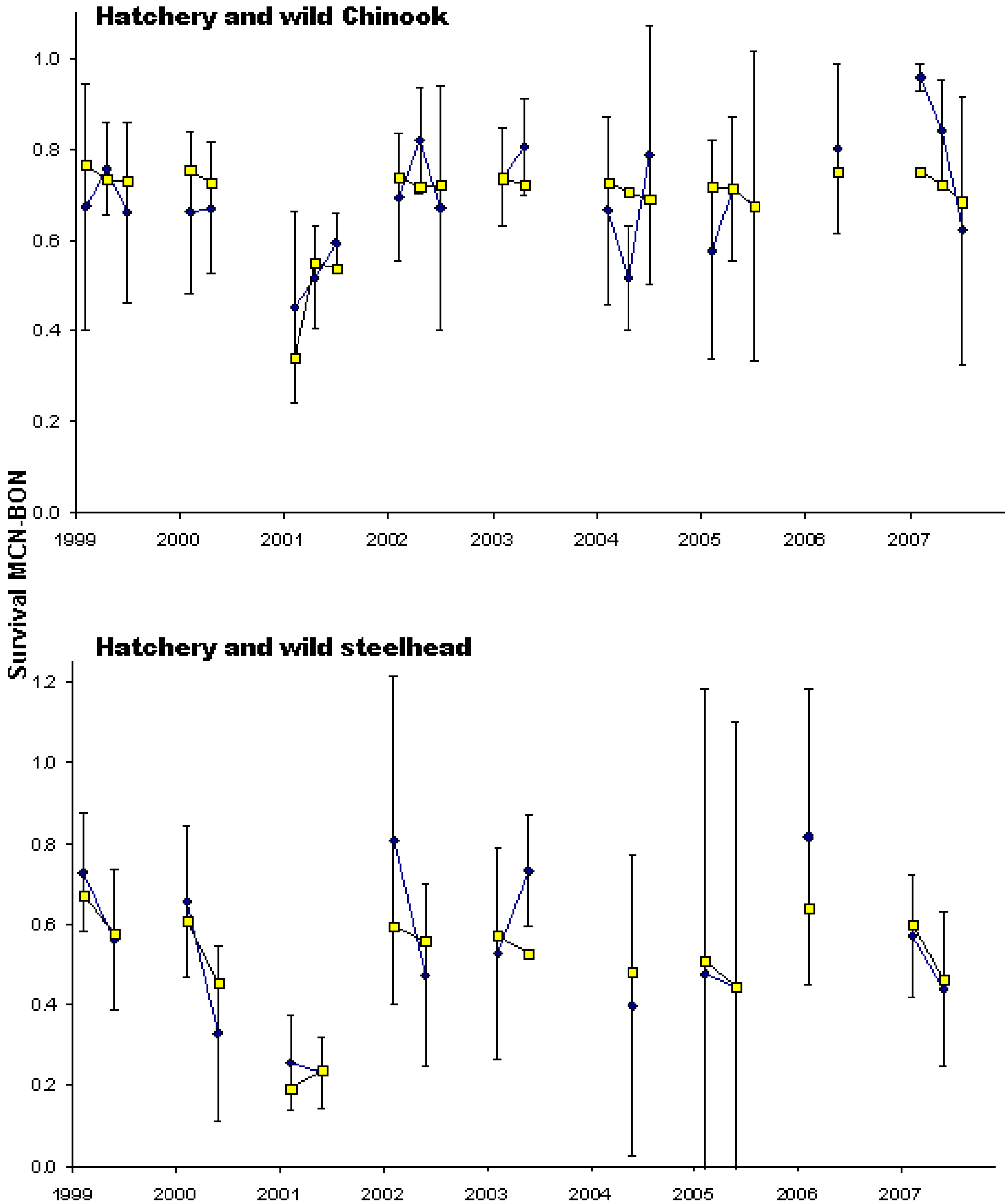


Figure 3-21 Estimates of in-river survival rates (closed diamonds) and predicted survival rates (open squares) for two-week release groups of combined hatchery and wild Chinook (upper panel) and for three-week release groups of combined hatchery and wild steelhead (lower panel) in the MCN-BON reach, 1999-2007. Error bars represent the 95% confidence limits on the survival rates.

Reach	Species & Rearing Type	Survival	Z	median *FTT*
LGR-MCN	CHN (W)	0.60	0.45	0.88
LGR-MCN	CHN (H)	0.48	0.35	0.79
LGR-MCN	STH (H&W)	0.73	0.49	0.89
MCN-BON	CHN (H&W)	0.38	0.25	0.94
MCN-BON	STH (H&W)	0.70	0.54	0.90

Table 3-1 Proportions of variation explained (r^2 values) in relationships characterizing Chinook and steelhead median FTT, instantaneous mortality rates (Z) and in-river survival rates within the LGR-MCN reach and the MCN-BON reach.

Reach	Species & Rearing type	Equation						
			Intercept	Julian	$Julian^2$	wtt	spill	
LGR-MCN	CHN (W)	$\log_e(ftt) =$	9.87721	-0.10954	0.00039	0.03083	-0.01005	
			Intercept	Julian	$Julian^2$	wtt	spill	
LGR-MCN	CHN (H)	$\log_e(ftt) =$	9.64537	-0.10145	0.00035	0.02252	-0.01097	
			Intercept	Julian		wtt	spill	
LGR-MCN	STH (H&W)	$\log_e(ftt) =$	2.09379	-0.00408		0.08732	-0.00610	
			Intercept	Julian		wtt	spill	$spill^2$
MCN-BON	CHN (H&W)	$\log_e(ftt) =$	4.43482	-0.01226		0.06783	-0.07913	0.00099
			Intercept	Julian		wtt	Julian:wtt	
MCN-BON	STH (H&W)	$\log_e(ftt) =$	-0.526711	0.01000		0.41211	-0.00207	

Table 3-2 Equations used for predicting median FTT of Chinook and steelhead within the LGR-MCN reach and the MCN-BON reach.

Reach	Species & Rearing type	Equation	Intercept	Julian	wtt	Julian:wtt	Temperature	spill
LGR-MCN	CHN (W)	$\log_e(Z) =$	-3.90622	0.00062	-0.20241	0.00194		
LGR-MCN	CHN (H)	$\log_e(Z) =$	-4.30831	0.00434	-0.14165	0.00135		
LGR-MCN	STH (H&W)	$Z =$	-0.15058	0.00198	0.000288			-0.00104
MCN-BON	CHN (H&W)	$\log_e(Z) =$	-5.60668	0.02081				
MCN-BON	STH (H&W)	$Z =$	-0.12759	0.00036			0.014272	

Table 3-3 Equations used for predicting instantaneous mortality rates (Z) of Chinook and steelhead within the LGR-MCN reach and the MCN-BON reach.

Effects of Snake River Spill in 2007

Snake River flow levels during the spring of 2007 were low, and were comparable to the flow conditions that occurred in 2004 and 2005 (Figure 1-4). However, the spring migration conditions during 2007 in the Snake River were notably different than either 2004 or 2005 because of the provision of spill at the Snake River transportation dams (Lower Granite, Little Goose and Lower Monumental, Figure 1-4). Under previous management strategies, hydrosystem operators have chosen to terminate spill in order to maximize transportation at the transportation dams when Snake River flows were low, as occurred in 2001, 2004 and 2005. Because of the provision of spill at the transportation dams in 2007, the PIT-tagged juvenile yearling Chinook and steelhead provide data on a set of migration conditions that has not previously been observed: spill under low-flow conditions. We were therefore interested in examining how spill and flow affected juvenile yearling Chinook and steelhead under the unique conditions present during the spring of 2007.

Our approach for examining the effects of spill in 2007 was to compare and contrast the fish travel times and survival rates observed in 2007 with the fish travel times and survival rates that were observed in a year with similar flow conditions, but without spill at the transportation projects. As mentioned above, spring migration conditions in both 2004 and 2005 were characterized by low flows in the Snake River, and flow levels in both years were comparable to spring flows during 2007 (Figure 1-4). However, spill was provided at the transportation projects through most of April during 2004 and was rescinded in May 2004, whereas voluntary spill was not provided at the transportation projects during the entire spring of 2005. As a result, the migration conditions during the springs of 2007 and 2005 provide reasonable analogues for comparing and contrasting fish travel times and survival rates with and without spill at the transportation dams under low-flow conditions.

We compared the 2005 and 2007 data on environmental conditions, median fish travel time and survival rates in the LGR-MCN reach for wild Chinook and the combined wild and hatchery steelhead (Figures 3-22 and 3-23, Tables 3-4 and 3-5). We also present environmental and biological data for 2001 (the lowest recent flow year) and 2006 (a high recent flow year) for comparative purposes. For wild yearling Chinook, water transit times were similar between 2005 and 2007, typically within three days of each other across the migration season (Figure 3-22[A], Table 3-4). Similarly, the combined wild and hatchery steelhead water transit times were also within three days of each other across the migration season (Figure 3-23[A], Table 3-5). For both species, water transit times in 2006 were faster than 2005 or 2007, while water transit times in 2001 were slower than 2005 or 2007. These results demonstrate that in terms of water transit times, 2005 was analogous to 2007 in the Snake River through the LGR-MCN reach for both species.

In contrast to the observations on water transit times in 2005 versus 2007, spill percentages were considerably higher in 2007. For wild Chinook, average spill percentages were 4 to 28 percentage points higher in 2007 than in 2005 (Table 3-4). For wild and hatchery steelhead, average spill percentages were 5 to 18 percentage points higher in 2007 than in 2005 (Table 3-5). The average percent spill estimates in the LGR-MCN reach during 2005 are greater than zero due to the provision of spill at Ice Harbor and McNary dams, which occurred despite the elimination of spill at the transportation dams in that year.

In terms of biological responses, both species showed marked improvements in fish travel time and survival in 2007 compared to 2005. Wild Chinook travel times were up to 8.6 days faster and survival rates were up to 20 percentage points higher in 2007 compared to 2005 (Table 3-4). Across release groups, the average reduction in fish travel time was 4.4 days and the average increase in survival was 11 percentage points (Table 3-4). Wild and hatchery steelhead travel times were up to 6.5 days faster and survival rates were up to 26 percentage points higher in 2007 compared to 2005 (Table 3-5). Across release groups, the average reduction in fish travel time for steelhead was 1.3 days and the average increase in survival was 12 percentage points (Table 3-5).

These observations demonstrate that the provision of spill, even under low-flow conditions, can result in improved juvenile migration rates and survival rates in the LGR-MCN reach. Water transit times were similar during the spring migrations in 2005 and 2007. Average water temperatures were also similar during the spring migrations in 2005 and 2007 (Table 3-6). The main environmental difference between 2005 and 2007 was that voluntary spill was provided at the transportation dams in 2007 but was not provided in 2005. There appear to be several environmental-biological mechanisms underlying these results. In terms of fish travel time, we have found that for a given water transit time and Julian day, spill reduces migratory delay (this Chapter). With reduced travel time and a fixed instantaneous mortality rate, survival is expected to increase. We have also found that steelhead instantaneous mortality rates decrease with increasing spill levels, which would further enhance survival (Table 3-3). In addition to altering migration rates, spill also functions to modify the proportion of fish passing the spillway, bypass and turbine routes. High spill percentages increase the proportion of fish that pass spillway routes, while low spill percentages increase the proportion of fish that pass turbine routes. Spillways have been found to be the migration route with the highest survival at Snake River dams, while turbine passage has been found to be the migration route with the lowest survival (Muir et al. 2001). Thus, the provision of spill increases the proportion of fish passing the highest survival route while also reducing the proportion of fish passing the lowest survival route. The provision of spill also decreases the proportion of the population that is transported, increasing the number of in-river migrants (Figure 1-4). If predation mortality is density-dependent, then the provision of spill, with the commensurate increase in the number of in-river migrants should result in higher survival than would be achieved with fewer in-river migrants. It appears that each of these environmental-biological mechanisms contributed to the results that were observed in 2007. With high spill levels and better water transit times than occurred in 2007, we would expect that Chinook and steelhead survival rates would be higher than was observed in 2007.

Release	Water transit time (days)			Average spill (percent)			Median fish travel time (days)			LGR-MCN Survival		
Group	2005	2007	Difference	2005	2007	Difference	2005	2007	Difference	2005	2007	Difference
1	16.6	16.7	0.0	24	52	28	30.1	21.7	-8.4	NA	NA	NA
2	15.9	13.7	-2.2	26	39	14	24.8	16.2	-8.6	0.61	0.69	0.08
3	15.1	14.1	-1.0	26	43	17	19.2	12.1	-7.1	0.68	0.75	0.07
4	13.7	10.9	-2.8	25	38	13	14.3	9.7	-4.6	0.65	0.81	0.17
5	11.1	10.8	-0.2	25	37	12	10.4	8.3	-2.1	0.68	0.81	0.12
6	9.4	9.5	0.1	29	33	4	8.9	7.8	-1.1	0.74	0.77	0.02
7	8.3	10.2	1.9	33	38	6	10.9	8.2	-2.7	0.64	0.84	0.20
8	10.5	13.7	3.2	23	39	16	11.3	10.7	-0.6	0.67	NA	NA
		Average:	-0.1		Average:	13.7		Average:	-4.4		Average:	0.11

Table 3-4 Estimates of water transit time, average percent spill, median fish travel time and survival rate for wild Chinook in the LGR-MCN reach during 2005 and 2007. The difference estimates are calculated by subtracting the 2005 values from the 2007 values.

Release	Water transit time (days)			Average spill (percent)			Median fish travel time (days)			LGR-MCN Survival		
Group	2005	2007	Difference	2005	2007	Difference	2005	2007	Difference	2005	2007	Difference
1	15.4	12.9	-2.5	26.0	38.0	12	17.1	10.7	-6.5	0.47	0.69	0.22
2	12.8	10.5	-2.3	23.4	37.6	14	12.6	10.3	-2.4	0.60	0.73	0.13
3	10.3	10.3	0.0	26.8	35.6	9	8.9	7.6	-1.3	0.62	0.76	0.15
4	8.8	9.5	0.7	30.0	35.6	6	8.6	7.7	-0.9	0.66	0.60	-0.06
5	8.0	10.8	2.8	31.9	37.0	5	6.6	7.2	0.6	0.54	0.59	0.05
6	10.5	14.0	3.5	25.6	43.7	18	7.7	10.0	2.3	0.27	0.53	0.26
		Average:	0.4		Average:	10.6		Average:	-1.3		Average:	0.12

Table 3-5 Estimates of water transit time, average percent spill, median fish travel time and survival rate for wild and hatchery steelhead in the LGR-MCN reach during 2005 and 2007. The difference estimates are calculated by subtracting the 2005 values from the 2007 values.

Release	Wild Chinook			Wild/Hatchery Steelhead		
Group	2005	2007	Difference	2005	2007	Difference
1	11.1	10.0	-1.1	NA	NA	NA
2	11.3	10.8	-0.6	NA	NA	NA
3	11.6	10.8	-0.8	11.5	10.9	-0.6
4	12.1	11.1	-1.0	12.1	11.6	-0.5
5	12.1	12.0	0.0	12.1	12.2	0.1
6	12.2	12.4	0.2	12.2	12.8	0.7
7	12.5	13.4	0.8	12.4	13.5	1.1
8	13.8	14.3	0.4	13.8	14.3	0.5
		Average:	-0.3		Average:	0.2

Table 3-6 Estimates of average water temperature (degrees C) for wild Chinook and wild and hatchery steelhead in the LGR-MCN reach during 2005 and 2007. The difference estimates are calculated by subtracting the 2005 values from the 2007 values. The steelhead release groups are offset roughly two weeks later than the Chinook release groups, with the first Chinook release group being 4/1 through 4/7 at LGR and the first steelhead release group being 4/17 through 4/23 at LGR.

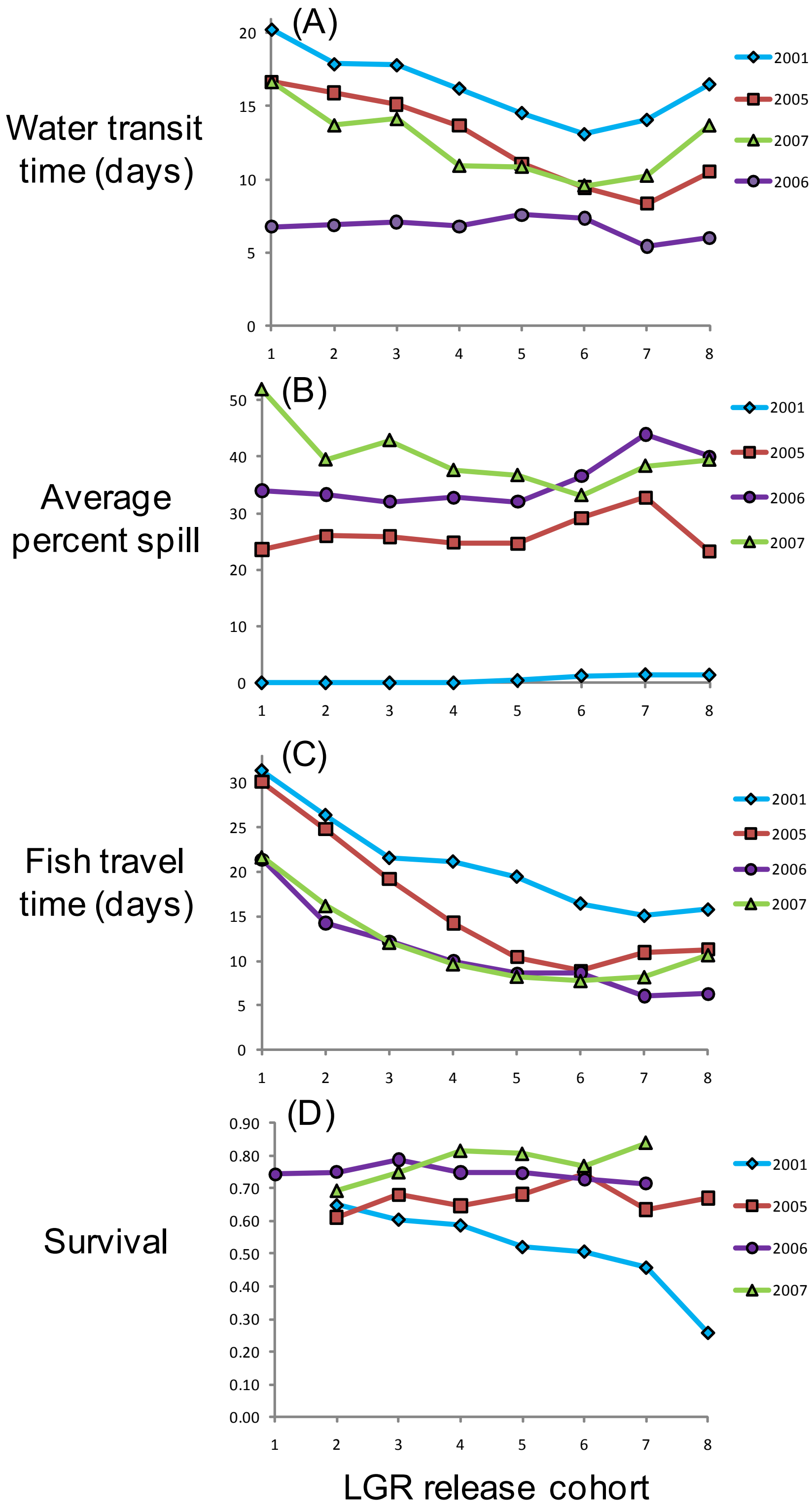


Figure 3-22 Water transit times (A), average percent spill levels (B), median fish travel times (C) and survival rates (D) for wild Chinook in the LGR-MCN reach during 2001, 2005, 2006 and 2007.

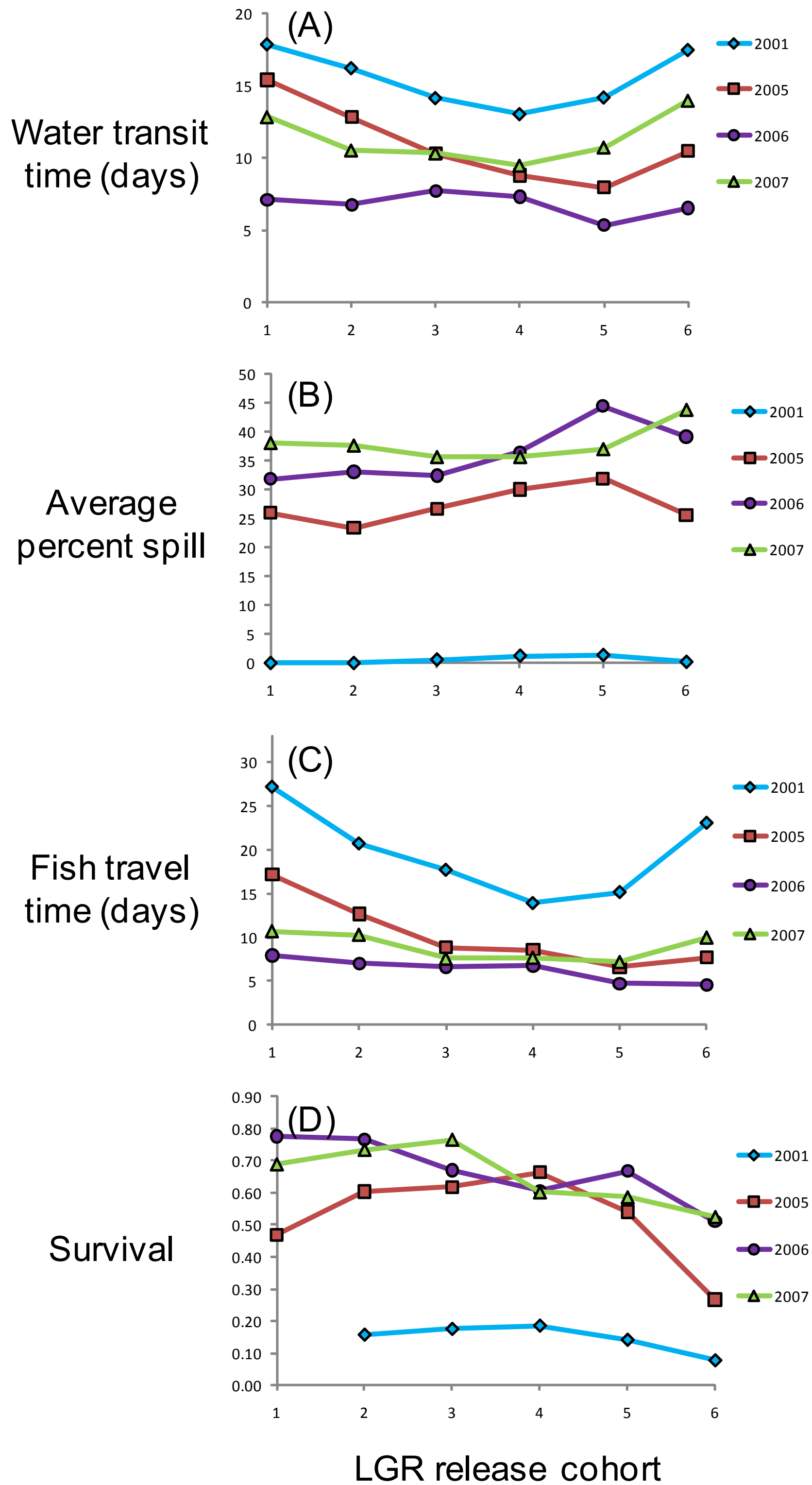


Figure 3-23 Water transit times (A), average percent spill levels (B), median fish travel times (C) and survival rates (D) for wild and hatchery steelhead in the LGR-MCN reach during 2001, 2005, 2006 and 2007.

Discussion

In this analysis we provided an extensive synthesis of the patterns of variation in juvenile yearling Chinook and steelhead fish travel time and survival within the hydrosystem. These metrics are presented both as annual estimates in management-oriented groups and in smaller temporal blocks. In addition to these commonly-used metrics of fish travel time and survival, we also developed and reported estimates of fish migration rates and instantaneous mortality rates, along with estimates of precision for those rates. We observed substantial variation in median fish migration rate, fish travel time, survival, and instantaneous mortality rates both within- and across-years. The models that were developed for characterizing the effects of various environmental and management factors on median fish travel times, survival rates, and instantaneous mortality rates capitalized on this variation and demonstrated a high degree of accuracy.

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. Particularly in the MCN-BON reach, we found that estimates of survival have substantial uncertainty. As a result, estimates of instantaneous mortality rates in this reach also have substantial uncertainty. Although we were able to develop models that explained a substantial proportion (38-70%) of the variation in MCN-BON survival rates, questions remain as to which factors are primarily important for determining survival in the lower river. We see the only way to resolve the remaining questions is to invest in more PIT-tagging efforts for reducing the uncertainty in the lower reach.

We believe that the models developed here provide some useful tools for predicting the effects of alternative hydrosystem management actions. Some of these could include changes in water volume, volume shaping/timing, spill levels and timing, or changes in reservoir elevations. At a minimum, these models provide a basis for hypothesis development for use in adaptive management experiments on the hydrosystem.

Chapter 4

Annual SAR by Study Category, TIR, and *D* for Hatchery and Wild Spring/Summer Chinook Salmon and Steelhead: Patterns and Significance

The following chapter presents survival rate estimates for the spring/summer Chinook and summer steelhead PIT-tagged smolts analyzed in the CSS. The primary focus of comparisons was between the transported and in-river smolts. Key parameters for these comparisons were SAR(T_0), SAR(C_0), SAR(C_1), TIR, and *D*. Graphical presentation of these five parameters for wild and hatchery Chinook and steelhead across migration years are presented in the main body of this chapter, with the nominal values provided in tables at the end of the chapter.

Additional tables of supportive data are presented in Appendix B. This includes the numbers of PIT-tagged wild Chinook, hatchery Chinook, wild steelhead, and hatchery steelhead utilized in the CSS analyses by location of origin (Tables B.1 to B.5). The individual reach survival estimates used to expand PIT-tag smolt counts in the three study categories to LGR equivalents for each migration year are in Tables B.15 to B.21 for wild and hatchery Chinook and steelhead. The estimated number of smolts in each study category (T_0, C_0, and C_1) along with the estimated population of tagged fish arriving at LGR are presented in Table B.6 for wild Chinook, Tables B.7 to B.11 for hatchery Chinook, Table B.12 for wild steelhead, and Table B.13 for hatchery steelhead. These tables also provide a bootstrapped 90% confidence interval around each estimate, along with the number of returning adults in each study category.

Until 2002, most PIT-tagged wild Chinook at the Snake River collector dams were routed back-to-river (default operation), while most run-at-large smolts were transported. Beginning in 2002, the CSS coordinated with IDFG, ODFW, and CTUIR research programs to route 50% (raised to 67% the following year) of the first-time detected PIT-tagged wild Chinook smolts at the Snake River transportation facilities to the raceways for transportation. This action has provided more PIT-tagged wild Chinook smolts in the transportation category in subsequent years. Similarly, most PIT-tagged wild steelhead followed the default return-to-river routing at collector dams in years prior to 2003. Beginning in 2003, more PIT-tagged wild steelhead have become available in the transport group as state and tribal research programs allowed a portion of their PIT-tagged wild steelhead smolts to be routed to the raceways at Snake River transportation facilities. In the years 1997 to 2006, with the exception of 2003, the number of PIT-tagged hatchery steelhead transported has been small relative to the number of untagged hatchery steelhead transported. In 2003, a portion of the PIT-tagged hatchery steelhead smolts released with production were routed to the raceways at Snake River dams for transportation. Large-scale routing of PIT-tagged hatchery steelhead to transportation did not begin until 2007, outside the range of years analyzed in this report.

The number of PIT-tagged smolts transported at each collector dam (plus estimated number if tagged fish had been transported in same proportion as the untagged population) and site-specific SAR estimates are presented in Tables B.22 to B.30.

Estimates of SAR by Study Category

Wild and hatchery Chinook

The estimated LGR-LGR SAR for PIT-tagged wild Chinook were generally low, exceeding 2% in only 3 of 14 years for the SAR(C_0) and only one for the SAR(T_0) and SAR(C_1) (Figure 4.1). Wild Chinook SARs are far below those recommended to maintain a stable population (2%) or to achieve recovery (4%; Marmorek et al. 1998). The estimated SARs were exceptionally low (< 0.6%) for both the SAR(C_0) and SAR(T_0) in 2003 to 2005, and were similar to the low SARs during 1994 to 1996. The SAR for in-river migrants was only 0.14% in 2001.

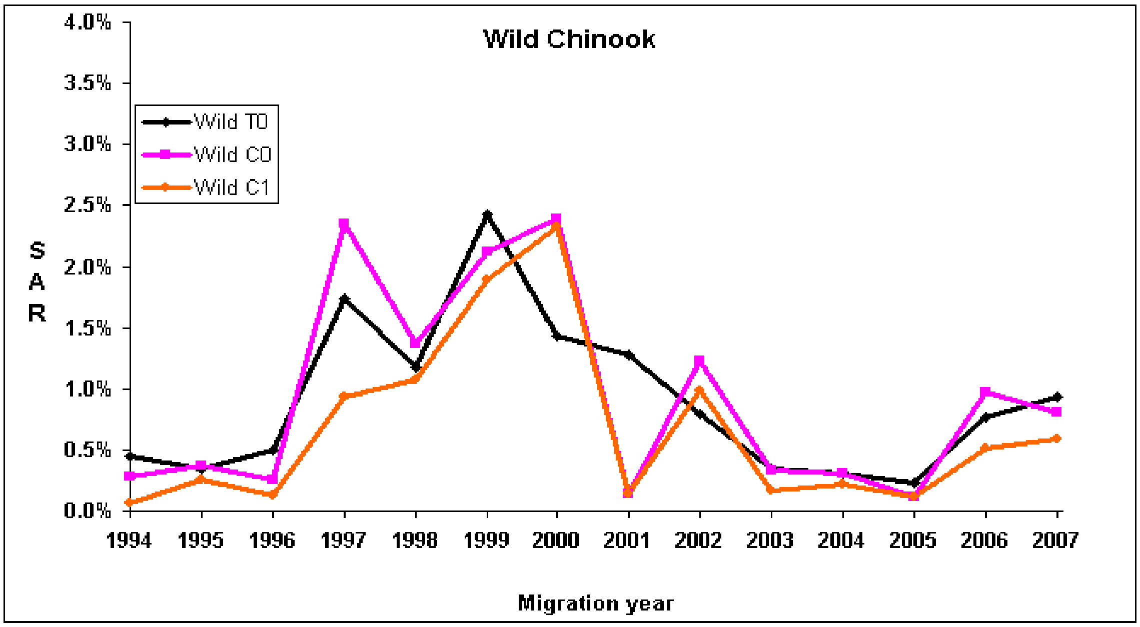


Figure 4.1 Estimated LGR-LGR SAR for PIT-tagged wild Chinook aggregate in transport [SAR(T_0)] and in-river [SAR(C_0) and SAR(C_1)] study categories for migration years 1994 to 2007 (incomplete adult returns for 2007).

SARs among the hatchery Chinook populations exhibit variation among years, among hatcheries, and among outmigration categories (Figure 4.2). However, the inter-annual patterns of variation are generally similar among hatcheries and between hatchery groups in the aggregate and wild Chinook for each of the outmigration categories. The aggregate hatchery groups appear to have the potential to serve as surrogates to represent trends in survival of wild Chinook, but may not reflect the actual magnitude of survival rates.

The SARs for the PIT-tagged hatchery Chinook are generally in the same range as the PIT-tagged wild Chinook for the C_0 smolts. McCall hatchery summer Chinook are the only hatchery population with an average SAR(C_0) equal to wild Chinook, all others exhibit lower SAR(C_0) values (Figure 4.2, top panel). SARs for the hatchery T_0 smolts had mixed performance relative to wild T_0 smolts (Figure 4.2 bottom). Two hatcheries (Dworshak and Catherine Creek) exhibited lower T_0 than wild smolts. The other three hatcheries (Rapid River, McCall, and Imnaha) exhibited greater T_0 than wild smolts. The C_1 category for the hatchery smolts had average SARs that were lower than the C_0 SARs for all hatcheries except Catherine Creek (Figure 4.2 middle).

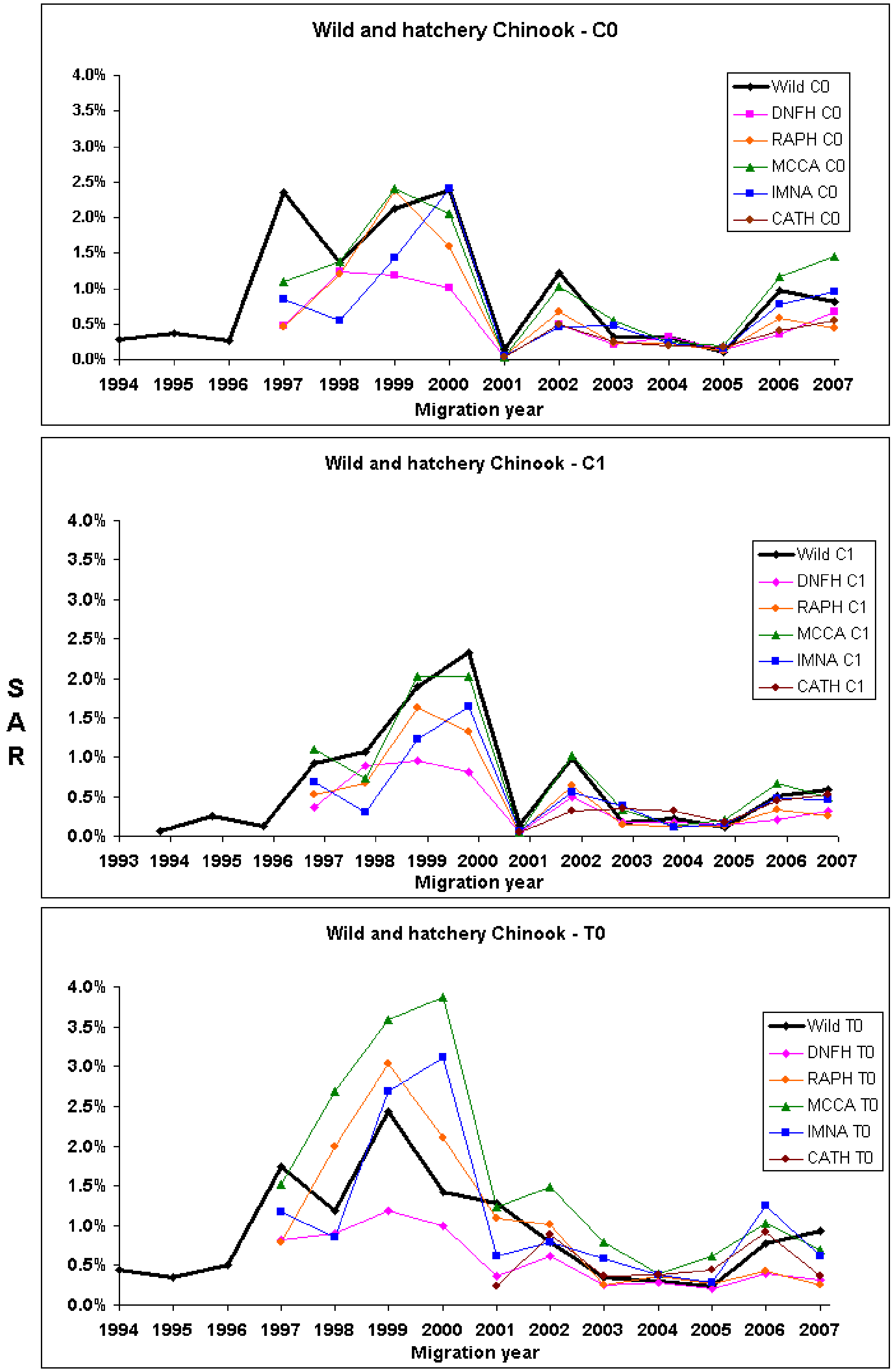


Figure 4.2 Trends in SAR(C_0) (top plot), SAR(C_1) (middle plot) and SAR(T_0) (bottom plot) for PIT-tagged Snake River wild and hatchery spring/summer Chinook in migration years 1994 to 2007.

Wild and hatchery Steelhead

The in-river C_0 SARs for PIT-tagged wild steelhead ranged from 0.06 to 1.92% and averaged 0.78% (Figure 4.3 and Table 4.19). The average transport T_0 SAR was 1.79% and exceeded 2% in four (1999 - 2002) of the 10 years analyzed. The sample sizes for wild steelhead have been small, which results in few adult returns and rather large 90% confidence intervals for the SAR estimates (Table 4.19).

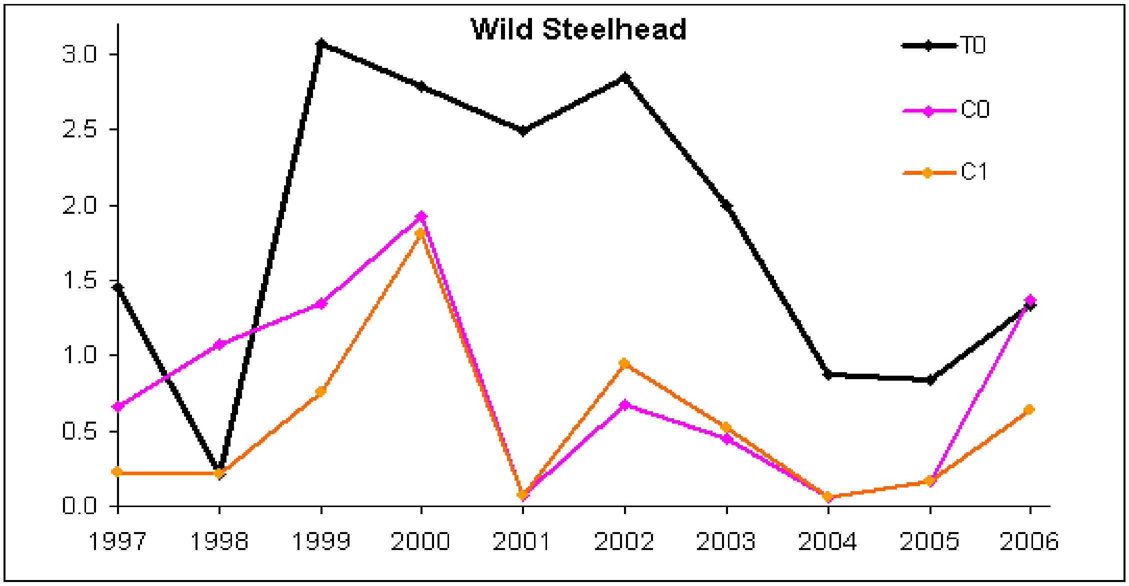


Figure 4.3 Estimated LGR-LGR SAR for PIT-tagged wild steelhead aggregate in transport [SAR(T_0)] and in-river [SAR(C_0) and SAR(C_1)] study categories for migration years 1997 to 2006.

The in-river C_0 SARs for PIT-tagged hatchery steelhead ranged from 0.21 to 1.42% and averaged 0.64% (Table 4.21). The SARs for transported smolts [SAR(T0)] were higher than the SARs of in-river migrants, averaging 1.40% and exceeding 2% in 2000, 2004, 2005, and 2006. The pattern of inter-annual variability for the in-river SARs was similar for hatchery and wild steelhead (Figures 4.3 and 4.4).

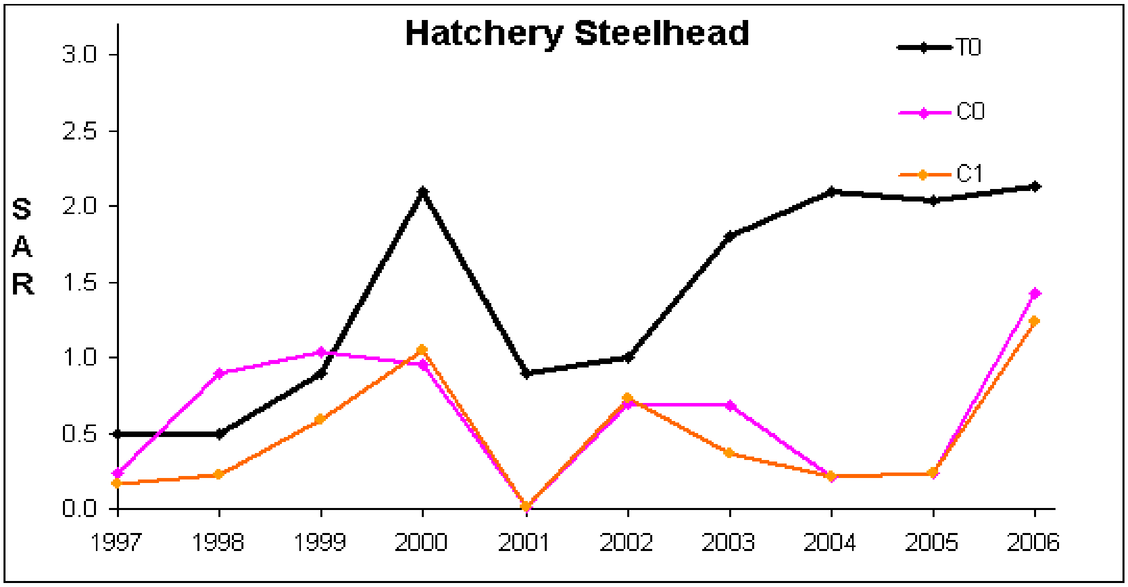


Figure 4.4 Estimated LGR-LGR SAR for PIT-tagged hatchery steelhead aggregate in transport [SAR(T_0)] and in-river [SAR(C_0) and SAR(C_1)] study categories for migration years 1997 to 2006.

Estimates of TIR and *D*

Wild and hatchery Chinook

The TIR is a measure of the relative performance of transported (T_0) and in-river migrating (C_0) smolts. A TIR > 1.0 indicates that a transported SAR was greater than an in-river SAR while a TIR < 1.0 indicates that a transported SAR was less than an in-river SAR. A TIR is statistically different from 1.0 when the 90% confidence interval does not encompass 1.0. For wild Chinook, the TIR values were greater than one in eight of the 14 years (Table 4.1). However, the wild Chinook TIRs were not statistically different from 1.0 in most study years. The wild Chinook TIR was significantly greater than one in only two of the 14 study years (the lower limit of the 90% CI exceeded 1 in 2001 and 2005). The remaining 12 years had wild Chinook TIRs that were not significantly different from one, including the 2007 low-flow year.

TIRs varied substantially among hatcheries and across years. Half of the hatchery TIRs were greater than one with statistical significance (Table 4.1). Statistically significant TIRs > 1.0 occurred for Dworshak Hatchery in 2 of 11 years, Catherine Creek hatchery stock in 2 of 7 years, Imnaha hatchery stock in 4 of 11 years, Rapid River Hatchery in 9 of 11 years, and McCall Hatchery in 9 of 11 years.

Both hatchery and wild TIR estimates appeared to vary with in-river migration conditions. For example, hatchery and wild TIRs were all relatively low during the 2006 high-flow, high-spill year. In contrast, TIRs were much higher during the 2001 low-flow, no-spill year. TIRs during 2001 ranged from 5.33 to 31.9, higher than all other years (Table 4.1). Despite 2007 flows being similar to the 2001 low-flow conditions in the Snake River (Figure 1.4), TIRs of wild and hatchery Chinook were much lower in 2007 than 2001 and were not significantly different from one. The results from 2007 suggest that the provision of spill may lower TIRs (i.e., increase the C_0 SAR relative to the T_0 SAR), even under low-flow conditions.

The annual trends in TIRs (natural log-transformed) are similar among the wild and hatchery groups. Wild Chinook TIRs are lower than hatchery TIRs (Figure 4.5). Among hatcheries, TIRs were lowest for Dworshak Hatchery and highest for McCall Hatchery.

Table 4.1 Estimated TIR and corresponding lower limit of non-parametric confidence interval, which provides a one-tail (α=0.05) test of H_0: TIR≤ 1 versus H_A: TIR>1, of PIT-tagged wild Chinook compared to hatchery spring Chinook. TIR lower limit >1 values are shaded in yellow.

Migr Year	Wild Chinook		Hatchery Spring Chinook						Hatchery Summer Chinook			
			Rapid River		Dworshak		Catherine Ck		McCall		Imnaha	
	TIR	LL	TIR	LL	TIR	LL	TIR	LL	TIR	LL	TIR	LL
1994	1.62	0.62										
1995	0.95	0.39										
1996	1.92	0.00										
1997	0.74	0.17	1.73	1.08	1.75	0.92			1.38	1.06	1.36	0.83
1998	0.87	0.50	1.66	1.32	0.72	0.59			1.96	1.54	1.55	0.93
1999	1.14	0.82	1.28	1.11	0.99	0.81			1.49	1.29	1.89	1.40
2000	0.60	0.32	1.32	1.13	0.99	0.82			1.89	1.67	1.29	1.06
2001 [A]	8.96	3.61	21.7	13.3	8.76	5.04	5.33	0	31.9	7.90	10.8	4.94
2002	0.65	0.45	1.5	1.20	1.24	0.93	1.81	1.02	1.44	1.18	1.75	1.07
2003	1.06	0.68	1.07	0.73	1.21	0.81	1.46	0.64	1.47	1.18	1.21	0.80
2004	1.09	0.68	1.57	0.88	0.89	0.59	1.94	0	1.59	0.87	1.64	0.54
2005 [B]	2.14	1.40	2.36	1.59	1.43	0.97	2.48	1.02	3.02	2.33	1.77	0.91
2006 [C]	0.79	0.58	1.37	1.003	0.90	0.66	0.45	0.21	1.12	0.91	0.62	0.42
2007 [C D]	1.15	0.80	1.84	1.27	2.19	1.24	1.46	0.71	2.09	1.64	1.57	0.96

[A] SAR(C_1) used in 2001 in derivation of TIR.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR.
[C] Mig. year 2006 and 2007 data is combined groups TWS & BWS
[D] Incomplete with 2-salt adult returns through August 3, 2009

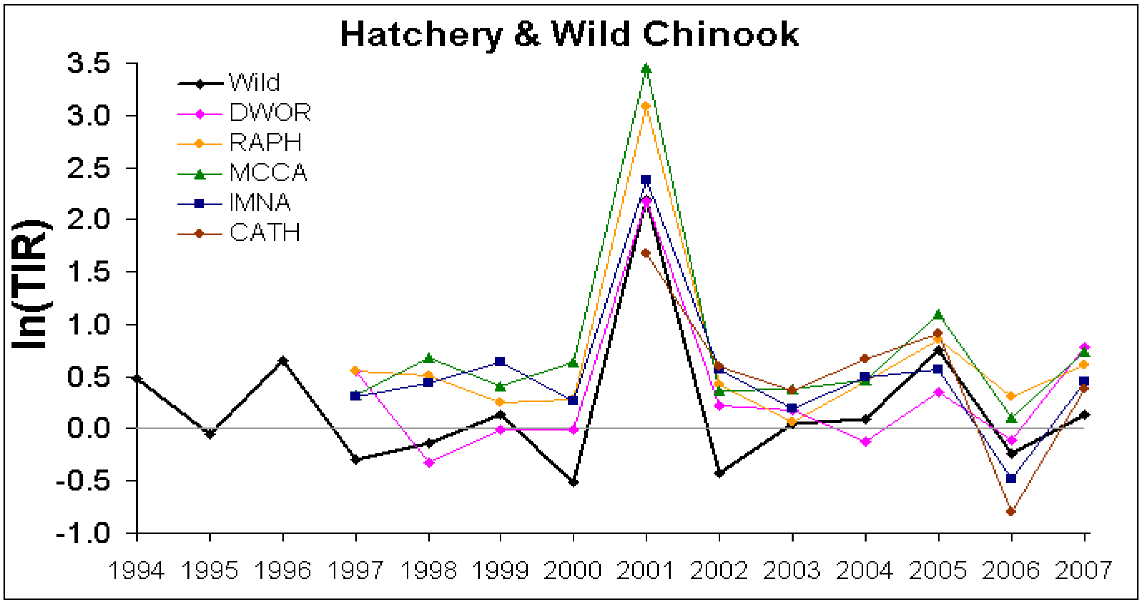


Figure 4.5 Trend in TIR (log-transformed) for PIT-tagged Snake river hatchery and wild Chinook for migration years 1994 to 2007. The grey reference line denotes where a TIR value of 1 would be plotted which is where the in-river and transport SARs are equal.

In the absence of differential delayed mortality post-Bonneville Dam of transported fish compared to in-river migrants, *D* would be equal to one. When *D* estimates are >1, the post-BON mortality is greater for the in-river migrants and when *D* estimates are <1, it is greater for the transported smolts. Statistical significance was demonstrated for *D* >1 when the lower limit of the 90% confidence interval for *D* was >1. Statistical significance was demonstrated for a *D* <1 when the upper limit of the 90% confidence interval for *D* was <1.

Significant *D* >1 (post-BON mortality of in-river fish is greater than that of transported fish) estimates were obtained for Rapid River, Dworshak, and McCall hatcheries and the Imnaha hatchery stock in 2001. *D* was not significantly greater than 1 for wild Chinook and Catherine Creek hatchery Chinook, though both had point estimates above 1 (Table 4.2a). A significant *D* >1 estimate was also demonstrated for McCall Hatchery Chinook in 2005 and 2007.

A significant *D* <1 (post-BON mortality of transported fish is greater than that of in-river fish) was demonstrated for PIT-tagged wild Chinook in 7 of 14 years and Dworshak Hatchery Chinook in 5 of 11 years, while in only 1 to 2 years for the remaining four hatcheries (Table 4.2b). It appears that since transport SARs were only significantly greater than in-river SARs in 2 years for PIT-tagged wild Chinook and Dworshak Hatchery Chinook smolts, and post-BON mortality of transported fish was not significantly less than post-BON mortality of in-river fish, then transportation provides no greater survival advantage over allowing wild Chinook and Dworshak Hatchery Chinook to migrate in-river.

Table 4.2a Estimated *D* and corresponding lower limit of non-parametric 90% confidence interval, which provides a one-tail (α=0.05) test of H_0: *D* ≤ 1 versus H_A: *D* >1, of PIT-tagged wild Chinook compared to hatchery spring and summer Chinook. *D* lower limit >1 values are shaded in yellow.

Migr Year	Wild Chinook		Hatchery Spring Chinook						Hatchery Summer Chinook			
			Rapid River		Dworshak		Catherine Ck		McCall		Imnaha	
	D	LL	*D*	LL	*D*	LL	*D*	LL	*D*	LL	*D*	LL
1994	0.36	0.13										
1995	0.42	0.17										
1996	0.92	0.00										
1997	0.40	0.08	0.61	0.37	0.88	0.40			0.64	0.43	0.45	0.24
1998	0.55	0.31	1.01	0.80	0.37	0.30			1.16	0.89	0.87	0.51
1999	0.72	0.52	0.79	0.65	0.60	0.47			0.87	0.72	1.11	0.75
2000	0.32	0.17	0.82	0.66	0.53	0.42			1.24	0.98	0.82	0.56
2001 [A]	2.16	0.87	7.33	4.40	2.21	1.23	1.38	0.03	8.95	4.87	4.15	1.83
2002	0.44	0.29	1.14	0.87	0.84	0.61	1.23	0.59	0.87	0.68	0.95	0.54
2003	0.68	0.43	0.75	0.50	0.88	0.58	0.94	0.41	1.09	0.85	0.91	0.57
2004	0.45	0.27	0.57	0.31	0.46	0.29	0.95	0	0.72	0.37	0.94	0.27
2005 [B]	1.06	0.63	1.31	0.84	0.77	0.51	1.32	0.50	1.67	1.23	1.11	0.54
2006 [C]	0.48	0.32	0.85	0.62	0.57	0.41	0.23	0.11	0.75	0.60	0.36	0.24
2007 [C D]	0.73	0.52	1.24	0.84	1.59	0.91	1.10	0.49	1.79	1.37	1.15	0.67

[A] SAR(C_1) used in 2001 in derivation of *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of *D*.
[C] Mig. year 2006 and 2007 data is combined groups TWS & BWS
[D] Incomplete with 2-salt adult returns through August 3, 2009

Table 4.2b Estimated *D* and corresponding upper limit of non-parametric 90% confidence interval, which provides a one-tail (α=0.05) test of H_0: *D* ≥ 1 versus H_A: *D* <1, of PIT-tagged wild Chinook compared to hatchery spring and summer Chinook. *D* upper limit <1 values are shaded in blue.

Migr Year	Wild Chinook		Hatchery Spring Chinook						Hatchery Summer Chinook			
			Rapid River		Dworshak		Catherine Ck		McCall		Imnaha	
	D	UL	*D*	UL	*D*	UL	*D*	UL	*D*	UL	*D*	UL
1994	0.36	1.09										
1995	0.42	1.09										
1996	0.92	3.24										
1997	0.40	0.95	0.61	1.09	0.88	2.01			0.64	0.93	0.45	0.92
1998	0.55	0.87	1.01	1.36	0.37	0.47			1.16	1.54	0.87	1.72
1999	0.72	0.98	0.79	0.99	0.60	0.81			0.87	1.07	1.11	1.72
2000	0.32	0.51	0.82	1.25	0.53	0.75			1.24	1.81	0.82	1.25
2001 [A]	2.16	4.16	7.33	16.9	2.21	5.30	1.38	3.79	8.95	24.1	4.15	15.3
2002	0.44	0.68	1.14	1.52	0.84	1.12	1.23	2.79	0.87	1.14	0.95	1.78
2003	0.68	1.12	0.75	1.15	0.88	1.37	0.94	2.53	1.09	1.37	0.91	1.41
2004	0.45	0.95	0.57	1.46	0.46	0.77	0.95	1.33	0.72	1.95	0.94	3.14
2005 [B]	1.06	1.85	1.31	2.30	0.77	1.22	1.32	5.90	1.67	2.36	1.11	2.69
2006 [C]	0.48	0.79	0.85	1.20	0.57	0.81	0.23	0.47	0.75	0.97	0.36	0.55
2007 [C D]	0.73	1.03	1.24	1.80	1.59	2.45	1.10	2.45	1.79	2.36	1.15	1.87

[A] SAR(C_1) used in 2001 in derivation of *D*.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of *D*.
[C] Mig. year 2006 and 2007 data is combined groups TWS & BWS
[D] Incomplete with 2-salt adult returns through August 3, 2009

Although Snake River wild and hatchery populations demonstrated differences in estimated magnitude of TIRs and *D*s, the historical patterns for these were similar among wild and hatchery populations. TIRs were higher for hatchery fish than wild fish, but the TIR pattern for the wild population tracked well with those of the hatchery populations across years (Figure 4.5). Similarly, hatchery fish had higher *D* values than wild fish, but wild and hatchery *D*s also tracked well across years (Figure 4.6).

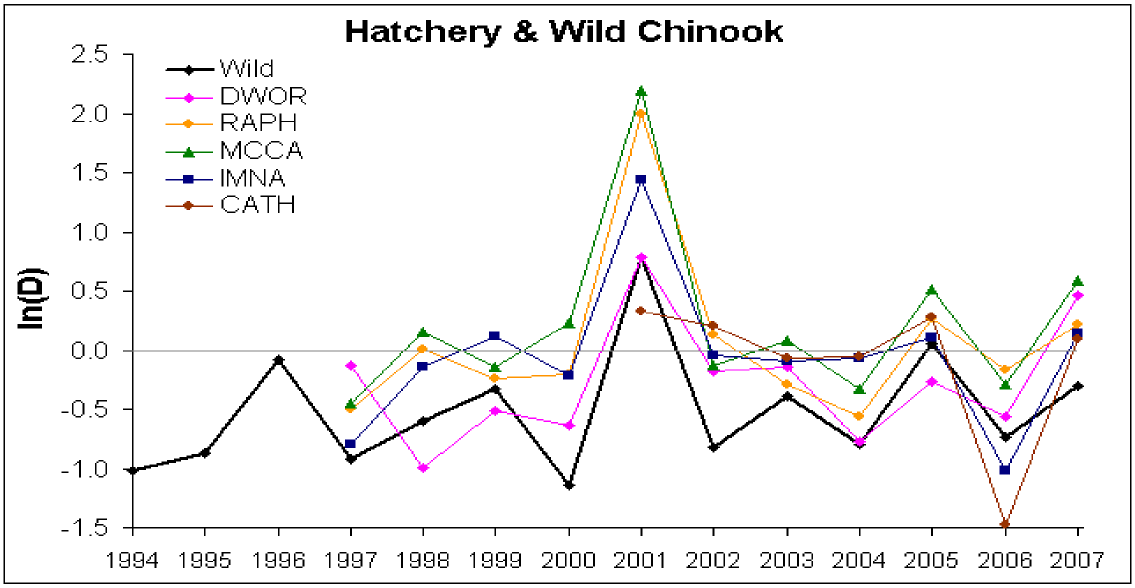


Figure 4.6 Trend in *D* (log-transformed) for PIT-tagged Snake River hatchery and wild Chinook in migration years 1994-2007. The grey reference line denotes where a *D* value of 1 would be plotted which is where the in-river and transport post-BON survivals are equal.

Wild and hatchery steelhead

The TIR estimates for wild and hatchery steelhead exceeded 1 in all years except 1998 and 2006 (near 1 in this year though) for wild steelhead and 1998 and 1999 for hatchery steelhead (Table 4.3). The lower limit of the 90% confidence interval for the wild steelhead TIRs was >1 in 6 of 10 years (1999 and 2001-2005), which demonstrates a statistical significance for those years (Table 4.3). A statistically significant TIR>1 was demonstrated in 4 of 10 years (2000 and 2003-2005) for PIT-tagged hatchery steelhead (Table 4.3). Similar to Chinook salmon TIRs, steelhead TIRs were markedly higher in 2001 than during all other years as demonstrated in the natural log TIR trend across years for both hatchery and wild steelhead (Figure 4.7).

Table 4.3 Estimated TIR and corresponding lower limit of non-parametric confidence interval, which provides a one-tail (α=0.05) test of H_0: TIR≤ 1 versus H_A: TIR>1, of PIT-tagged hatchery steelhead compared to wild steelhead. TIR lower limit >1 values are shaded in yellow.

Migr. Year	Hatchery Steelhead		Wild Steelhead	
	TIR	Lower Limit	TIR	Lower Limit
1997	2.21	0.99	2.20	0.00
1998	0.58	0.23	0.20	0.00
1999	0.87	0.48	2.28	1.15
2000	2.20	1.22	1.45	0.77
2001 [A]	59.7	0.00	37.0	10.6
2002	1.51	0.38	4.25	2.12
2003	2.65	1.93	4.41	2.74
2004 [B]	10.3	5.43	14.3	7.19
2005 [B]	8.44	5.04	4.88	3.01
2006 [C]	1.49	0.86	0.98	0.57

[A] SAR(C1) used in 2001 in derivation of TIR.
[B] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR.
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after 7/1/2009 at GRA.

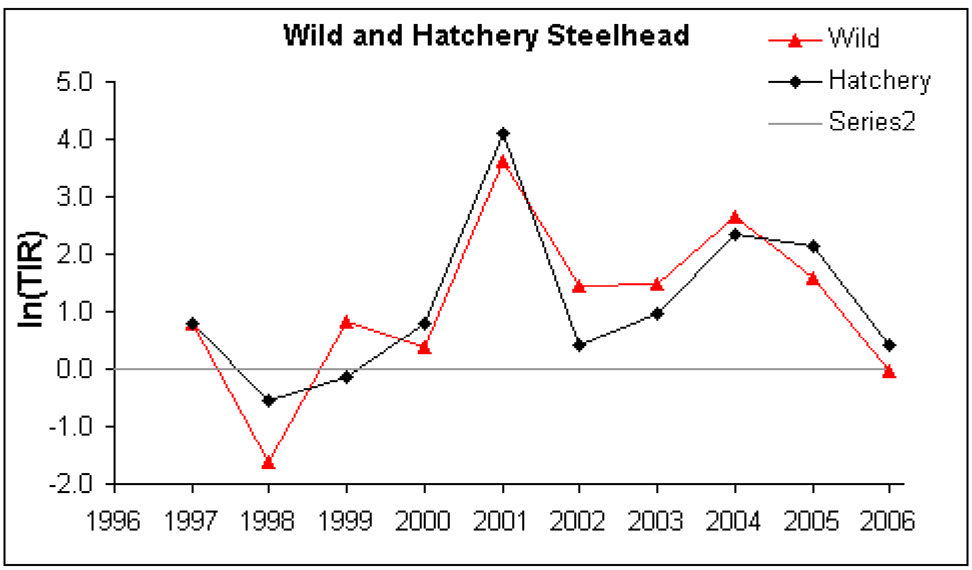


Figure 4.7 Trend in TIR (log-transformed) for PIT-tagged Snake River hatchery and wild steelhead in migration years 1997 to 2006. The grey reference line denotes where a TIR value of 1 would be plotted which is where the in-river and transport SARs are equal.

The estimate of *D* was >1 in 7 of 10 years for PIT-tagged wild steelhead and 4 of 10 years for PIT-tagged hatchery steelhead (Table 4.4). Statistical significance was demonstrated for *D* >1 when the lower limit of the 90% confidence interval for D was >1, which occurred in 2005 for hatchery steelhead and 2002 to 2004 for wild steelhead. Statistical significance was demonstrated for a *D* <1 when the upper limit of the 90% confidence interval for *D* was <1, which occurred in 1998 to 2000 for hatchery steelhead and 1998 and 2000 for wild steelhead.

Table 4.4 Estimated *D* and corresponding lower and upper limits of non-parametric 90% confidence interval, which, of PIT-tagged hatchery steelhead compared to wild steelhead. *D* lower limit >1 values are shaded in yellow and *D* upper limit <1 values are shaded in blue.

Migr. Year	Hatchery Steelhead			Wild Steelhead		
	D	Lower Limit [A]	Upper Limit [B]	*D*	Lower Limit [A]	Upper Limit [B]
1997	0.92	0.36	2.67	1.18	0.00	5.74
1998	0.39	0.16	0.85	0.11	0.00	0.41
1999	0.41	0.22	0.70	1.07	0.53	2.09
2000	0.55	0.30	0.93	0.50	0.27	0.82
2001 [C]	2.40	0.00	10.0	1.46	0.40	4.40
2002	0.60	0.14	1.38	2.24	1.09	4.25
2003	1.43	0.99	2.10	1.75	1.04	3.16
2004 [D]	1.85	0.91	3.46	2.69	1.29	8.78
2005 [D]	3.19	1.86	5.37	1.30	0.76	2.30
2006 [E]	0.98	0.56	1.72	0.60	0.34	1.39

[A] provides a one-tail (α=0.05) test of H_0: $D \leq 1$ versus H_A: $D > 1$
[B] provides a one-tail (α=0.05) test of H_0: $D \geq 1$ versus H_A: $D < 1$
[C] SAR(C_1) used in 2001 in derivation of *D*.
[D] In-river SAR is combination of groups C_0 and C_1 in derivation of *D*.
[E] Incomplete steelhead adult returns until 3-salt returns (if any) occur after 7/1/2009 at GRA.

The natural log *D* trend across years is presented for both hatchery and wild steelhead in Figure 4.7. Although differences arise between the estimates for wild and hatchery steelhead, the TIR and *D* data suggest that steelhead as a whole respond more favorably to transportation than do the listed wild Chinook.

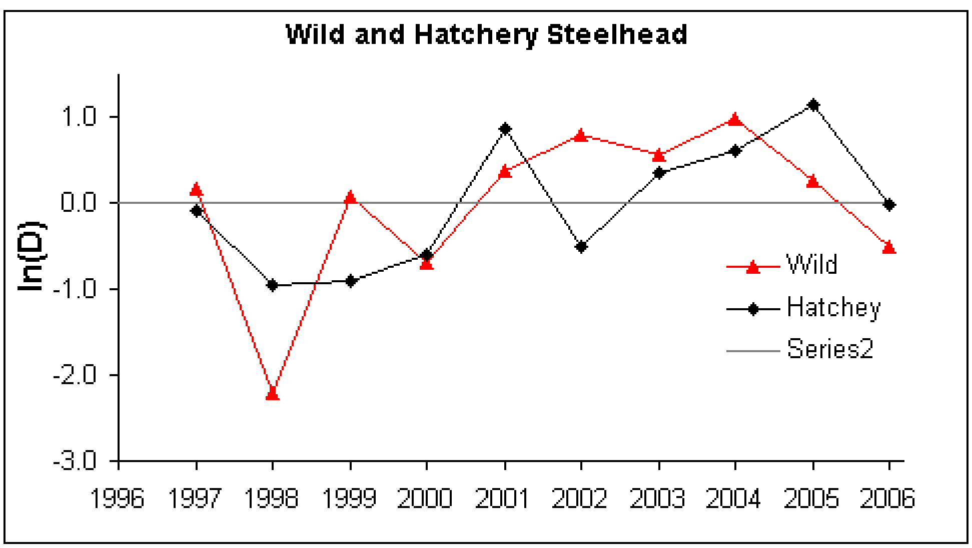


Figure 4.8 Trend in *D* (log-transformed) for PIT-tagged Snake River hatchery and wild steelhead in migration years 1997-2006. The grey reference line corresponds to a *D* value of 1, which is the level at which in-river and transport post-BON survivals are equal.

Patterns in survival across years

The long-term monitoring data provided by the CSS study groups for wild spring/summer Chinook, hatchery spring Chinook, hatchery summer Chinook, wild steelhead, and hatchery steelhead provide information on variability in smolt survival among life stages, study groups and migration years. In this section, we explore patterns of variation in the relative survival of transported versus in-river migrants as well as patterns of variation in the SARs of smolts that migrate through the transportation projects undetected (C_0 smolts) versus smolts that are bypassed at the transportation projects (C_1 smolts).

The Transportation: In-river Ratio (TIR) is a measure of relative life-cycle survival for smolts experiencing two disparate outmigration conditions: transportation and in-river migration. The TIR includes survival during the smolt stage, with survival on the transportation barges assumed to be high (98%) and in-river survival through the hydrosystem being quite variable across years (Chapter 3). The TIR also includes survival after passing Bonneville Dam for transported and in-river migrants, which is measured by *D*. Given that the TIR includes survival during the smolt life stage, we hypothesized that TIRs may decrease as smolt survival increases. To examine this hypothesis on the relationship between in-river survival and TIRs, we conducted regression analyses on the associations between S_R and TIR for wild Chinook and wild steelhead.

We considered four possible models for characterizing the association between log-transformed TIRs and S_R: species-specific slopes and intercepts, species-specific slopes with a common intercept, a common slope with species-specific intercepts and a common slope and intercept (Table 4.5). We calculated Akaike's Information Criterion for small sample sizes (AIC_c), along with AIC differences and AIC weights for each model. The results indicate that a model with a common slope and intercept for the two species achieves the best fit according to its AIC_c value, followed by the species-specific intercept with a common slope model (Table 4.5). The association between $\log_e$(TIR) and S_R is highly significant ($P < 0.00002$), with $\log_e$(TIR) decreasing as S_R increases (Figure 4.9). The parameters of the fitted relationship indicate that at S_R values greater than 0.55, the expected value of $\log_e$(TIR) drops to less than zero. Put another way, average TIRs are expected to be less than one when S_R values are greater than 0.55. These results lend support to our initial hypothesis that TIRs decrease as in-river survival increases.

Table 4.5 Akaike's Information Criterion for small sample sizes (AIC_c), AIC differences (Δ_i) and AIC weights (w_i) for four models of $\log_e$(TIR) versus S_R with common or species-specific intercepts and slopes.

Intercept	Slope	AIC_c	Δ_i	w_i
Common	Common	58.6	0.0	0.54
Species-specific	Common	60.6	2.0	0.20
Species-specific	Species-specific	61.1	2.5	0.16
Common	Species-specific	61.8	3.2	0.11

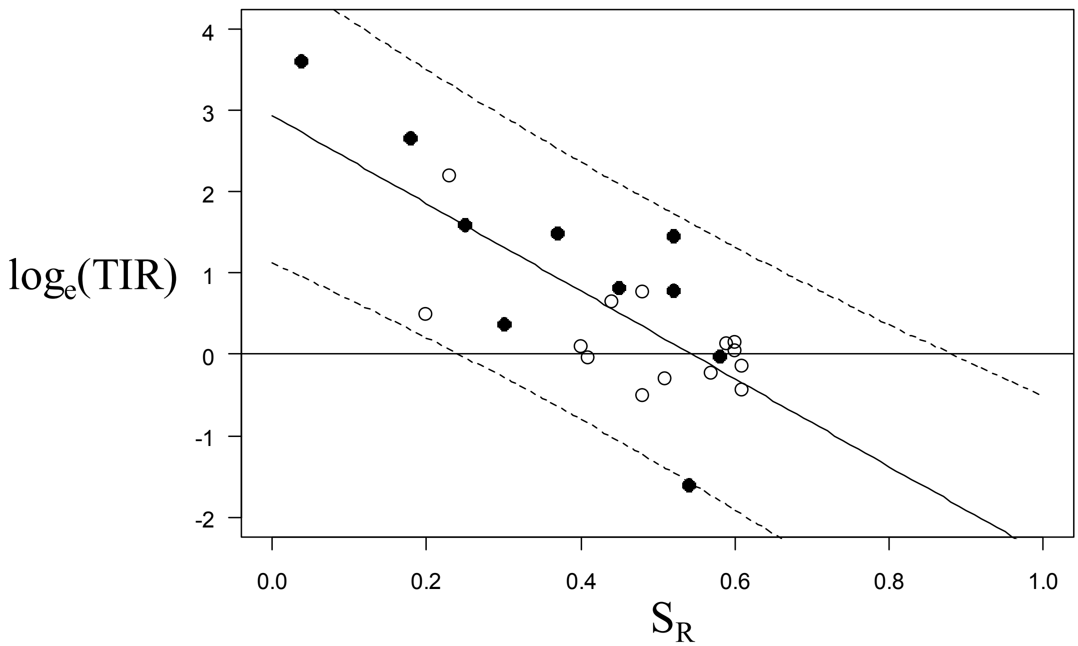


Figure 4.9 Natural logarithm of Transportation : In-river Ratio (TIR) versus in-river survival rate (SR) for wild Chinook (open points) for juvenile migration years 1994-2007 and wild steelhead (filled points) for juvenile migration years 1997-2006. Broken lines represent the 95% prediction intervals for $\log_e$(TIR).

Another aspect of the CSS survival data we were interested in exploring was patterns of variation in the SARs of smolts that migrate through the transportation projects undetected (C_0 smolts) versus smolts that are bypassed at the transportation projects (C_1 smolts). We hypothesized that SARs of fish that experience the bypass systems may be compromised due to the stress, injury, and/or disease factors associated with the "collection" process (Budy et al. 2002). To explore this hypothesis, we calculated ratios of the SAR(C_0) relative to SAR(C_1) for each of the groups analyzed in the CSS. Values greater than one indicate that the SAR(C_0) is higher than the SAR(C_1), while values less than one indicate that the SAR(C_0) is less than the SAR(C_1). For hatchery Chinook, we calculated the average across the 4-5 hatchery stocks analyzed each year in the CSS.

The results of these analyses are provided in Table 4.6 and Figure 4.10. The SAR(C_0) values were generally higher than the SAR(C_1) values across years and across species/rear-type groups. Yearly average values for the ratios ranged from near one (2000 and 2002) up to two (1997) or three (1998). Wild Chinook and steelhead generally had higher values for the ratios than hatchery Chinook and steelhead. In 1998 the ratio estimates for steelhead were quite high (4.05-5.10), but the estimates for Chinook were much lower (1.27-1.73). The average across all the estimates in Table 4.6 is 1.75, indicating that on average, the SAR(C_0) is 75% higher than the SAR(C_1). These results lend support to the Budy et al. (2002) hypothesis that the bypass systems may compromise SARs due to stress, injury and/or disease factors associated with the collection process relative to SARs of smolts that migrate past the collector dams undetected.

Table 4.6 Ratio of SAR(C_0) : SAR(C_1) across juvenile migration years for wild (W) and hatchery (H) Chinook (CHN) and steelhead (STH). Estimates for hatchery Chinook are the within-year mean ratio values across hatcheries, while the remaining values are for aggregate groups. Across-year averages for each species/rear-type group as well as across-species/rear-type averages for each year are also provided.

Year	CHN-H	CHN-W	STH-H	STH-W	Average:
1994		4.00			4.00
1995		1.48			1.48
1996		2.00			2.00
1997	1.10	2.53	1.41	2.87	1.98
1998	1.73	1.27	4.05	5.10	3.03
1999	1.27	1.13	1.76	1.78	1.48
2000	1.23	1.03	0.90	1.06	1.06
2001					
2002	1.08	1.23	0.96	0.71	1.00
2003	1.25	1.94	1.84	0.87	1.47
2004	1.60	2.23			1.91
2005					
2006	1.89	1.90	1.15	2.14	1.77
2007	1.24	1.37			1.31
Average:	1.38	1.84	1.73	2.07	

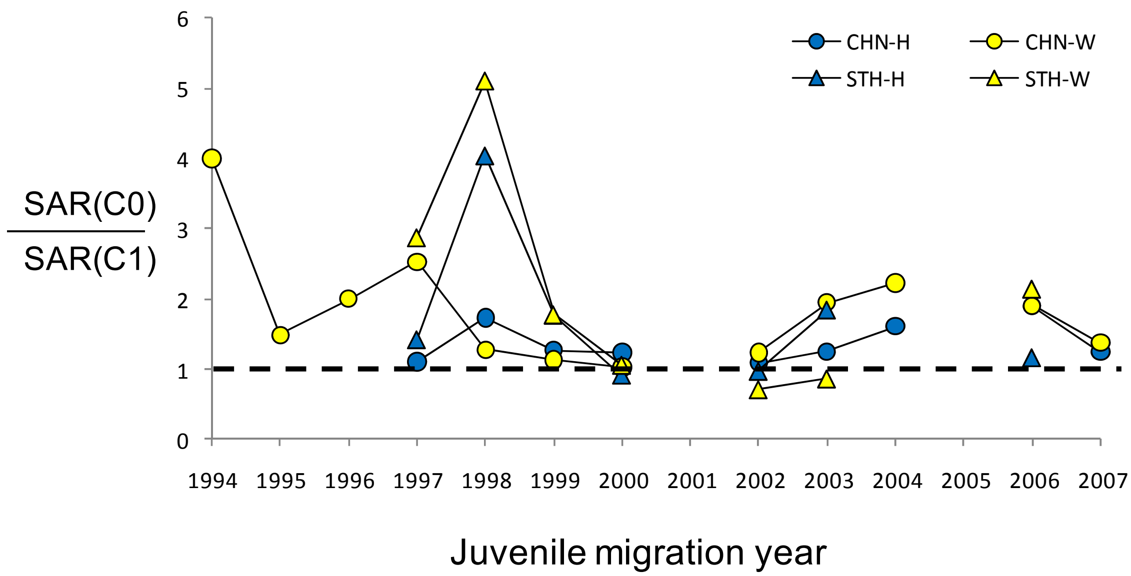


Figure 4.10 Ratio of SAR(C_0) : SAR(C_1) across juvenile migration years for wild (yellow) and hatchery (blue) Chinook (circles) and steelhead (triangles). The broken horizontal line at 1.0 denotes equivalent SARs for the C_0 and C_1 categories. Estimates plotted for hatchery Chinook are the within-year mean ratio values across hatcheries. The wild Chinook, wild steelhead and hatchery steelhead SARs are aggregate groups. Comparisons could not be made in 2001 or 2005 due to the lack of smolts in the C_0 category.

Discussion

The long-term monitoring data provided by the CSS study groups for wild spring/summer Chinook, hatchery spring Chinook, hatchery summer Chinook, wild steelhead, and hatchery steelhead have demonstrated considerable variability in smolt survivals among study groups and between years. The TIR estimates have been used as the initial indicator of potential benefit for smolt transportation for each study grouping. The combination of exceptionally low in-river smolt survivals in 2001 and generally average survivals for transported smolts resulted in exceptionally large TIR values for all study categories for the 2001 migration year. Those TIRs indicated a substantial benefit for smolt transportation in 2001, under unusual environmental conditions, extreme drought, and hydrosystem operations which included no spill and maximization of smolt transportation.

For the rest of the CSS evaluation years, TIR estimates indicate the relative smolt transportation performance has been as follows: wild spring/summer Chinook TIRs (14 TIR estimates) were statistically indistinguishable from one in most years, but were statistically greater than one in 2001 and 2005 and statistically less than one in 2000 and 2002; hatchery spring and summer Chinook TIRs (51 TIR estimates) were statistically indistinguishable from one for half of the years, statistically less than one in three years and statistically greater than one in the remaining years; similarly, wild and hatchery steelhead TIRs (20 TIR estimates) were statistically indistinguishable from one for half of the years and statistically greater than one for the remaining years, with one year of the wild steelhead TIR being significantly less than one (1998). Small sample sizes, especially for steelhead, warrant some degree of caution in the degree of confidence on the relative performance of transportation relative to in-river migration.

Some of the relative transport benefit seen for wild steelhead may be due to their poorer in-river survival compared to Chinook (Tables 4.8 and 4.20). Plots of S_R versus ln(TIR) for wild Chinook and steelhead suggest a relative detriment of transportation when S_R increases above 55%. Whereas in-river survival of wild Chinook has been above 55% in several recent years, wild steelhead in-river survival has only rarely exceeded 55%.

TIRs of both wild Chinook and steelhead demonstrated considerable variability across study years and were significantly associated with in-river survival rates, which are a function of migration conditions (Chapter 3). For example, wild steelhead and wild Chinook TIRs were both less than 1.0 in 2006, a high-flow, high-spill year. In contrast, TIRs were high during the 2001 low-flow, no-spill migration year. Environmental conditions in 2007 were unique in that flows were similar to 2001 (Figure 1.4), but relatively high levels of spill were provided. Despite 2007 flows being similar to the 2001 low-flow conditions (Figure 1.4), TIRs of wild Chinook were much lower in 2007 than 2001 and were not significantly different from one. The results from 2007 suggest that the provision of spill may lower TIRs (i.e., increase the C_0 SAR relative to the T_0 SAR), even under low-flow conditions. One mechanism for this result is that spill increases the survival of in-river migrants and reduces migration delay (Chapter 3), thus increasing the C_0 SAR relative to the T_0 SAR, with the result being a TIR less than or equal to one.

For the majority of smolt groups analyzed across species and wild and hatchery production, the SAR(C_1) was less than the SAR(C_0), indicating that the process of being "collected" to the point necessary for PIT-tag detection and subsequently migrating in-river compromised smolt survival. This reduction in smolt viability is potentially due to the stress, injury, and/or disease factors associated with the "collection" process (Budy et al. 2002; Marmorek et al. 2004). Improving SARs for bypassed and transported salmonid smolts would appear to require a reduction in the detrimental effects of the "collection" process. Alternatively, operations could be implemented which reduced the proportion of in-river migrating fish that experience the collection process, such as increasing spill and/or flow levels, thereby increasing the SARs of in-river migrants through reducing the number of collection and bypass experiences of smolts.

Supporting tables

Wild spring/summer Chinook

Table 4.7 Estimated $SAR_{LGR\text{-}to\text{-}LGR}$ (%) for PIT-tagged wild Chinook in annual aggregate for each study category from 1994 to 2007 (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)	
2006 [B]	0.77	(0.62 – 0.91)	0.97	(0.70 – 1.26)	0.51	(0.39 – 0.64)
2007 [B C]	0.93	(0.68 – 1.22)	0.81	(0.66 – 0.95)	0.59	(0.44 – 0.73)
Average	0.93		0.94		0.67	
90% CI	(0.63 – 1.22)		(0.55 – 1.34)		(0.34 – 1.01)	

[A] In-river SAR is combination of groups C_0 and C_1
[B] Mig. year 2006 and 2007 data is combined groups TWS & BWS
[C] Incomplete with 2-salt adult returns through August 3, 2009

Table 4.8 Estimated in-river survival LGR to BON (SR), TIR, and *D* of PIT-tagged wild Chinook for migration years 1994 to 2007 (with 90% confidence intervals).

Mig. Year	S_R		TIR		*D*	
1994	0.20 [A]	(0.17 – 0.22)	1.62	(0.62 – 5.05)	0.36	(0.13 – 1.09)
1995	0.41 [B]	(0.32 – 0.56)	0.95	(0.39 – 2.14)	0.42	(0.17 – 1.09)
1996	0.44 [A]	(0.35 – 0.55)	1.92	(0.00 – 6.80)	0.92	(0.00 – 3.24)
1997	0.51 [A]	(0.33 – 0.82)	0.74	(0.17 – 1.58)	0.40	(0.08 – 0.95)
1998	0.61 [C]	(0.54 – 0.69)	0.87	(0.50 – 1.35)	0.55	(0.31 – 0.87)
1999	0.59	(0.53 – 0.68)	1.14	(0.82 – 1.51)	0.72	(0.52 – 0.98)
2000	0.48	(0.41 – 0.58)	0.60	(0.32 – 0.92)	0.32	(0.17 – 0.51)
2002	0.61	(0.52 – 0.76)	0.65	(0.45 – 0.94)	0.44	(0.29 – 0.68)
2003	0.60	(0.52 – 0.69)	1.05	(0.68 – 1.68)	0.68	(0.43 – 1.12)
2004	0.40	(0.33 – 0.51)	1.09	(0.68 – 2.19)	0.45	(0.27 – 0.95)
2005 [D]	0.48	(0.39 – 0.61)	2.14	(1.40 – 3.45)	1.07	(0.65 – 1.85)
2006 [E]	0.57	(0.43 – 0.79)	0.79	(0.58 – 1.13)	0.48	(0.32 – 0.79)
2007 [E F]	0.60	(0.57 – 0.63)	1.15	(0.80 – 1.61)	0.73	(0.52 – 1.03)
Geomean	0.48		1.05		0.54	
2001 [G]	0.23	(0.20 – 0.27)	8.96	(3.61 – 16.8)	2.16	(0.87 – 4.16)

[A to C] Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 77% expansion LMN to BON; B = 51% expansion MCN to BON; C = 25% expansion JDA to BON).
[D] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[E] Migr. year 2006 and 2007 data is combined groups TWS & BWS
[F] Incomplete with 2-salt adult returns through August 3, 2009
[G] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.

Rapid River hatchery spring Chinook

Table 4.9 Estimated $SAR_{LGR\text{-}to\text{-}LGR}$ (%) for PIT-tagged spring Chinook from Rapid River Hatchery for each study category from 1997 to 2007 (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)		
2006 [B]	0.58	(0.49– 0.67)	0.42	(0.31 – 0.54)	0.33	(0.24 – 0.43)
2007 [B C]	0.45	(0.34 – 0.58)	0.25	(0.19 – 0.31)	0.25	(0.17 – 0.34)
Average	1.08		0.69		0.53	
90% CI	(0.59 – 1.58)		(0.29 – 1.09)		(0.24 – 0.81)	

[A] **In-river SAR is combination of groups C_0 and C_1**
[B] **Mig. year 2006 and 2007 data is combined groups TWS & BWS**
[C] **Incomplete with 2-salt adult returns through August 3, 2009**

Table 4.10 Estimated in-river survival LGR to BON (SR), TIR, and *D* of PIT-tagged Rapid River Hatchery spring Chinook for 1997 to 2007 (with 90% confidence intervals).

Mig. Year	S_R		TIR		*D*	
1997	0.33 [A]	(0.24 – 0.45)	1.73	(1.08 – 2.85)	0.61	(0.37 – 1.09)
1998	0.59 [C]	(0.52 – 0.66)	1.66	(1.32 – 2.16)	1.01	(0.80 – 1.36)
1999	0.57	(0.49 – 0.67)	1.28	(1.11 – 1.51)	0.79	(0.65 – 0.99)
2000	0.58	(0.48 – 0.83)	1.32	(1.13 – 1.55)	0.82	(0.66 – 1.25)
2002	0.71	(0.60 – 0.84)	1.51	(1.20 – 1.91)	1.14	(0.87 – 1.52)
2003	0.66	(0.57 – 0.78)	1.07	(0.73 – 1.58)	0.75	(0.50 – 1.15)
2004	0.35	(0.27 – 0.51)	1.57	(0.88 – 3.67)	0.57	(0.31 – 1.46)
2005 [D]	0.54	(0.42 – 0.69)	2.36	(1.59 – 3.79)	1.31	(0.83 – 2.30)
2006 [E]	0.55 [C]	(0.51 – 0.61)	1.37	(1.00 – 1.91)	0.85	(0.62 – 1.20)
2007 [E F]	0.63	(0.56 – 0.72)	1.84	(1.27 – 2.62)	1.24	(0.84 – 1.80)
Geomean	0.54		1.54		0.88	
2001 [G]	0.33	(0.28 – 0.40)	21.7	(13.3 – 54.1)	7.33	(4.40 – 16.9)

[A to C] **Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 77% expansion LMN to BON; B = 51% expansion MCN to BON; C = 25% expansion JDA to BON).**
[D] **In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.**
[E] **Migr. year 2006 and 2007 data is combined groups TWS & BWS**
[F] **Incomplete with 2-salt adult returns through August 3, 2009**
[G] **For migration year 2001, the $SAR(C_1)$ value is used in the derivation of TIR and *D*.**

Dworshak hatchery spring Chinook

Table 4.11 Estimated $SAR_{LGR\text{-}to\text{-}LGR}$ (%) for PIT-tagged spring Chinook from Dworshak Hatchery for each study category from 1997 to 2007 (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)		
2006 [B]	0.35	(0.28 – 0.44)	0.39	(0.30 – 0.49)	0.20	(0.14 – 0.27)
2007 [B C]	0.68	(0.39 – 0.97)	0.31	(0.26 – 0.37)	0.32	(0.23 – 0.41)
Average	0.61		0.53		0.42	
90% CI	(0.42 – 0.79)		(0.30 – 0.76)		(0.24 – 0.60)	

[A] In-river SAR is combination of groups C_0 and C_1
[B] Mig. year 2006 and 2007 data is combined groups TWS & BWS
[C] Incomplete with 2-salt adult returns through August 3, 2009

Table 4.12 Estimated in-river survival LGR to BON (SR), TIR, and *D* of PIT-tagged Dworshak Hatchery spring Chinook for 1997 to 2007 (with 90% confidence intervals).

Mig. Year	S_R		TIR		*D*	
1997	0.49 [A]	(0.31 – 0.80)	1.75	(0.92 – 3.46)	0.88	(0.40 – 2.01)
1998	0.51 [C]	(0.44 – 0.58)	0.72	(0.59 – 0.88)	0.37	(0.30 – 0.47)
1999	0.54	(0.47 – 0.65)	0.99	(0.81 – 1.24)	0.60	(0.47 – 0.81)
2000	0.48	(0.40 – 0.65)	0.99	(0.82 – 1.19)	0.53	(0.42 – 0.75)
2002	0.62	(0.54 – 0.72)	1.24	(0.93 – 1.61)	0.84	(0.61 – 1.12)
2003	0.68	(0.58 – 0.81)	1.21	(0.81 – 1.75)	0.88	(0.58 – 1.37)
2004	0.50	(0.40 – 0.66)	0.89	(0.59 – 1.43)	0.46	(0.28 – 0.77)
2005 [D]	0.51	(0.42 – 0.63)	1.43	(0.97 – 2.17)	0.77	(0.51 – 1.22)
2006 [E]	0.54 [C]	(0.49 – 0.59)	0.90	(0.66 – 1.25)	0.57	(0.41 – 0.81)
2007 [E F]	0.67	(0.60 – 0.75)	2.19	(1.24 – 3.27)	1.59	(0.91 – 2.45)
Geomean	0.55		1.17		0.69	
2001 [G]	0.24	(0.20 – 0.30)	8.76	(5.04 – 20.4)	2.21	(1.23 – 5.30)

[A to C] Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 77% expansion LMN to BON; B = 51% expansion MCN to BON; C = 25% expansion JDA to BON).
[D] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[E] Migr. year 2006 and 2007 data is combined groups TWS & BWS
[F] Incomplete with 2-salt adult returns through August 3, 2009
[G] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.

Catherine Creek AP hatchery Chinook

Table 4.13 Estimated $SAR_{LGR\text{-}to\text{-}LGR}$ (%) for PIT-tagged spring Chinook from Catherine Creek AP for each study category from 2001 to 2007 (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)	
2006 [B]	0.41	(0.21 – 0.61)	0.92	(0.55 – 1.34)	0.44	(0.21 – 0.73)
2007 [B C]	0.54	(0.30– 0.80)	0.37	(0.21 – 0.54)	0.52	(0.26 – 0.84)
Average	0.46		0.35		0.31	
90% CI	(0.31 – 0.62)		(0.14 – 0.56)		(0.19 – 0.43)	

[A] **In-river SAR is combination of groups C_0 and C_1**
[B] **Mig. year 2006 and 2007 data is combined groups TWS & BWS**
[C] **Incomplete with 2-salt adult returns through August 3, 2009**

Table 4.14 Estimated in-river survival LGR to BON (SR), TIR, and *D* of PIT-tagged Catherine Creek AP spring Chinook for 2001 to 2007 (with 90% confidence intervals).

Mig. Year	S_R		TIR		*D*	
2002	0.65	(0.44 – 1.06)	1.81	(1.02 – 3.43)	1.23	(0.59 – 2.79)
2003	0.62 [C]	(0.51 – 0.74)	1.45	(0.65 – 3.79)	0.94	(0.41 – 2.53)
2004	0.48 [C]	(0.34 – 0.72)	1.94	(0.0 – 2.57)	0.95	(0.0 – 1.33)
2005 [D]	0.51 [C]	(0.37 – 0.80)	2.48	(1.02 – 10.6)	1.32	(0.50 – 5.90)
2006 [E]	0.48 [C]	(0.38 – 0.61)	0.45	(0.21 – 0.84)	0.23	(0.11 – 0.47)
2007 [E F]	0.72	(0.53 – 1.07)	1.46	(0.71 – 2.93)	1.10	(0.49 – 2.45)
Geomean	0.57		1.42		0.85	
2001[G]	0.25	(0.18 – 0.37)	5.33	(0.0 – 13.6)	1.38	(0.03 – 3.79)

[A to C] **Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 77% expansion LMN to BON; B = 51% expansion MCN to BON; C = 25% expansion JDA to BON).**
[D] **In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.**
[E] **Migr. year 2006 and 2007 data is combined groups TWS & BWS**
[F] **Incomplete with 2-salt adult returns through August 3, 2009**
[G] **For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.**

McCall hatchery summer Chinook

Table 4.15 Estimated $SAR_{LGR\text{-}to\text{-}LGR}$ (%) for PIT-tagged summer Chinook from McCall Hatchery for each st5dy category from 1997 to 2007 (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)	
2006 [B]	1.16	(1.02 – 1.31)	1.03	(0.86 – 1.21)	0.67	(0.53 – 0.83)
2007 [B C]	1.46	(1.19 – 1.75)	0.70	(0.59 – 0.81)	0.50	(0.34 – 0.65)
Average	1.71		0.97		0.80	
90% CI	(1.07 – 2.35)		(0.56 – 1.39)		(0.42 – 1.18)	

[A] In-river SAR is combination of groups C_0 and C_1
[B] Mig. year 2006 and 2007 data is combined groups TWS & BWS
[C] Incomplete with 2-salt adult returns through August 3, 2009

Table 4.16 Estimated in-river survival LGR to BON (SR), TIR, and *D* of PIT-tagged McCall Hatchery summer Chinook for 1997 to 2007 (with 90% confidence intervals).

Mig. Year	S_R		TIR		*D*	
1997	0.43 [A]	(0.32 – 0.59)	1.38	(1.06 – 1.80)	0.64	(0.43 – 0.93)
1998	0.56 [C]	(0.50 – 0.64)	1.96	(1.54 – 2.56)	1.16	(0.89 – 1.54)
1999	0.52	(0.46 – 0.61)	1.49	(1.29 – 1.73)	0.87	(0.72 – 1.07)
2000	0.61	(0.51 – 0.83)	1.89	(1.67 – 2.15)	1.24	(0.98 – 1.81)
2002	0.58	(0.51 – 0.68)	1.44	(1.18 – 1.79)	0.87	(0.68 – 1.14)
2003	0.70	(0.62 – 0.77)	1.47	(1.18 – 1.83)	1.09	(0.85 – 1.37)
2004	0.44	(0.35 – 0.59)	1.59	(0.87 – 4.37)	0.72	(0.37 – 1.95)
2005 [D]	0.53	(0.45 – 0.65)	3.02	(2.32 – 4.12)	1.66	(1.23 – 2.36)
2006 [E]	0.60 [C]	(0.53 – 0.67)	1.12	(0.91 – 1.40)	0.75	(0.60 – 0.97)
2007 [E F]	0.82	(0.73 – 0.94)	2.09	(1.64 – 2.66)	1.79	(1.37 – 2.36)
Geomean	0.57		1.68		1.02	
2001 [G]	0.27	(0.22 – 0.34)	31.9	(17.9 – 88.4)	8.95	(4.87 – 24.1)

[A to C] Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 77% expansion LMN to BON; B = 51% expansion MCN to BON; C = 25% expansion JDA to BON).
[D] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[E] Migr. year 2006 and 2007 data is combined groups TWS & BWS
[F] Incomplete with 2-salt adult returns through August 3, 2009
[G] For migration year 2001, the SAR(C_1) value is used in the derivation of TIR and *D*.

Imnaha River AP hatchery summer Chinook

Table 4.17 Estimated $SAR_{LGR\text{-}to\text{-}LGR}$ (%) for PIT-tagged summer Chinook from Imnaha River AP for each study category from 1997 to 2007 (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)	
2006 [B]	0.77 (0.58 – 0.97)	1.25 (0.93 – 1.60)	0.48 (0.30 – 0.67)
2007 [B C]	0.96 (0.60 – 1.32)	0.61 (0.47 – 0.77)	0.47 (0.31 – 0.65)
Average	1.11	0.77	0.55
90% CI	(0.60 – 1.61)	(0.39 – 1.15)	(0.29 – 0.82)

[A] In-river SAR is combination of groups C_0 and C_1
[B] Mig. year 2006 and 2007 data is combined groups TWS & BWS
[C] Incomplete with 2-salt adult returns through August 3, 2009

Table 4.18 Estimated in-river survival LGR to BON (SR), TIR, and *D* of of PIT-tagged Imnaha AP summer Chinook for 1997 to 2007 (with 90% confidence intervals).

Mig. Year	S_R	TIR	*D*
1997	0.31 [A] (0.20 – 0.49)	1.36 (0.83 – 2.37)	0.45 (0.24 – 0.92)
1998	0.53 [C] (0.46 – 0.62)	1.55 (0.93 – 3.15)	0.87 (0.51 – 1.72)
1999	0.54 (0.42 – 0.75)	1.89 (1.40 – 2.51)	1.11 (0.75 – 1.72)
2000	0.57 (0.43 – 0.83)	1.29 (1.06 – 1.58)	0.82 (0.56 – 1.25)
2002	0.50 (0.41 – 0.66)	1.75 (1.07 – 3.03)	0.95 (0.54 – 1.78)
2003	0.70 [C] (0.62 – 0.80)	1.21 (0.80 – 1.86)	0.91 (0.57 – 1.41)
2004	0.56 [C] (0.44 – 0.73)	1.64 (0.54 – 5.32)	0.94 (0.27 – 3.14)
2005 [D]	0.58 [C] (0.47 – 0.78)	1.77 (0.91 – 3.93)	1.11 (0.54 – 2.69)
2006 [E]	0.50 [C] (0.43 – 0.58)	0.62 (0.42 – 0.90)	0.36 (0.24 – 0.55)
2007 [E F]	0.69 (0.57 – 0.88)	1.57 (0.96 – 2.37)	1.15 (0.67 – 1.87)
Geomean	0.54	1.41	0.82
2001 [G]	0.37 (0.27 – 0.61)	10.8 (4.94 – 39.8)	4.15 (1.83 – 15.3)

[A to C] Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 77% expansion LMN to BON; B = 51% expansion MCN to BON; C = 25% expansion JDA to BON).
[D] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[E] Migr. year 2006 and 2007 data is combined groups TWS & BWS
[F] Incomplete with 2-salt adult returns through August 3, 2009
[G] For migration year 2001, the $SAR(C_1)$ value is used in the derivation of TIR and *D*.

Wild summer steelhead

Table 4.19 Estimated SARLGR-to-LGR (%) for PIT-tagged wild steelhead in annual aggregate for each study category from 1997 to 2006 (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)		
2006 [B C]	1.34	(1.02 – 1.72)	1.37	(0.63 – 2.22)	0.64	(0.45 – 0.87)
Average	1.79		0.78		0. 54	
90% CI	(1.21 – 2.36)		(0.41 – 1.14)		(0.23 – 0.85)	

[A] **In-river SAR is combination of groups C_0 and C_1**
[B] **Mig. year 2006 data is combined groups TWS & BWS**
[C] **Incomplete steelhead adult returns until 3-salt returns (if any) occur after 7/1/2009 at GRA.**

Table 4.20 Estimated in-river survival LGR to BON (SR), TIR, and *D* of PIT-tagged wild steelhead for migration years 1997 to 2006 (with 90% confidence intervals).

Mig. Year	S_R		TIR		*D*	
1997	0.52 [C]	(0.28 – 1)	2.20	(0.0 – 8.16)	1.18	(0.0 – 5.74)
1998	0.54 [C]	(0.48 – 0.62)	0.20	(0.0 – 0.70)	0.11	(0.0 – 0.41)
1999	0.45	(0.38 – 0.54)	2.28	(1.15 – 4.38)	1.07	(0.53 – 2.09)
2000	0.30 [C]	(0.28 – 0.33)	1.45	(0.77 – 2.40)	0.50	(0.27 – 0.82)
2002	0.52	(0.41 – 0.69)	4.25	(2.12 – 7.67)	2.24	(1.09 – 4.25)
2003	0.37	(0.31 – 0.44)	4.41	(2.74 – 7.73)	1.75	(1.04 – 3.16)
2004 [D]	0.18 [B]	(0.13 – 0.26)	14.3	(7.2 – 42.1)	2.69	(1.29 – 8.78)
2005 [D]	0.25 [C]	(0.20 – 0.34)	4.88	(3.01 – 7.98)	1.30	(0.76 – 2.30)
2006 [E F]	0.58 [C]	(0.50 – 0.67)	0.98	(0.57 – 2.26)	0.60	(0.34 – 1.39)
Geomean	0.39		2.31		0.94	
2001 [G]	0.038	(0.027 – 0.059)	37.0	(10.6 – 94.6)	1.46	(0.40 – 4.40)

[A to C] **Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 77% expansion LMN to BON; B = 51% expansion MCN to BON; C = 25% expansion JDA to BON).**
[D] **In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.**
[E] **Mig. year 2006 data is combined groups TWS & BWS**
[F] **Incomplete steelhead adult returns until 3-salt returns (if any) occur after 7/1/2009 at GRA.**
[G] **For migration year 2001, the $SAR(C_1)$ value is used in the derivation of TIR and *D*.**

Hatchery summer steelhead

Table 4.21 Estimated SARLGR-to-LGR (%) for PIT-tagged hatchery steelhead in annual aggregate for each study category from 1997 to 2006 (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 C]	2.13	(1.34 – 3.02)	1.42	(0.92 – 1.95)	1.23	(1.06 – 1.41)
Average	1.41		0.64		0.48	
90% CI	(1.01 – 1.81)		(0.38 – 0.90)		(0.25 – 0.72)	

[A] In-river SAR is combination of groups C_0 and C_1
[B] Mig. year 2006 data is combined groups TWS & BWS
[C] Incomplete steelhead adult returns until 3-salt returns (if any) occur after 7/1/2009 at GRA.

Table 4.22 Estimated in-river survival LGR to BON (SR), TIR, and *D* of PIT-tagged hatchery steelhead for migration years 1997 to 2006 (with 90% confidence intervals).

Mig. Year	S_R		TIR		*D*	
1997	0.40 [C]	(0.26 – 0.71)	2.21	(0.99 – 5.66)	0.92	(0.36 – 2.67)
1998	0.64	(0.47 – 1)	0.58	(0.23 – 1.05)	0.39	(0.16 – 0.85)
1999	0.45	(0.39 – 0.53)	0.87	(0.48 – 1.41)	0.41	(0.22 – 0.70)
2000	0.22 [C]	(0.19 – 0.25)	2.20	(1.22 – 3.58)	0.55	(0.30 – 0.93)
2002	0.37	(0.29 – 0.49)	1.51	(0.38 – 3.33)	0.60	(0.14 – 1.38)
2003	0.51	(0.42 – 0.61)	2.65	(1.93 – 3.71)	1.43	(0.99 – 2.10)
2004 [D]	0.17 [B]	(0.13 – 0.23)	10.3	(5.4 – 17.9)	1.85	(0.91 – 3.46)
2005 [D]	0.36 [C]	(0.30 – 0.46)	8.44	(5.04 – 13.41)	3.19	(1.86 – 5.37)
2006 [E F]	0.62 [C]	(0.56 – 0.69)	1.49	(0.86 – 2.61)	0.98	(0.56 – 1.72)
Geomean	0.38		2.21		0.90	
2001 [G]	0.038	(0.023 – 0.082)	59.7	(0.0 – 215.6)	2.40	(0.0 – 10.0)

[A to C] Footnote shows percent of reach with a constant "per/mile" survival rate applied (A = 77% expansion LMN to BON; B = 51% expansion MCN to BON; C = 25% expansion JDA to BON).
[D] In-river SAR is combination of groups C_0 and C_1 in derivation of TIR and *D*.
[E] Mig. year 2006 data is combined groups TWS & BWS
[F] Incomplete steelhead adult returns until 3-salt returns (if any) occur after 7/1/2009 at GRA.
[G] For migration year 2001, the $SAR(C_1)$ value is used in the derivation of TIR and *D*.

Chapter 5

Evaluation of Wild Chinook and Steelhead TIR and *D* with Random Effects Meta-analysis

Introduction

Wide variation in sampling variance of TIR and *D* between years limits the utility of simple measures of central tendency, such as an unweighted mean, for drawing general conclusions from the historical dataset concerning the efficacy of smolt transportation or the magnitude of delayed mortality for transported fish. Also, inter-annual variation in these quantities is large (Schaller et al. 2007: Chapter 4), confounding attempts to distinguish how often or by how much these quantities exceed values of management and research interest (e.g., TIR = 1, *D* = 1). Further, the magnitude of actual inter-annual variability in TIR and *D* is of interest itself, as such variance can be expected to influence population viability, as well as the ability to detect impacts of actions aimed at increasing the SAR of transported fish.

In their Chapter 4, Schaller et al. (2007) estimated probability distributions of TIR and *D* for wild Snake River steelhead and spring/summer Chinook using data from 6 and 10 migration years, respectively. The variances of these distributions were estimated to reflect only environmental variation (i.e., inter-annual variance in the true values of the quantities); the TIR and *D* distributions were derived from simulations using estimated transport and in-river SAR distributions. The SAR distributions were derived by separating estimates of sampling variance from total inter-annual variance, with contributions to the overall mean and environmental variance from a year inversely proportional to the sampling variance in that year. Transport and in-river SAR estimates were project-specific; consequently, unlike the analysis in this chapter, the TIR and *D* distributions were also project-specific.

Here we employ a less computationally intensive method, and include the additional data available since the 10 year retrospective report to estimate an overall weighted mean, with confidence and prediction intervals, of TIR and *D* for wild Chinook and steelhead. We also estimate a variance reflecting inter-annual variation in these quantities. These estimates are of the overall TIR and *D* from all projects, i.e., using SAR(T_0) for the transport group. The method does not require estimating SAR distributions, nor involve estimating correlation between transport and in-river SARs as in Schaller et al. (2007).

Meta-analyses usually focus on estimation of "effect size", a value which reflects the magnitude of a treatment effect, or more generally, the strength of a relationship between two values. In fact, an effect size can refer simply to the estimate of a single value (Borenstein et al. 2009). One goal is usually to compute a "summary effect". An important rationale for meta-analyses is the possibility of increased power, compared with the individual studies, to detect moderate effects (Higgins et al. 2009). Under the fixed-effect model, all studies in the analysis are assumed to share the same true effect size, and the summary effect estimates this common effect size. Under the random-effects model, the true effect size is assumed to vary from study to study, and the summary effect estimates the mean of the distribution of effect sizes (Borenstein et al. 2009).

Our approach is to perform a random effects meta-analysis, using ln(TIR) or ln(*D*) as the "effect size" and each migration year's data as a separate study. If the study effect sizes are seen as having been sampled from a distribution of effect sizes, then the random-effects model is preferable (Borenstein et al. 2009). Under this model, it is assumed that the true effect size varies from study to study, and the summary effect is an estimate of the mean of the distribution of effect sizes. The heterogeneity (or random effects) variance is a measure of the variance in true effect between studies (years), and is directly analogous to the "environmental variance" estimated in Chapter 4 of Schaller et al. (2007). Unlike Schaller et al. (2007), and unlike a fixed-effect meta-analysis, a random effects analysis incorporates the underlying among-study variation of effects into the weights (Sutton & Higgins 2008). Whenever heterogeneity variance is nonzero, the relative weights assigned under random effects will be more balanced than those assigned under fixed effects. Compared to the fixed-effect model, extreme studies will lose influence if they are large (i.e., precise), and will gain influence if they are small (i.e., imprecise) (Borenstein et al. 2009). White (2000) proposed using a form of random effects meta-analysis to estimate inter-annual environmental variance from survivorship data with annually varying sampling variance, though he did not call it a meta-analysis.

There are a number of possible approaches to conducting a random effects meta-analysis. The alternative approaches involve the choice of a procedure to estimate confidence intervals around the mean effect, and the choice of an estimator for the heterogeneity variance. In this analysis, we use the "weighted variance" CI method recommended in a recent, comprehensive comparison of random-effects meta-analysis methods, and employ a heterogeneity variance estimator found to work well with all CI methods when heterogeneity variance is > 0, and best with the weighted variance CI method (Sánchez-Meca & Marín-Martínez 2008). We estimate heterogeneity variance and summary mean with confidence intervals and prediction intervals for wild steelhead and spring/summer Chinook TIR and *D*, using bootstrapped estimates of sampling variance for these quantities from Chapter 4 of this report.

Methods

Under the random-effects model the null hypothesis being tested is that the mean effect is zero (Borenstein et al. 2009). Consequently, confidence intervals on the summary effect should provide answers to the question of whether, over the course of the CSS, evidence indicates that TIR > 1 or $D \geq 1$ for a particular species and origin. Estimates of either TIR or *D* can be considered a "response ratio" as defined by Hedges et al. (1999): "the ratio of some measured quantity in experimental and control groups." Meta-analyses on the logarithm of response ratios are widely performed in ecological investigations (Mosquera et al. 2000; Wan et al. 2001; Bancroft et al. 2008; Molloy et al. 2008; Kopper et al. 2009). Hedges et al. (1999) recommend performing analyses on the natural logarithm of the response ratios for two reasons. They note first that the logarithm linearizes the metric, treating deviations in the numerator the same as deviations in the denominator; and second, that the sampling distribution of the ratio will be skewed, while the distribution of the logarithm will be much more normal in small samples. The second feature is useful because in a random effects meta-analysis, the true effects are usually assumed to be normally distributed (Borenstein et al. 2009). Schaller et al. (2007: Chapter 4) showed that in the range of parameters of SAR distributions reflecting inter-annual variation estimated in the CSS, TIR and *D* were approximately lognormally distributed, if beta distributions are used to represent the SAR distributions. Therefore, this analysis is done on log-transformed values of these quantities, i.e. ln(TIR) and ln(*D*). Studies are usually assumed to be statistically independent as well and we adopt that assumption in this analysis. In the CSS, estimates from adjacent years are not strictly independent because of the overlapping of Chinook and steelhead generations, although each year is independent of most other years.

We use the Sidik and Jonkman (SJ) estimator for heterogeneity variance, as described by Sánchez-Meca & Marín-Martínez (2008) and proposed by Sidik and Jonkman (2005). The SJ estimator is a simple, noniterative estimator of the heterogeneity variance that is based on a reparameterization of the total variance in the effect estimates (Sánchez-Meca & Marín-Martínez 2008). The heterogeneity variance is represented by τ^2 and the SJ estimator is calculated by

$$\hat{\tau}^2 = \frac{\sum_i \hat{v}_i^{-1}(\hat{\theta}_i - \hat{\mu}_{\hat{v}})^2}{k-1} \qquad [5.1]$$

where k is the number of studies (years), $\hat{v}_i = \hat{\sigma}_i^2 / \hat{\tau}_0^2 + 1$, $\hat{\theta}_i$ is the effect size estimate in study (year) i, $\hat{\sigma}_i^2$ is the sampling variance estimate for study (year) i, and $\hat{\tau}_0^2$ is an initial estimate of the heterogeneity variance, given by

$$\hat{\tau}_0^2 = \frac{\sum (\hat{\theta}_i - \hat{\mu}_{uw})^2}{k} \qquad [5.2]$$

where $\hat{\mu}_{uw}$ is the unweighted mean of effect sizes, and $\hat{\mu}_{\hat{v}}$ is given by

$$\hat{\mu}_{\hat{v}} = \frac{\sum_i \hat{v}_i^{-1}\hat{\theta}_i}{\sum_i \hat{v}_i^{-1}} \quad . \qquad [5.3]$$

The parametric mean effect size is estimated by weighting each effect size estimate by the inverse of the sum of the heterogeneity variance and the sample variance for that effect size (Sánchez-Meca & Marín-Martínez 2008; Borenstein et al. 2009):

$$\hat{\mu} = \frac{\sum_i \hat{w}_i \hat{\theta}_i}{\sum_i \hat{w}_i} \qquad [5.4]$$

where the weights w_i are estimated by the inverse of the sum of within-study variance and the between-study variance: $\hat{w}_i = 1/(\hat{\sigma}_i^2 + \hat{\tau}^2)$.

The typical procedure to calculate a CI around an overall effect size assumes a standard normal distribution. In an extensive simulation study, Sánchez-Meca & Marín-Martínez (2008) found that when comparing the four alternatives for estimating confidence intervals of the mean effect, the "weighted variance CI" method proposed by Hartung (1999) was the most accurate and most robust to the value of heterogeneity variance, the use of different heterogeneity variance estimators, and the number of studies. They found that the good coverage achieved by the weighted variance CI was consistent with the results obtained in previous studies (Sidik & Jonkman 2002, 2003, 2006). Makambi (2004) also found the weighted variance CI to exhibit good control of type I error probability regardless of the magnitude of the heterogeneity variance and the heterogeneity variance estimator used. Instead of a *z*-distribution, this method uses a *t*-distribution with *k* - 1 degrees of freedom, in addition to a weighted extension of the usual formula for estimating the sampling variance of $\hat{\mu}$. Higgins et al. (2009) also note that a *t*-distribution should provide a better basis for a confidence interval than a normal distribution, due to uncertainty in τ^2.

The weighted sampling variance of $\hat{\mu}$ is estimated as

$$\hat{V}_w(\hat{\mu}) = \frac{\sum_i \hat{w}_i (\hat{\theta}_i - \hat{\mu})^2}{(k-1)\sum_i \hat{w}_i} \qquad [5.5]$$

where $\hat{w}_i$ is as defined above. The CI around the summary effect size is computed by

$$\hat{\mu} \pm t_{k-1,1-\alpha/2}\sqrt{\hat{V}_w(\hat{\mu})}\,. \qquad [5.6]$$

A prediction interval for the individual estimates from new studies (i.e. new years of TIR and *D* estimates) can be derived by summing the sampling variance of $\hat{\mu}$ and the heterogeneity variance, and using the value from a *t*-distribution with *k* – 2 degrees of freedom (Higgins et al. 2009; Borenstein et al. 2009):

$$\hat{\mu} \pm t_{k-2,1-\alpha/2}\sqrt{\hat{\tau}^2 + \hat{V}_w(\hat{\mu})}\,. \qquad [5.7]$$

We calculated heterogeneity variance, summary mean, confidence interval around the summary effect mean, and prediction intervals for spring/summer Chinook and wild steelhead ln(TIR) and ln(*D*), using data from the 1994 – 2006 and 1997 – 2006 migration years, respectively. For both TIR and *D*, we performed two meta-analyses for each species: 1) including data from the 2001 migration, and 2) without data from the 2001 migration. Fish outmigrated in 2001 under severe drought conditions, and the 2001 TIR and *D* estimates are mostly significant outliers, with very few adult returns from the C_0 group, leading to large sampling variance and wide confidence intervals. Estimates and bootstraps for in-river SARs for both species in 2001 were done solely with C_1 fish, instead of C_0 fish. Due to low levels of spill in 2004 and 2005, and consequent low numbers of C_0 fish, the in-river groups for steelhead consisted of C_0 and C_1 migrants added together, as well as for Chinook in 2005 only (Berggren et al. 2008). Except as noted below, sample variances used for each year were derived from bootstrap outputs.

For Chinook TIR, we performed an additional meta-analysis using only C_0 fish as the in-river group for all migrating years, including 2001. Since no bootstrap runs were performed for 2001 using only C_0 fish, sampling variance for all years was estimated using the theoretical variance of the natural logarithm of the ratio of two survival rates (after Burnham et al. 1987: pgs 205 and 211):

$$Var[\ln(TIR)] = \frac{1}{AT} + \frac{1}{AC_0} - \frac{1}{T_0} - \frac{1}{C_0} \qquad [5.8]$$

where T_0 is the estimated number of PIT-tagged smolts transported, in LGR equivalents, from all projects, C_0 is the estimated number of smolts in the C_0 group at LGR, AT is the number of adult returns from the T_0 group detected at LGR, and AC_0 is the number of adults detected at LGR from the C_0 group. Equation 5.8 does not strictly apply, since both T_0 and C_0 are estimated, rather than known quantities. However, Schaller et al. (2007: Chapter 4) demonstrated that variance estimates of SAR that assumed SAR(C_0) was a binomial proportion were insensitive to observed sampling variance of C_0; sampling variance of T_0 is of similarly low magnitude and would likely have little effect on Var[ln(TIR)] estimates.

In analyzing steelhead TIR and *D*, bootstrap variances from the 1998 outmigration of smolts were unusable. With only one adult return in either or both of the study groups, the resampling performed by the bootstrap cannot realistically recreate the variation in outcomes that would properly reflect the sampling variance of the SAR or the ratio of SARs. In 1998 only one adult return from the transport group was observed and the variance from the output bootstrapped values is much smaller than would be expected. Instead, the sampling variance of ln(TIR) was estimated using Equation 5.8. Since *D* is estimated from the TIR estimate and additional estimated terms, sampling variance of *D* is expected to be greater than that of TIR. The sampling variance of ln(*D*) in 1998 was estimated by multiplying the sampling variance estimate of ln(TIR) by 1.35, which was the approximate geometric mean ratio of bootstrap-estimated variance of steelhead ln(*D*) to theoretical variance of steelhead ln(TIR) in the other years.

We present heterogeneity variance estimates, summary means, and 90% summary mean confidence intervals for Chinook TIRs and *D*s, with and without 2001 data, Chinook TIRs with 2001 and C_0 fish only, and steelhead TIRs and *D*s with and without 2001. We used the summary means and heterogeneity variance estimates to construct lognormal distributions of TIRs and *D*s representing inter-annual environmental variance, allowing comparison with the analogous distributions in Chapter 4 of Schaller et al. (2007).

Results

Means, variances, confidence and prediction intervals from the TIR meta-analyses are presented in Table 5-1. The heterogeneity variance estimates for Chinook for the different procedures show that 2001 contributes significantly to the inter-annual variance: with 2001 data, the estimated variance is four times as great as without it. However, the estimate of τ^2 including 2001 and using only C_0 fish as the in-river group is only slightly higher than the estimate from the alternative omitting 2001. This suggests that the large sampling variance in the 2001 estimate due to using only C_0 fish results in a relatively low weight for that year's TIR in the summary estimators. The mean and confidence intervals of the mean, as well as the prediction intervals of the TIR estimate, also show that the estimates aren't very sensitive to the use of only C_0 fish for the in-river group in all years, compared with using C_0 and C_1 fish without 2001. The estimates for all three Chinook alternatives concur that mean TIR is indistinguishable from 1.0, though the mean is higher and the upper limit of the confidence interval on the mean is considerably higher if the data from 2001, using C_1 as the in-river group, are included. Distributions of Chinook TIR from the three alternative estimates, representing both heterogeneity variance and variance of the summary mean, are shown in Figures 5-1 to 5-3. Including 2001 data greatly increases the right skew of the prediction interval distribution (Table 5-1; Figures 5-1 & 5-2).

Table 5-1. Estimated heterogeneity variance of ln(TIR) (τ^2), estimated weighted summary mean (e^{μ}) with upper and lower 90% confidence limits of the mean for TIR, and upper and lower limits of the 90% prediction interval for TIR. Wild Chinook estimates calculated using data from 1994-2006 migration years both with and without 2001, as well as using only C_0 fish. Wild steelhead estimates calculated using data from 1997-2006 migration years both with and without 2001.

Species/alternative	τ^2	e^{μ}	Lower CL on Mean TIR	Upper CL on Mean TIR	Lower PL on TIR	Upper PL on TIR
Chinook w/ 2001	0.367	1.17	0.834	1.65	0.375	3.67
Chinook w/o 2001	0.086	0.993	0.811	1.22	0.562	1.76
Chinook C_0 only	0.101	0.940	0.785	1.13	0.517	1.71
Steelhead w/ 2001	1.57	3.26	1.50	7.07	0.278	38.2
Steelhead w/o 2001	1.00	2.61	1.34	5.08	0.348	19.5

Steelhead heterogeneity variance estimates are considerably higher than those for Chinook, primarily due to a wider range of point estimates of TIR (0.195 to 37.0 if 2001 is included; 0.195 to 14.3 if 2001 is omitted). The lower number of PIT tagged smolts, over fewer years, also contributes to wider confidence intervals on the mean. With or without 2001 data, the mean TIRs are substantially > 1.0, and the 90% CI for steelhead is entirely > 1.0, suggesting survival benefit from transportation compared to in-river migration under the system as configured and operated in recent years. The estimates are somewhat sensitive to the inclusion of 2001, with a decline of mean TIR of 20% if 2001 is omitted. Prediction intervals of steelhead TIR are driven by the large heterogeneity variance and are extremely wide, with the upper limit with 2001 included double the upper limit with 2001 omitted. Distributions are shown in Figures 5-4 and 5-5.

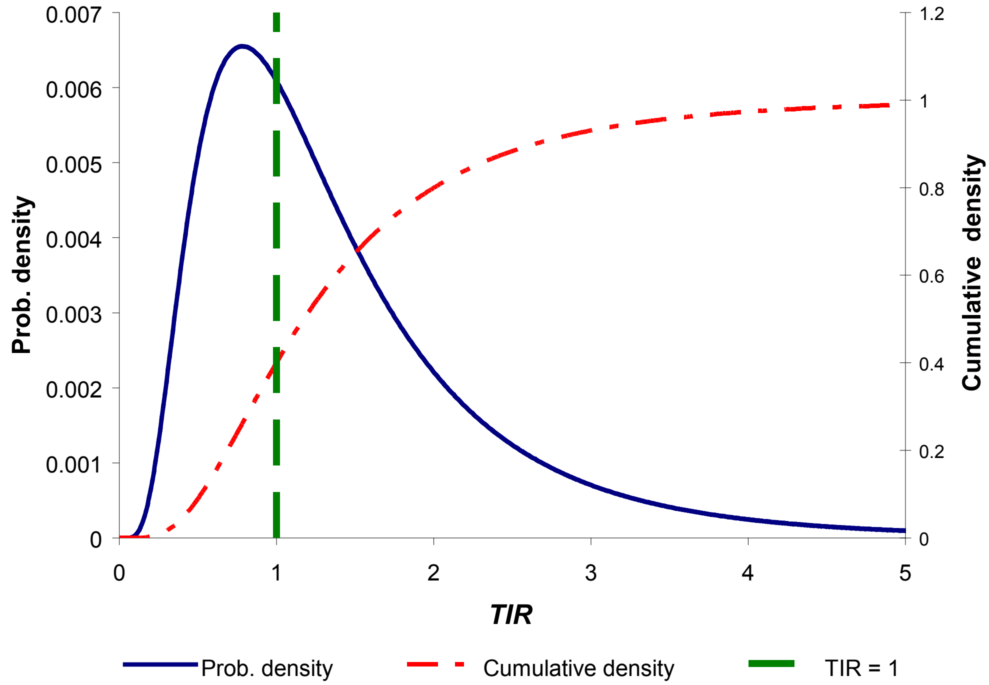


Figure 5-1. Estimated distribution for wild Chinook TIR ($C_0 + C_1$ in 2005; C_1 in 2001). Variance = heterogeneity variance + variance of estimated mean.

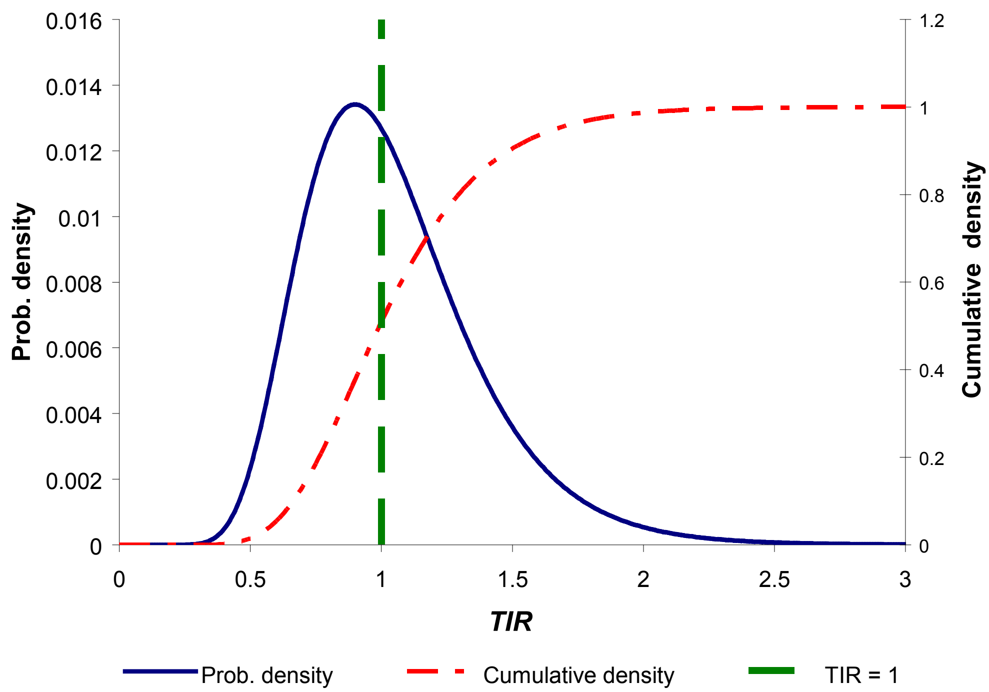


Figure 5-2. Estimated distribution for wild Chinook TIR ($C_0 + C_1$ in 2005; 2001 omitted). Variance = heterogeneity variance + variance of estimated mean.

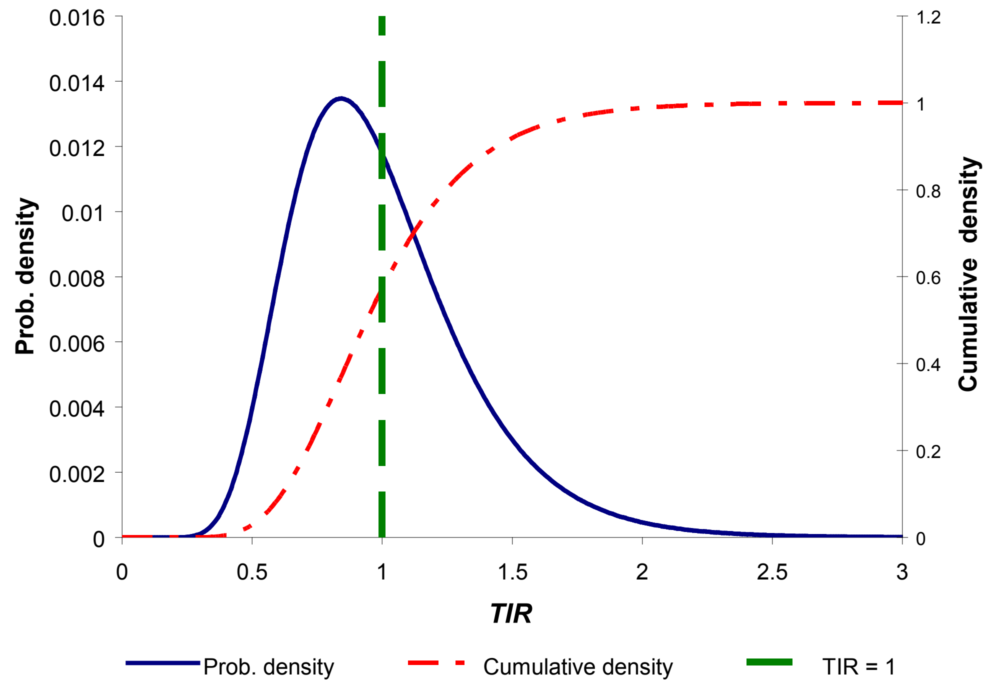


Figure 5-3. Estimated distribution for wild Chinook TIR (C_0 only; 2001 included). Variance = heterogeneity variance + variance of estimated mean.

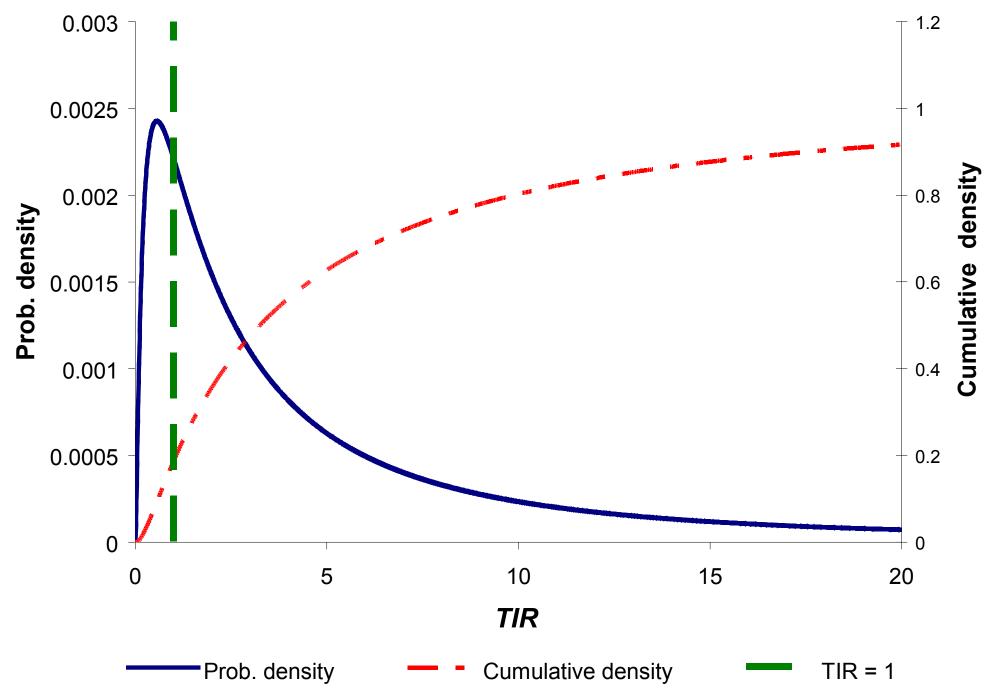


Figure 5-4. Estimated distribution for wild steelhead TIR with 2001 data included. Variance = heterogeneity variance + variance of estimated mean.

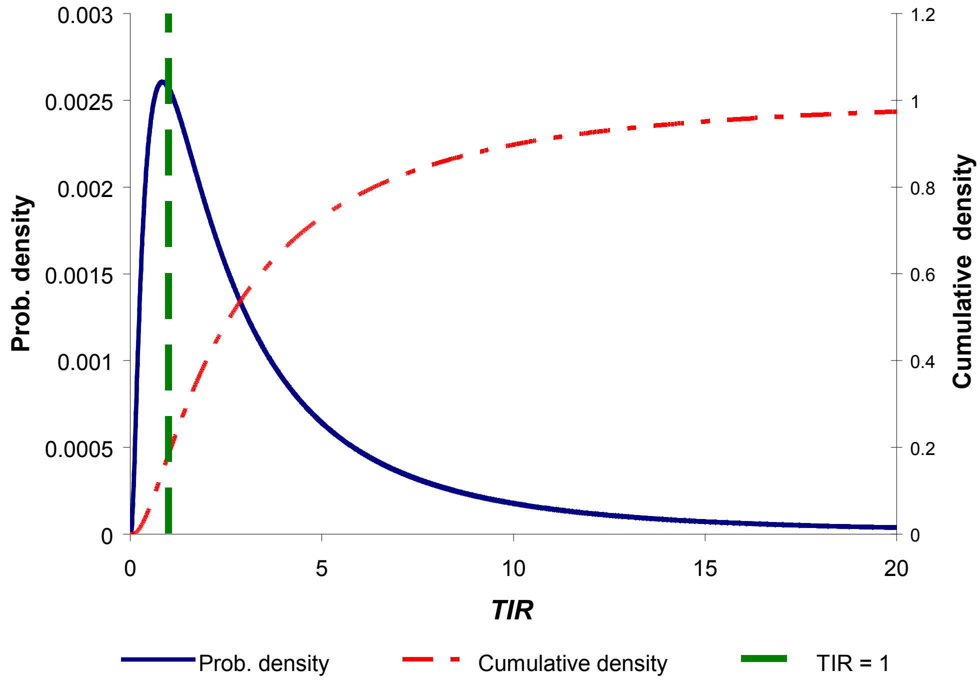


Figure 5-5. Estimated distribution for wild steelhead TIR without 2001 data. Variance = heterogeneity variance + variance of estimated mean.

Results of the meta-analyses on *D* are shown in Table 5.2. The heterogeneity variance estimates for Chinook ln(*D*) show that 2001 strongly influences the inter-annual variance, as it did for ln(TIR). The mean *D* is substantially < 1.0 in either case, though higher if 2001 is included. In either case, the confidence interval of the mean is entirely < 1.0, providing evidence of substantial delayed mortality of transported wild spring/summer Chinook. As with TIR, the heterogeneity variance of steelhead *D* is considerably higher than for Chinook. Heterogeneity variance of steelhead *D* is relatively insensitive to the inclusion of 2001 data. The mean *D* and confidence intervals of the mean *D* are insensitive to the inclusion of 2001 data, suggesting that the extreme TIR observed in 2001 is a consequence primarily of extremely low in-river downstream survival, which agrees with our estimates of 2001 steelhead S_R (see Chapter 4, Table -.18). The mean and confidence intervals indicate steelhead *D* is indistinguishable from 1.0, providing no conclusive evidence for or against the existence of delayed transport mortality for wild steelhead smolts. Prediction intervals of steelhead *D* are considerably narrower than those of steelhead TIR, but wider than those of Chinook *D*. Distributions representing prediction intervals for *D* are shown in Figures 5-6 – 5-9.

Table 5-2. Estimated heterogeneity variance of ln(*D*) (τ^2), estimated weighted summary mean (e^{μ}) with upper and lower 90% confidence limits of the mean for *D*, and upper and lower limits of the 90% prediction interval for *D*. Wild Chinook estimates calculated using data from 1994-2006 migration years both with and without 2001. Steelhead estimates calculated using data from 1997-2006 migration years both with and without 2001.

Species/alternative	τ^2	e^{μ}	Lower CL on Mean *D*	Upper CL on Mean *D*	Lower PL on *D*	Upper PL on *D*
Chinook w/ 2001	0.159	0.593	0.464	0.757	0.278	1.26
Chinook w/o 2001	0.063	0.552	0.458	0.666	0.337	0.904
Steelhead w/ 2001	0.430	1.12	0.728	1.71	0.306	4.07
Steelhead w/o 2001	0.493	1.09	0.671	1.76	0.263	4.49

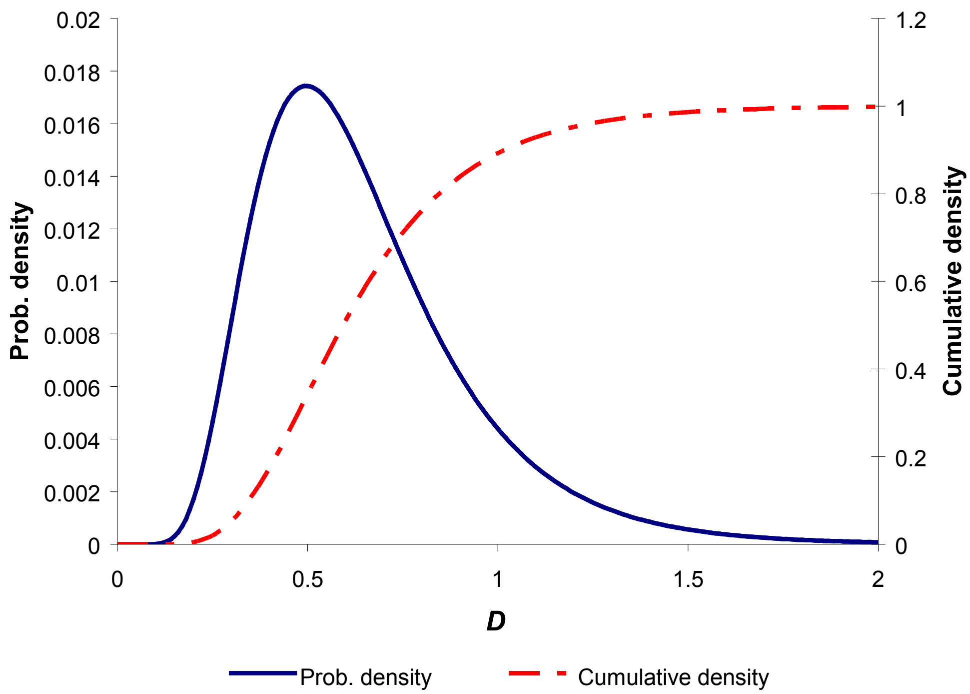


Figure 5-6. Estimated distribution for wild Chinook *D* with 2001 data included. Variance = heterogeneity variance + variance of estimated mean.

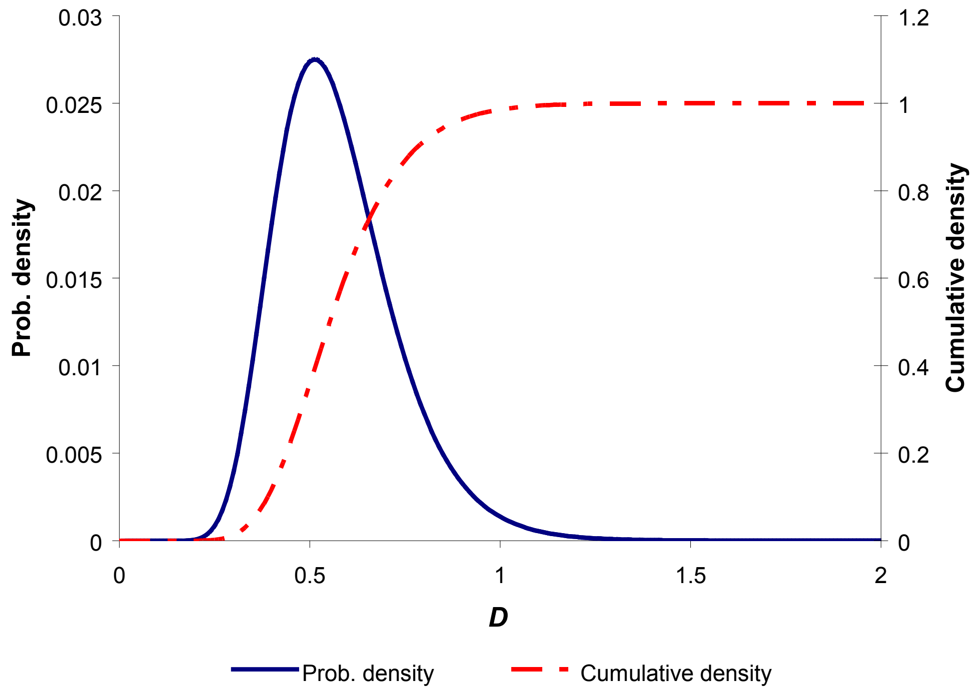


Figure 5-7. Estimated distribution for wild Chinook *D* without 2001 data. Variance = heterogeneity variance + variance of estimated mean.

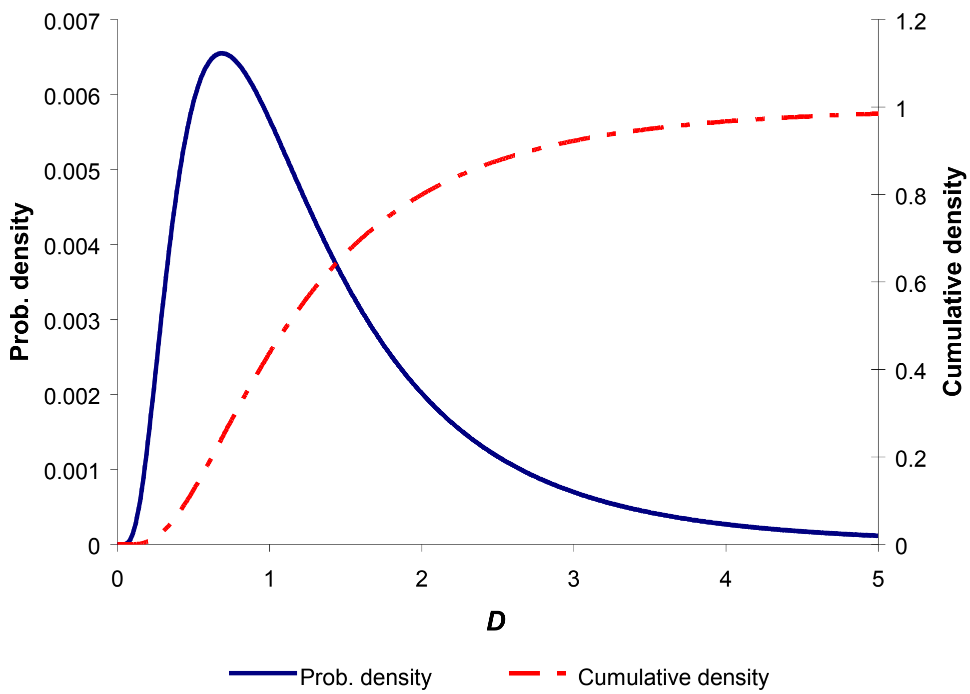


Figure 5-8. Estimated distribution for wild steelhead *D* with 2001 data included. Variance = heterogeneity variance + variance of estimated mean.

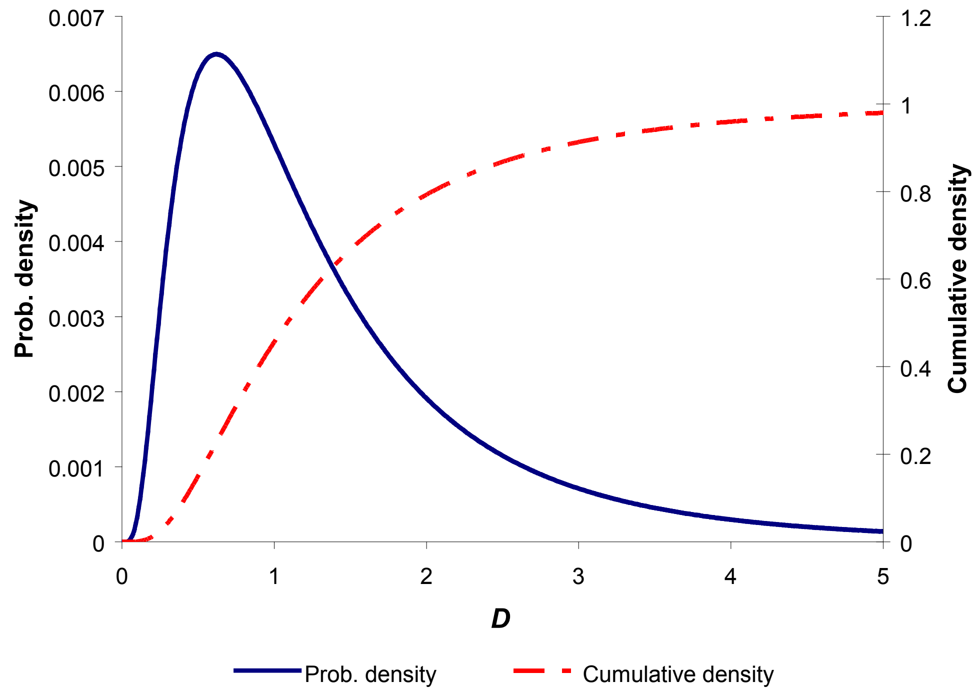


Figure 5-9. Estimated distribution for wild steelhead *D* without 2001 data. Variance = heterogeneity variance + variance of estimated mean.

Discussion

The methods employed here to estimate central tendencies of TIR and *D* give more rigorous estimates than simple unweighted means of annual estimates, as they include sampling error in the weighting process. They can be compared to the unweighted geometric means shown in Tables 4-6 and 4-18, which are calculated excluding the 2001 estimate. The unweighted Chinook geometric mean TIR is 1.05, which falls between the meta-analysis mean including 2001 and the mean excluding 2001. For wild steelhead, the unweighted TIR mean (2.31) is slightly lower than the meta-analysis TIR mean without 2001, and about 30% lower if 2001 is included in the meta-analysis estimate. For Chinook, the unweighted mean *D* (0.54) is very close to the meta-analysis mean without 2001, and not quite as close to the meta-analysis mean with 2001. The meta-analysis mean *D* estimates for steelhead, with or without 2001, are slightly higher than the unweighted estimate (0.94).

Schaller et al. (2007), in their Chapter 4, estimated environmental variance in SARs, TIRs, and *D* for wild Chinook and steelhead. These were project-specific, and based on data only up until 2003 (Chinook) or 2002 (steelhead) migration years, so direct comparison with these results is not in order. However, the magnitude of environmental (heterogeneity) variance they found is similar, with much higher variance evident in the steelhead TIR and *D* distributions than in the Chinook distributions (Schaller et al. 2007; Figures 4-4 – 4-9 and Figs 4-10 – 4-15). The meta-analysis found that as measured by τ^2, *D*s are consistently less variable than TIRs. This is intuitive, since TIR represents a ratio of survival rates that include the downstream migration through the hydrosystem, whereas *D* does not include this portion of the life cycle. This can be seen explicitly in the relationship between TIR and *D*: TIR = $D / S_R * S_T$, where S_R and S_T both vary annually. Conversely, the environmental variances of *D* estimated in Schaller et al.'s (2007) Chapter 4 were consistently slightly higher than TIR variances. This may have to do with the way *D* distributions are arrived at in that analysis, where TIR distributions are derived by first using means and sampling variances to estimate environmental variance in transport and in-river SAR distributions, then constructing TIR distributions. Then, the parameters representing *D* distributions are found from multiplying or dividing the TIR distributions by mean and variance estimates of the S_R and S_T terms. In contrast, in the meta-analysis the sampling variance estimates come directly from the bootstrap program, which integrates uncertainty in survival estimates over the entire LGR-to-LGR smolt-to-adult life cycle.

The methods used in Schaller et al. (2007) estimated distributions of environmental variance in SARs using a different weighting between years than was used in this analysis. In effect, the SAR estimate from each year was weighted by the inverse of the sampling variance of the estimate. This is analogous to the weighting done in estimating the mean and variance of the summary effect in a fixed effects meta-analysis (Borenstein et al. 2009). The choice of weighting method affects the estimates of the mean of and confidence interval around the summary effect, since the random effects approach lessens the penalty attached to estimates with high sample variance. This could be important in estimating heterogeneity variance and summary mean, if sample size and survival are somehow correlated, which could be the case in SAR estimates of certain groups.

A basic assumption of meta-analysis is that the individual studies summarized are statistically independent from each other (Gurevitch et al. 2001). The juvenile downstream migration conditions in each year are largely independent of each other, as are the estuarine conditions the smolts encounter upon exiting the hydrosystem. Since estuary and early ocean experience are thought to be most influential in determining saltwater survival rates for salmon and steelhead, it provides some assurance that fates of adjacent year classes are largely independent. However, since adjacent year classes of both Chinook and steelhead overlap during their ocean residence, and fish from two or more year classes can make the upstream adult migration in the same year, annual environmental conditions can influence the survival of multiple cohorts.

Since this analysis examined ratios of smolt-to-adult survival rates, any consequences of non-independence between adjacent year classes overlapping in the ocean or in the upstream migration would be due to inter-cohort dependence showing up in the ratio of SARs, rather than SARs themselves. The degree of this dependence can't be estimated with available information, and non-independence in meta-analysis in general is an unresolved problem (Gurevitch et al. 2001). We can, however, make some inferences about how the lack of complete independence in survivorship might influence conclusions drawn from the meta-analyses of TIR and *D*. Wan et al. (2001) caution that violation of the independence assumption may inflate significance levels and increase the chance of a Type I error. Gurevitch & Hedges (1999) and Gurevitch et al. (2001) also note that unaccounted dependence between studies will tend to result in underestimates of the standard error of the mean effect, and therefore inappropriately narrow confidence intervals and increased probability of a Type 1 error. Underestimation of the width of confidence intervals likely would not change the primary conclusions of the meta-analyses of TIR and *D*, unless it was severe. Widening the confidence intervals would not affect the finding that mean Chinook TIR could not be distinguished from 1.0, or that mean steelhead *D* could not be distinguished from 1.0. The contraction of the confidence intervals on the mean from dependence between estimates from adjacent years would have to be very large in order for the lower confidence limit of mean steelhead TIR to fall below 1.0, or for the upper confidence limit of mean Chinook *D* to reach above 1.0.

The results of this analysis provide convincing evidence of the existence of delayed transport mortality for Chinook, while providing little help to judge the hypothesis of delayed transport mortality of steelhead. However, the findings echo those found in Schaller et al. (2007) that wild steelhead TIR is higher than that of wild Chinook both because steelhead S_R is lower and steelhead *D* is higher. Methods and results of this analysis can also be used for purposes other than investigating the credibility of hypotheses about whether TIR or *D* are greater or less than specific values. The methods can be applied to data for migration years after 2006, under altered transportation and hydrosystem operation regimes, to monitor the efficacy of different strategies to improve transport SARs or overall SARs. Estimates of heterogeneity variance can be used in stochastic modeling of the listed populations such as investigating viability under different management and climate scenarios. The meta-analytic methods applied here could be extended to do more in-depth investigations. For example, Bayesian methods can be applied to meta-analysis to estimate distributions reflecting uncertainty in the estimate of the heterogeneity variance (Sutton & Higgins 2008; Higgins et al. 2009). Meta-regression, as described by Sutton and Higgins (2008) and Higgins et al. (2009), could be performed. It uses within-year precision and among-year variation with regression to predict effects using covariates. Since much of the inter-annual variation in TIR seems to be explained by S_R (Figure 4-9), S_R's utility as a covariate could be explored with this technique.

Chapter 6

Adult success rates between dams, *D*, and the expression of delayed effects.

Introduction

In the early 1990s, Mundy et al. (1994) concluded that research results to date were not conclusive regarding the ability of transportation to improve returns to the spawning grounds (or hatcheries) due to problems associated with experimental design. Even if transportation provides an apparent survival improvement relative to juvenile migration through the hydrosystem (as measured by adult return to the dams), the benefit may not carry through to natal areas if transported fish were more likely to stray or die before spawning. One of several advantages of the CSS experimental design of tagging fish at hatcheries or in tributaries before release (rather than at the dams as in previous studies) is that it allows for partitioning survival rates by treatment of known-origin fish between locations along their juvenile and adult migrations.

Hatchery Chinook SARs from smolts at LGR to adults at LGR are a primary focus of CSS and are addressed in detail in Chapter 4. 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.

Given that estimates of TIR ratios 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. Partitioning *D* which includes BON_{smolt} to LGR_{adult} differential survival, into two additional segments can help to describe where any differences in survival took place. In the 2005 and 2006 reports Berggren et al. 2005b and 2006), we initiated an analysis/comparison of the inter-dam 'drop out' rates of hatchery and wild Chinook salmon. In the 2008 report (Berggren et al. 2008), we updated adult success rates, the complement of drop out rates, for CSS Snake River groups from migration years 2003-2005 and used this to partition *D* into ocean and BON_{adult} to LGR_{adult} differential survival parameters. Here we update and extend the analyses from the 2008 report to include migration years 2000-2007 for all CSS Snake River groups.

In this chapter we summarize and update findings from previous annual reports (Berggren et al. 2003; 2005a; 2005b; 2006; 2008, Schaller et al 2007) regarding adult migration (BON-LGR) success by migration year for both transport and in-river study categories. We used these estimates to separate *D* into ocean and adult escapement partitions. Because it is of interest to managers, we also estimated the success parameter by return year. We update the logistic modeling exercise for hatchery and wild Chinook from Chapter 6 of the 10-year report and extend these analyses to included hatchery rand wild steelhead. Finally, we describe the available information on the observations of straying fish and calculated a straying rate for in-river and transported outmigrants.

Methods

Adult passage success by migration year

We estimated adult success rates by migration year and ocean survival for Snake River CSS groups from migration year 2000-2007. We used data on the number of PIT-tagged adults passing various dams within the FCRPS 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_0) and in-river (C_0 and C_1) study categories in the CSS. Ocean survival (e.g., BON as juvenile to BON as adult) was estimated indirectly by removing the success rate from the differential delayed mortality estimate (the *D* estimate; see Chapter 4).

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 hydro system. 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 inclusive. 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 and both harvest and passage mortality.

The adult success rate is the proportion of returning PIT-tagged adults that passed BON and were detected at LGR. To determine this, we required an estimate of number of PIT-tagged adults (excluding jacks for Chinook) passing BON in the fish ladders. Beginning with return year 2002 there was the capability to detect nearly all PIT-tagged adult fish passing the three ladders at BON. However, since a portion of the fish swim over the weir crests and do not pass through the orifices where the detection equipment is installed, the detection rate for PIT-tagged adult fish at BON remains less than 100%. We used upstream adult PIT-tag detections that were not detected at BON (*e.g.*, detected at MCN, ICH, or LGR but not at BON) to estimate the BON detection efficiency. BON detection efficiency is the number of PIT tag detections at BON divided by the sum of BON detections and upstream detections not observed at BON. This parameter was then used to expand the number of BON adult detections in the adult success rate. The adult success rate was calculated as:

$$Adult.success.rate = \frac{GRA_{count}}{\left(BON_{count} \div BON_{efficiency}\right)} \qquad [6.1]$$

which can be re-arranged as:

$$Adult.success.rate = \frac{GRA_{count}}{BON_{count}} \times BON_{efficiency} \qquad [6.2]$$

The efficiency was calculated specific to each group of interest. We first calculated efficiency at BON by aggregating adult detections from the T_0, C_1, and C_0 study groups. Detectability at BON of adults was likely the same regardless of juvenile history and this approach allowed for use of the maximum number of detections. Then we calculated adult success rates for adults with in-river and transportation juvenile histories. Because the C_1 and C_0 in-river groups had a much smaller sample size than the T_0 group, and few adults returned overall, we combined the C_0 and C_1 group (C_X). Finally, the $BON_{efficiency}$ was used to correct the adult success rate for the T_0 and the C_X subset from a particular migration year, species and release group (*e.g.* Dworshak Hatchery Chinook that out-migrated in 2005).

The use of fish detected upstream that were not detected at BON to estimate BON efficiency was the best available measurement of this parameter. However, this nominal estimator of efficiency could have been inaccurate if fish passed BON undetected and through straying/harvest/mortality were never again detected. This problem was alleviated by comparing these two rates in a fraction (*e.g.*, $Success_{T0}/Success_{Cx}$). The assumption here was that the rate for passing BON undetected and never being detected again was the same for the transported and in-river fish. Since the fish were from the same species/hatchery the assumption seemed reasonable.

To calculate the differential survival in the ocean, both the juvenile and adult hydrosystem survival components were removed from the LGR_{smolt} to LGR_{adult} SARs. We used *D* (see Chapter 2 & 3) for a particular group and divided by the differential adult success rate for that same group. The result is an estimate that compares ocean survival of fish that were transported to ocean survival for fish with an in-river history:

$$Ocean.survival.differential = \frac{\left(\frac{SAR(T_0)}{S_T}\right)}{\left(\frac{SAR(C_0)}{S_R}\right)} \div \frac{Success_{T_0}}{Success_{C_x}} \qquad [6.3]$$

Success rates by 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 calculations for the success rate by return year were similar to those for success by migration year above except that fish are grouped by their apparent return year (2002-2008). In cases where adult steelhead passed BON during one calendar year and LGR during the following year, the BON detect year was used to assign the return migration year.

Bootstrapped 90% confidence intervals for both the success rates by migration year and return year were calculated using a non-parametric percentile bootstrap with 1,000 iterations in program R version 2.9.0 (R Development Core Team 2009). Bootstrapped confidence intervals for *D* are presented in chapter 4 of this report.

Modeling success rates vs. smolt outmigration experience and return year conditions

We updated the logistic regression analysis from chapter 6 of the 10-year report with additional years' data and, to further bolster our sample size, included individuals marked at Lower Granite Dam. We evaluated relationships between upstream adult success and juvenile outmigration experience as well as riverine conditions during adult upstream migration. For this exercise, adult success was defined as simply a detection of an adult at LGR that was previously detected at BON. Individuals were excluded if they were not detected as an adult at BON. This analysis was performed for hatchery Chinook, wild Chinook, hatchery steelhead, and wild steelhead separately. We relied on CSS-affiliated hatchery marks because there was incomplete coverage across years and the in-river group for hatchery Chinook and steelhead that were marked at LGR. For the wild groups we incorporated LGR marking because there was consistent marking of both transported and in-river migrants across years. For Chinook salmon, we included in our analysis only >1-ocean adults (i.e., we excluded jacks) from migration years (MYs) 2000-2007 that were detected as adults by the PIT-tag interrogation sites at BON in return years (RYs) 2001-2009. For steelhead, we included individuals from MY's 2001-2007 which were detected as adults in RYs 2001-2008; because of the potential for overwintering behavior would bias the success rate, RY 2009 was excluded for steelhead.

Within the context of our logistic regression-based assessment of transportation effects, we also wished to account for variation in BON-LGR survival that could be attributed to in-river migration conditions. Specifically, given the results from the University of Idaho's radio telemetry work (Keefer et al. 2004; Naughton et al. 2006), we quantified the influence of discharge, spill, and water temperature on adult passage success. We summarized these variables using records from the Fish Passage Center and USACE's websites. Discharge and temperature data were summarized for BON (i.e., as a proxy for Columbia River conditions) and averaged across 2-week time blocks in each RY. Similarly, spill was summarized as average Lower Columbia (BON, TDA, JDA, and MCN, averaged) values for the same time blocks. Environmental variables were matched with individual fish records based on their BON arrival date. We followed the same approach used in the 10-year report of utilizing Lower Columbia in-river variables because the majority of adults (hatchery Chinook: 1671/2010, or 83%; wild Chinook: 356/442, or 80%, hatchery steelhead: 110/133, or 83%; wild steelhead: 353/469, or 75%) that failed to arrive at LGR dropped out before MCN, and in-river variables are correlated across sites.

We evaluated the effects of both transportation history and management/environmental conditions (i.e., Lower Columbia flow, spill, and temperature) on the upstream migration success of individual fish using logistic regression. We followed the same model structure used in the 10-year report except for wild groups. Thus, for the hatchery groups, we fit 11 a priori models describing an individual's survival response

(0 = unsuccessful; 1 = successful) as a function of a combination of transportation and/or management/environmental predictor variables. Because we included fish marked at LGR and to control for any possible difference between these and CSS-affiliated marked fish we added a dummy variable ("LGR.marking") for LGR mark individual's in wild model sets. Therefore, the wild model sets included 22 total models.

We used an AIC-based model selection approach to determine the level of support for different models (i.e., hypotheses). To asses the importance of predictor variables in each model set, we calculated the "relative variable importance" by summing the Akaike weights across all the models in the set where a particular variable occurs (Burnham and Anderson 2002; pg 168). Finally, we assessed slope parameter sign (+/-) and significance (using a t-test; alpha = 0.05) from our top model(s) in each model set.

Observations of straying and straying rates

We include a summary of the data for fish detected outside the assumed migration corridor between BON and LGR. In this effort, we looked at all individuals from Snake River CSS groups from migration year 2000-2007 that had detections outside of the FCRPS. Although new observation sites are added to the PTAGIS database every year, the historical record for these straying fish was limited. For example, while adult detection capability at PRD has existed since 2003, detection capability has been available in the Deschutes and John Day rivers only since 2007 and 2008. Nonetheless, we compiled these data to characterize where presumed straying fish have last been observed.

We calculated straying rates for Chinook and steelhead. We defined a stray as any adult fish detected outside the FCRPS without a subsequent detection within the FCRPS; for Chinook, jacks were excluded. Most of the Chinook strays were found in the Mid Columbia River; we pooled data for hatchery Chinook from migration years 2001-2007 to overlap with potential adult detection in this area. Only a single wild Chinook was detected as a stray so we did not include this group. The majority of the steelhead strays were found in lower Columbia River subbasins (Deschutes and John Day rivers); we pooled steelhead data from migration years 2005-2007 to overlap with the detection of adults in this area. The stray rate was the sum the strays divided by the numbers of adults detected at BOA for a particular group of interest. This was calculated for both adults that were transported as juveniles and those that emigrated in-river. To test for a significant difference between these estimates, we used a non-parametric bootstrap approach (e.g. resampling with replacement) and calculated a new test statistic θ where, $\theta = Straying\_rate_{transport} - Straying\_rate_{bypassed}$. The 90% confidence interval around this statistic in relation to the value zero was used to indicate whether $Straying\_rate_{transport}$ was different than $Straying\_rate_{bypassed}$. At best, any straying rates would be minimal conservative estimates, because detections are not distributed across the Columbia Basin for all years, detection efficiencies at some of the newer detectors have not been established, and there are likely potential straying sites without PIT-tag detection.

Results

Adult passage success by migration year

The counts of adults at BON and LGR for the 2000-2007 smolt migration years in each of the CSS groups are shown in Table 6-2 (see end of chapter). The geometric mean of the BON detection efficiency for Chinook ranged from 94.6% to 99.1% across migration year groups. This is similar to those calculated for Chinook in the 2005 annual report (range: 93.1% to 98.3%; CSS 2005 annual report, Table 58). The adult success rates calculated from these counts are shown in Figure 6-2, Figure 6-3, and Table 6-3 (see end of chapter) along with the success rate differential (*i.e.*, $Success_{T0}/Success_{Cx}$). The geometric mean success rate differential across years for hatchery Chinook, wild Chinook, hatchery steelhead and wild steelhead were 91%, 93%, 94%, and 89% respectively. The geometric mean of the BON detection for steelhead was slightly less than for Chinook and ranged from 80.1% to 99.2% with the lowest rate for migration year 2000. The 2000 migration year is low because adult steelhead could have passed BON undetected in the summer/fall of 2001 and subsequently passed LGR with a detection in the spring of 2002; this would results in a low efficiency at BON for the 2000 outmigration of steelhead. However, using this efficiency to expand the number of BON adult detections in the adult success rate allows for the inclusion of the 2000 migration year for steelhead in these analyses. In cases where each of the individual fish detected at upstream sites was also detected at BON, the efficiency and the adult success rate are 100%. So, given equation 6-2, the inclusion of the BON detection efficiency in calculation of the adult success rate adjusted the value of the adult success rate down by as much as 6.9% but more typically by 5% or less.

The adult passage success rates of fish that were transported (T_0) and fish that emigrated in-river (Cx) are shown with 90% confidence intervals in Table 6-3. The success rate differential estimates are shown in with their 90% confidence intervals in Table 6-3, Figure 6-2 and Figure 6-3. In the case of CATH 2001, only 3 adults passed BON from the in-river group which resulted in many bootstrap iterations having a zero in the denominator of the success rate and thereby an upper confidence interval of ∞ (shown as N/A in Table 6.3). All 8 of the adults for the 2005 Imnaha hatchery group that passed BON also passed LGR resulting in no confidence interval for this case.

Schaller et al. (2007; Chapter 6) found evidence suggesting that the effects of outmigration experience (i.e. transportation) may be tempered by a distance from release effect. As a preliminary examination of this hypothesis, we plotted the adult hatchery Chinook success rates for transported smolts vs. the distance of each hatchery from LGR (Figure 6-1). Although smolts from each hatchery origin may be transported from LGR, LGS, or LMN, this provides a preliminary overview of the adult success rates data from this perspective. Figure 6-1 shows an increase in success rate as the upstream distance from LGR increases, although there is a large amount of variation in estimates across years for each hatchery. This pattern may suggest a direction for analyses in future reports.

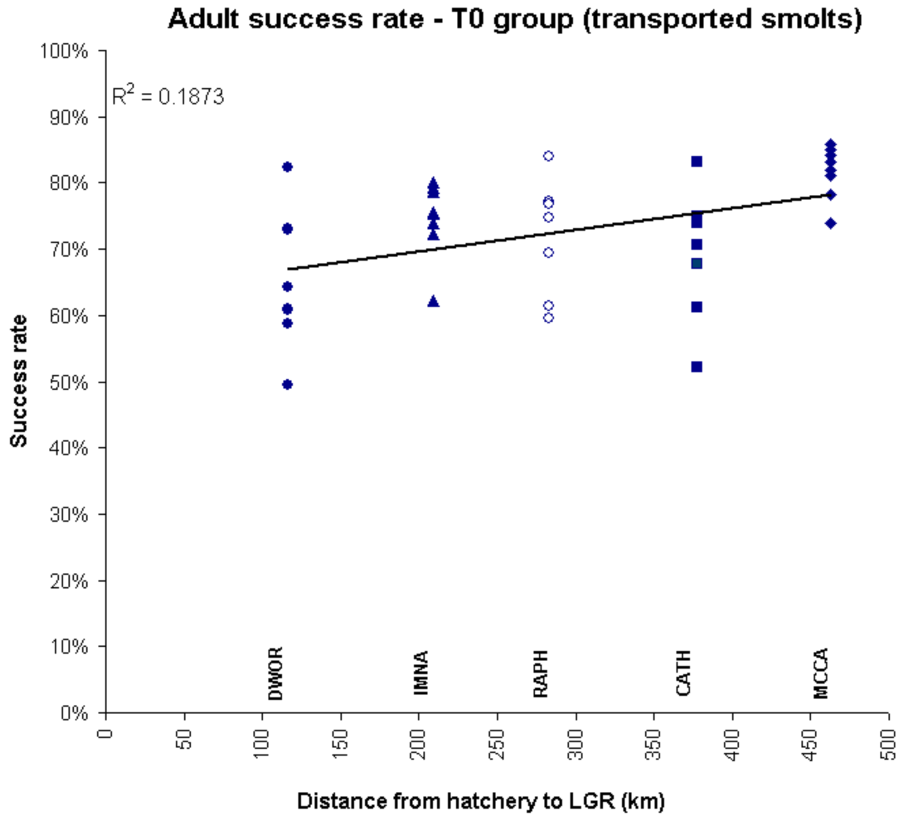


Figure 6.1. Hatchery Chinook adult success rate by migration year (2000-2007; see table 6.4) for transported smolts plotted vs. the distance of each hatchery from Lower Granite Dam.

As with *D*, when the value of the adult success rate differential is above or below one, this indicates that transport was beneficial or detrimental for the group being measured respectively. The point estimate of the adult success rate differential for transported to in-river fish was below one on 44 of 61 occasions (Table 6-3, Figure 6-2, Figure 6-3). The 90% confidence interval around this statistic in relation to the value 1 can be used to indicate whether transport was statistically beneficial or detrimental in regards to the adult success rate in each case (similar to *D* in Chapter 4). If the upper confidence interval was less than one, we conclude at that alpha level that the practice of transportation was detrimental in regards to the adult success rate portion of the SAR. If the lower confidence interval is more than one, then transportation is found to be beneficial in regards to adult success. In Table 6-2, the upper confidence interval of the adult success rate differential was less than one 12 times, more than one once and straddled one 48 times. This is statistically significant evidence indicating that the transportation of smolts can negatively affect adult success.

Partitioning D

When removing the differential adult success from *D*, the differential ocean survival remains. The differential ocean survival is displayed in the bottom panel of Figure 6-2. Here, many values are similar in pattern to those for *D* (top panel; Figure 6-2 and 6-3;) as the ocean survival represents the greatest portion of *D* temporally. There is a marked contrast between the differential adult success rates for wild and hatchery steelhead and the differential ocean survival (middle and lower panel; Figure 6.2). So, despite some positive effects measured by *D* for hatchery and wild steelhead, there remains a measureable negative effect felt once adults enter the hydrosystem.

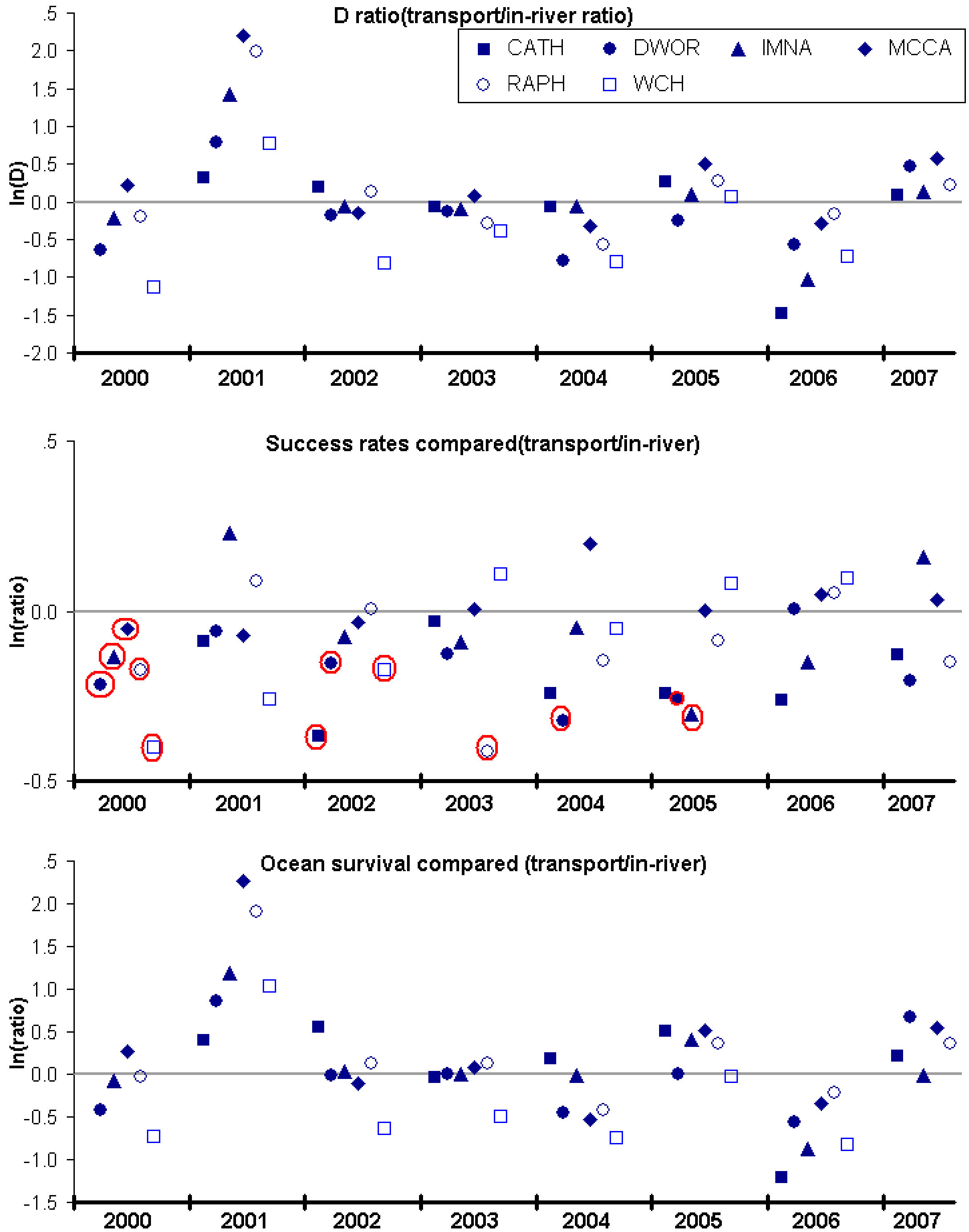


Figure 6-2 The three panels display the log transformed *D*, the differential adult success, and the differential ocean survival in the top middle and bottom panels respectively. Each differential compares groups that emigrated via transportation (numerator) and in-river (denominator). In each panel, when the log-transformed point estimate is above zero (grey reference line) transported smolts survived at a higher rate, when below zero, in-river emigrants survived at a higher rate. Cases where this was significant for the differential adult success (middle panel) are circled in red.

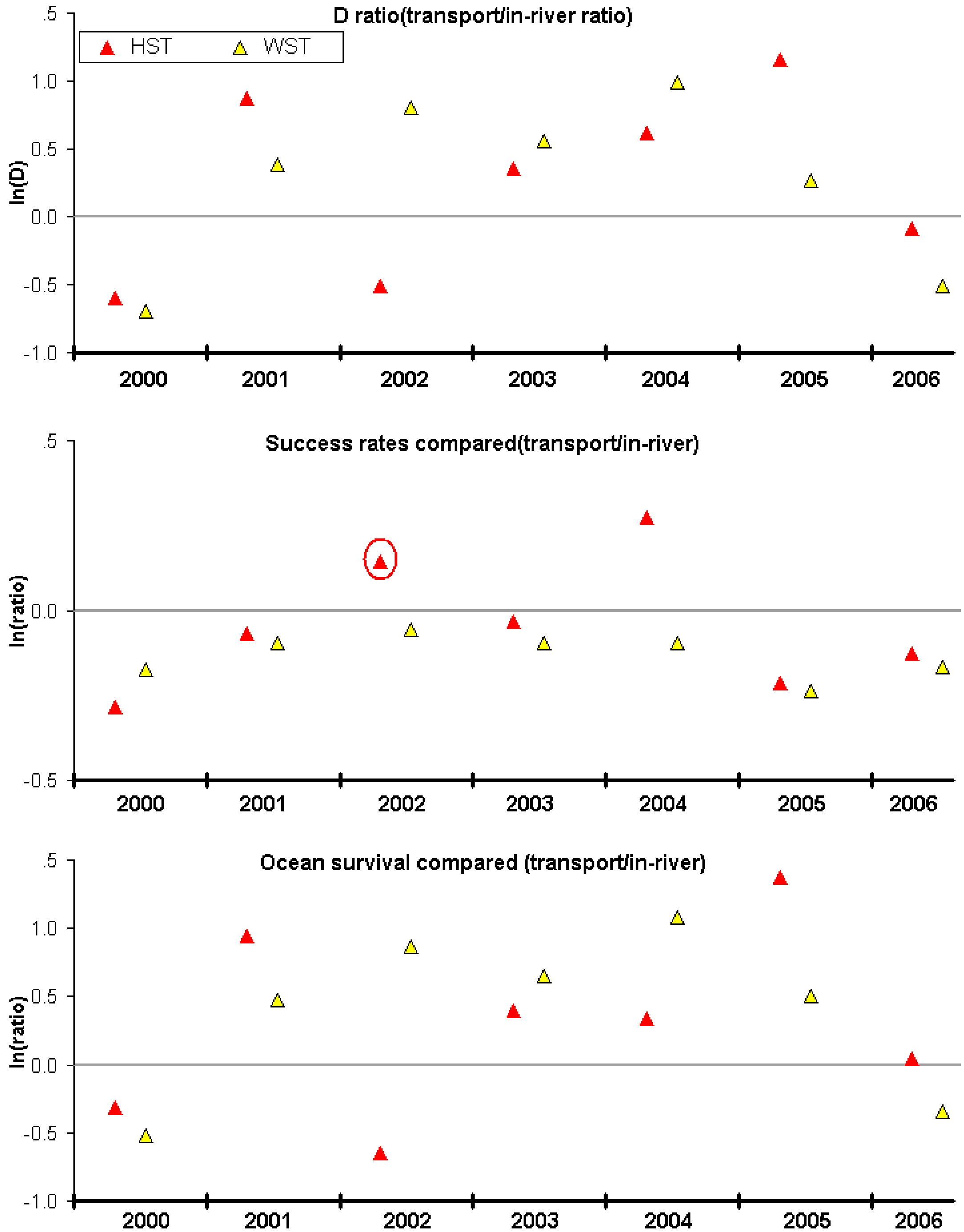


Figure 6-3 The three panels display the log transformed *D*, the differential adult success, and the differential ocean survival in the top middle and bottom panels respectively. Each differential compares groups that emigrated via transportation (numerator) and in-river (denominator). In each panel, when the log-transformed point estimate is above zero (grey reference line) transported smolts survived at a higher rate, when below zero, in-river emigrants survived at a higher rate. Cases where this was significant for the differential adult success (middle panel) are circled in red.

Adult passage rates by return year

Annual rates by return year for adult upstream passage (with 90% CI) from BON to LGR for CSS PIT-tagged wild and hatchery Chinook and steelhead originating from the Snake River Basin upstream of LGR are presented by return year in Table 6-4. When compared as a ratio, adult passage success rates for fish that were transported (T0) were never significantly higher than for fish that emigrated in-river (Cx). However, adult passage success rates for fish that that emigrated in-river (Cx) were higher than for those transported (T0) in 12 of 61 cases.

Modeling success rates vs. smolt outmigration experience and return year conditions

Consistent with the 10-year report (Schaller 2007; Chapter 6), and the results of the differential success rates in this chapter, our AIC-based model-selection exercise also demonstrates an effect of transportation history on upstream adult migration success. For wild Chinook, the best model describing individual migration success included transport, and flow effects (Table 6-5) although the top four models had nearly the same AICc score. The relative variable importance across all models in the set for wild Chinook was 96%, 79%, 47%, 38%, and 14% for transport, flow, LGR.marking, temperature, and spill effects respectively. Because the top four models in this set were nearly indistinguishable in their AICc scores, we tested for significance of the coefficients in each model. The transport (-) and flow (+) variables were significant in each case while the temperature and LGR.marking variables were not significant.

For hatchery Chinook, the best model included transport flow and temperature effects (Table 6-6). The relative variable importance was 100%, 100%, 79%, and 6% for transport, temperature, flow, and spill respectively. For the top model, transport (-), temperature (+) and flow (+) were all significantly different from zero.

The best model for wild steelhead included transport, spill and temperature effects. The relative variable importance across the entire model set was 100%, 81%, 70%, 27%, and 16% for transport, spill, temperature, LGR.marking, and flow respectively. Because the second and third models differed from the first by a Δ AICc of ~ 2, we tested for significance of the coefficients in each model. In each case, the transport (-), spill (-), and temperature (+) variables were significant and the LGR.marking variable was not significant.

For hatchery steelhead, the best model was the transport variable model though each of the top four models differed by a Δ AICc of ~ 2. The relative variable importance across the entire model set was 96%, 28%, 24%, and 21% for transport, temperature, spill, and flow respectively. We tested for significance of the coefficients in each of the top four models. In each case, the transport (-) variable was significant while the flow, spill, and temperature variables were not significant.

Observations of straying and straying rates

The adult success rate reflects a combination of fishing and other mortality and straying between BON and LGR. Here we summarize data from salmon and steelhead individuals of Snake River Basin origin marked as part of the CSS for the 2000-2007 migration years that might be categorized as strays. We defined strays as any fish detected at any site other than BON, MCN, ICH, or LGR during the BON to LGR adult migration. Very few fish were detected from this aggregation of data so we were unable to estimate straying rates. However, these results do give some indication of where wild and hatchery steelhead and Chinook may stray to or overwinter.

Information about the 43 adult salmon and steelhead individuals with "out-of-hydrosystem" detections is summarized in Table 6-3. All but seven of these fish were collected and transported as juveniles (83%). Of these 43 individual adult salmon, 12 eventually migrated past LGR. Most of these adults detected outside as probable strays were transported as juveniles (83%). Transported fish from Dworshak hatchery we detected outside of the FCRPS more commonly than any other group; all of the Dworshak Hatchery origin Chinook were detected within the Mid Columbia upstream of the Snake River mouth. All but one of these fish were never detected after their mid Columbia River detection. This is in sharp contrast to Rapid River hatchery, which had a similar number of PIT tagged fish as Dworshak over these years (Table B-3) but no detects outside the FCRPS. Also, there were no adults that emigrated in-river from Dworshak hatchery that were detected outside the FCRPS although 16-73% of the PIT tagged juveniles from Dworshak had emigrated in-river over these years (Table 7-7).

Four individuals from McCall and Catherine Creek hatcheries were last detected in the Deschutes and John Day rivers although adult detection capability has only been available here since 2007. Three of these four individuals were transported as juveniles. These stocks were not detected in the Mid Columbia and represent the only CSS hatchery groups detected in these lower Columbia River tributaries (Table 6-3). One wild Chinook was detected in the Mid Columbia before being detected again at IHA. Steelhead presence outside the presumed migration corridor may be partially due to the selection of a cold-water holding or overwintering refugi before completing the adult migration the following spring. Three times as many of these individuals were later detected passing LGR as compared to Chinook (Table 6-3). About half of the individual steelhead adults detected outside the FCRPS were last seen in the Deschutes, John Day or Mid Columbia River system. Two wild and one hatchery steelhead were detected at Sherar's Falls (river mile on the Deschutes River) and were later detected at LGR. Three other hatchery steelhead were last seen at Sherar's falls.

It should be noted that several of these PIT tag detector sites were operating only over a portion of the years aggregated. The John Day river detector (JD1) and the Sherar's falls detector (SHERFT) composed 11 "last detects" of these fish and these two sites have operated only since 2007; the Sherar's falls detected operated only over a portion of 2007. This suggests that many fish that were never seen after BON during years prior to 2007 may have been entering these Lower Columbia River tributary rivers. This is in agreement with the 2003 & 2004 CSS annual report (Berggren et al. 2005a) and the results in this chapter, where most of the drop-rate (the complement of success rate) for wild and hatchery Chinook took place between BON and MCN.

	Group	My	BON (2002)	SHERFT (2007)	JD1 (2007)	MCN (2002)	PRA (2003)	RIA (2003)	TUM (2005)	RRF (2006)	WEA (2002)	IHA (2003)	LTR (2005)	LGR (1988)
			Lower Columbia				Mid Columbia					Snake River		
Hatchery Chinook														
1	CATH	2006	4/20/08		**5/16/08**	5/7/08						5/9/08		
2	DWOR	2000	6/6/02			6/20/02					**6/30/02**			
3	DWOR	2002	5/3/04			5/8/04	5/25/04				**5/31/04**	5/14/04		
4	DWOR	2004	5/18/06			6/3/06	6/7/06	6/8/06		6/9/06	**6/11/06**			
5	DWOR	2004	5/6/06			5/14/06	5/29/06	6/1/06		**6/2/06**				
6	DWOR	2004	5/12/06			5/29/06	6/6/06	6/8/06		6/9/06	**6/11/06**	5/31/06		
7	DWOR	2004	5/30/06			5/18/06	6/10/06	6/12/06		6/13/06	**6/16/06**			
8	DWOR	2004	5/26/06			5/19/06	6/8/06	**6/12/06**						
9	DWOR	2005	6/28/07			5/24/07	7/10/07	7/14/07		7/16/07	**7/19/07**			
10	DWOR	2005	5/19/07			5/24/07	5/30/07	6/3/07	**6/26/07**	6/7/07		5/26/07		
11	DWOR	2005	5/5/08			6/23/08	6/27/08	7/3/08		**7/5/08**				
12	DWOR	2005	5/18/06			6/23/06	6/3/06	6/5/06		6/6/06		6/27/06		**7/1/06**
13	DWOR	2005	5/19/07			5/24/07	**6/8/07**							
14	IMNA	2006	7/21/07			7/25/07	7/28/07	7/30/07		**7/31/07**				
15	MCCA	2005	6/8/08		**7/20/08**	6/23/08								
16	MCCA	2005	6/7/08		**6/25/08**	6/14/08						6/16/08		
17	MCCA	2006	6/14/08		6/19/08	6/22/08						6/23/08		**6/27/08**
18	MCCA	2007	5/12/09		5/29/09	5/20/09						6/2/09		**6/9/09**
19	MCCA	2003	5/25/06			6/7/06	**7/24/06**					6/9/06		
20	MCCA	2007	7/15/08	**8/11/08**										
Wild Chinook														
21	Wild	2002	5/26/03			6/5/03	**6/17/03**					6/7/03		
Hatchery Steelhead														
22	Hatchery	2001	7/21/03			7/30/03	8/7/03				**8/18/03**			
23	Hatchery	2003	8/14/04			8/31/04	9/7/04					9/18/04		**9/22/04**
24	Hatchery	2005	8/22/06			10/26/06						10/28/06	11/6/06	**3/21/07**
25	Hatchery	2006	8/19/07	**9/25/07**										
26	Hatchery	2006	8/18/07		**2/23/08**	10/7/07								
27	Hatchery	2006	8/24/07	**10/1/07**										
28	Hatchery	2007	8/30/08	**9/24/08**										
29	Hatchery	2003	7/7/05			7/14/05	7/29/05					9/25/05		**9/30/05**
30	Hatchery	2006	8/2/07	9/22/07		10/26/07						11/5/07		**12/27/07**
31	Hatchery	2006	8/3/07			8/13/07	8/26/07	8/31/07				9/18/07		**9/23/07**
Wild Steelhead														
32	Wild	2003	8/3/05			9/13/05	9/20/05					**5/4/06**		
33	Wild	2004	8/9/06			4/19/07						4/27/07	**5/20/07**	
34	Wild	2005	7/12/07			7/18/07	**7/29/07**							
35	Wild	2006	8/6/07		**4/3/08**	8/14/07								
36	Wild	2006	8/28/08		**2/19/09**									
37	Wild	2006	8/5/08			9/28/08	10/5/08					10/10/08		**10/21/08**
38	Wild	2006	7/30/07			9/21/07	9/27/07	11/20/07		**11/21/07**				
39	Wild	2006	8/3/07	10/14/07		12/10/07						3/7/08		**3/21/08**
40	Wild	2007	7/12/08		**3/8/09**	8/22/08								
41	Wild	2007	7/9/08	9/16/08		3/21/09						3/23/09		**3/30/09**
42	Wild	2005				7/29/06	8/20/06					10/28/06		**11/2/06**
43	Wild	2006	7/18/08			7/27/08	**8/18/08**							

Detection site codes: BON = Bonneville Dam, MCN = McNary Dam, JD1 = John Day River flat plat detector, SHERFT = Sherar's Falls, PRA = Priest Rapids Dam
RIA = Rock Island Dam, TUM = Tumwater Dam (Wenatchee River), RRF = Rocky Reach Dam, WEA = Well's Dam, IHA = Ice Harbor Dam,
LTR = Lower Tuccanen River, GRA = Lower Granite Dam

Table 6-1 Summary of individuals from Snake River Basin originating CSS PIT tagged groups with detections other than at BON, MCN, ICH, and LGR dams. These individuals are from the 2000-2007 outmigration years. The bold red entries note the final detection for that individual. Grey high-lighted lines are individuals that out-migrated in-river; un-highlighted individuals were transported. Detections above LGR and below BON are not included here. Each site code is shown with its first year of operation in parentheses.

Straying rates for adults at BON that were transported as juveniles were significantly higher than for adults at BON that had emigrated in-river. This relationship was true for Chinook and steelhead. The point estimate of straying rates for hatchery Chinook that were transported as juveniles was 0.49%; for adults at BON that emigrated via in-river routes this was 0.08%. For steelhead, this was more disparate. The straying rates for transport and in-river categories of steelhead were 3.0% and 0.2% respectively. The p-values for

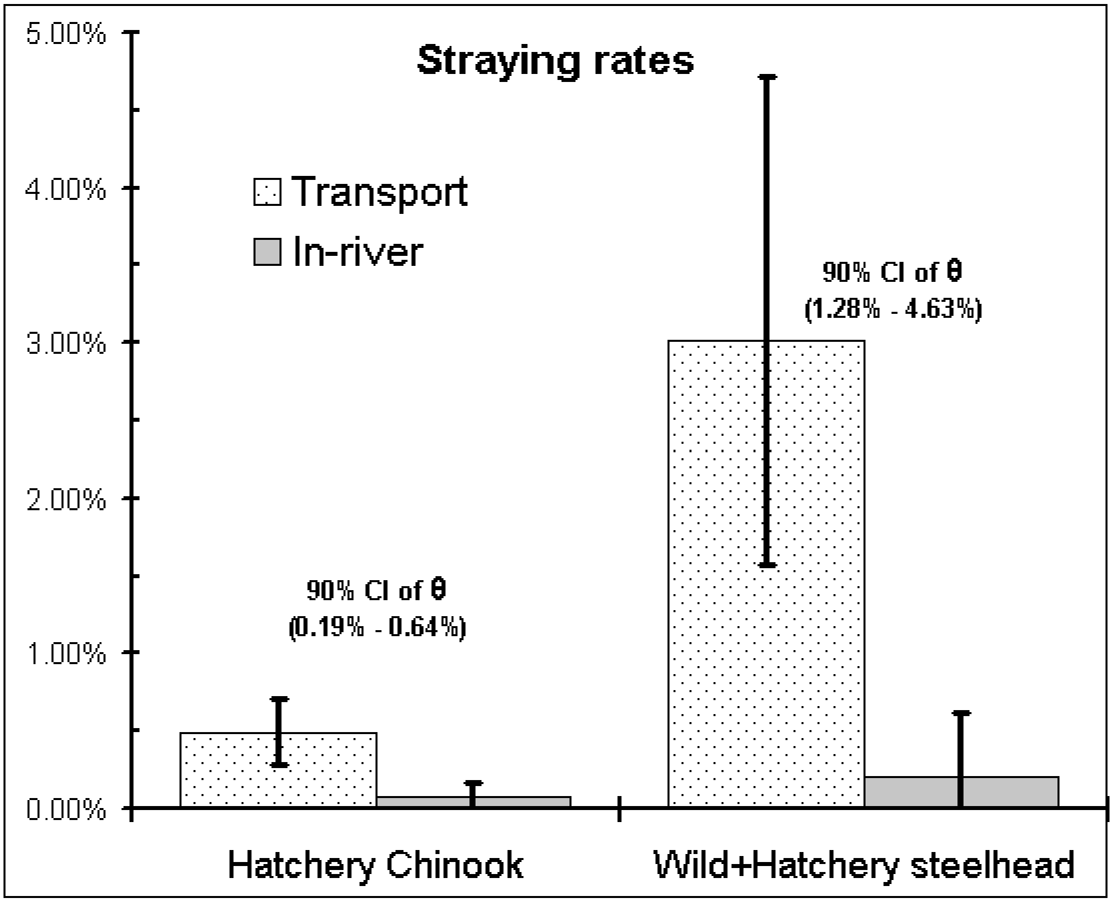


Figure 6-3 Straying rates for hatchery Chinook (pooled across migration years 2001-2007) and wild + hatchery steelhead (pooled across migration years 2005-2007). Each is shown for adults that were both transported as smolts and those that emigrated in-river. The bootstrapped 95% confidence interval for each rate is plotted. The confidence interval for the difference between bootstrapped straying rates (ie. θ) is printed above each pair of estimates._ Strays were defined as adults detected outside the FCRPS without a subsequent detection within the FCRPS, including LGR.

Discussion

D represents the differential delayed mortality between transported and in-river subsets of CSS groups. Because *D* is a differential expression, a value greater than one could result from a relatively lower post-Bonneville survival for in-river fish, an increase for transported fish or both. It appears that most of the positive effects are evident in the ocean component of the post-Bonneville survival. A lower adult success rate may be due to higher harvest and natural mortality or impaired homing, straying, and the subsequent greater exposure to harvest. The adult success rate differentials for these groups are typically below one in these years. The geometric mean of the adult success rate differential across all Chinook hatcheries and years is 90%. These results indicate that transportation of hatchery Chinook interferes with the adult success rate. The consequence is that the benefits of transportation decrease for these groups as adults move upstream.

The distance of these hatcheries from LGR could also play a role in these results. The distances from release site to LGR are 116, 209, 283, 378, and 463 kilometers for Dworshak, Imnaha, Rapid River, Catherine Creek, and McCall hatcheries respectively. The McCall hatchery consistently had one of the highest adult success rate differentials within the hatchery groups across years. Dworshak hatchery often had lower values as compared to other Chinook hatcheries. Also, there is evidence to suggest that transported Dworshak origin fish are straying into the Mid Columbia River. Evidence that the effects of outmigration experience on upstream adult success are tempered by a distance-from-release effect was also found, using a different approach, in the CSS 2006 annual report (Berggren et al. 2006) and this concept is also consistent with results of Solazzi et al. (1991).

As compared to hatchery Chinook, the adult success rate differential for wild Chinook is nearer to and above one in years when many hatchery groups are not. The geometric mean of these adult success rates across all years is 91%. However, the ocean component differential is below one in all years but 2001. This may indicate that wild Chinook are more strongly imprinted at the time they enter the hydrosystem but overall the effects of transportation after passage of BON on the juvenile migration appear to be negative as compared with in-river juvenile outmigration.

D is generally higher for wild and hatchery steelhead than for other CSS groups (see Chapter 4) and this is typically expressed in the ocean differential component. There is evidence to suggest some overwintering behavior in the Lower and Mid Columbia for both transported and in-river out-migrants. However, when comparing the success of the two groups, the success of the returning adults is negatively affected by transportation. The geometric means of adult success rate differential for hatchery and wild steelhead across all years were 90% and 86% respectively. In the 2008 CSS annual report (Berggren et al. 2008) bypassed steelhead were found to have a slightly smaller median length than in-river steelhead for 2003-2005. If this difference resulted in an ostensibly less fit transported fish, this would make the transported population more susceptible to predation, and one would expect the ocean component differential for these groups to be less than one. However, since the opposite is true, if there is an effect of this size difference it does not preclude a positive effect of transportation in the ocean component.

The adult success differential measures the relative success in surviving the straying/harvest/mortality gauntlet during the adult return for fish that out-migrated via the transportation program and in-river routes. This parameter expresses the combined difference in natural mortality, straying, and any changes in harvest pressure as a result of straying. A large majority of point measurements of the adult success rate differential were less than one (less than zero when log transformed). These results indicate that overall during 2000-2007 while transportation can increase or decrease ocean survival, it tends to decrease the fidelity of adults returning to their natal habitat once in the hydrosystem.

Consistent with these results, our AIC-based model-selection exercise also demonstrates a negative effect of transportation history on upstream adult migration success. The transport variable was in the top model(s) within each of four model sets for wild and hatchery steelhead and wild and hatchery Chinook. This was always a significantly negative relationship.

Strays were identified in the Lower Columbia and the Middle Columbia rivers from both Chinook and steelhead stocks. We identified a significant difference in adult straying rates for fish that were transported as juveniles when compared to those that had outmigrated in-river. Straying rates during the adult migration were higher for individuals that were transported as juveniles versus those that outmigrated in-river. This was significant for Snake River hatchery Chinook and Snake River wild and hatchery steelhead.

Supporting tables

Table 6-2 Counts of adults at LGR and BON for all Snake River CSS groups for the juvenile outmigration years 2000-2007. Counts are shown for fish with two different routes of passage as emigrating juveniles (transported [T0] and in-river groups [CX]). The "adds" column is for any individual adults seen at any upstream facility (MCA, ICH, or LGR) and not seen at BON; BON efficiency is calculated with these counts.

Rear-type, species - Hatchery	LGR-T_0	BON-T_0	BON-T_0 adds	LGR-C_X	BON-C_X	BON-C_X adds	BON efficiency
2000							
HCH-CATH	N/A	N/A	N/A	N/A	N/A	N/A	N/A
HCH-DWOR	183	295	5	176	228	6	97.9%
HCH-IMNA	211	262	1	143	155	2	99.3%
HCH-MCCA	497	583	8	360	400	5	98.7%
HCH-RAPH	349	491	12	246	291	6	97.8%
WCH	12	21	0	547	640	11	98.4%
HST	14	17	5	239	218	68	76.3%
WST	13	15	3	228	221	42	84.0%
				Geom(ST)	80.1%	Geom (CH)	98.4%
2001							
HCH-CATH	11	18	0	2	3	0	100.0%
HCH-DWOR	79	96	0	7	8	0	100.0%
HCH-IMNA	48	61	0	5	8	0	100.0%
HCH-MCCA	206	246	8	9	10	0	97.0%
HCH-RAPH	207	265	2	10	14	1	98.9%
WCH	7	10	0	30	33	1	97.7%
HST	4	6	0	5	7	1	92.9%
WST	5	8	0	11	16	0	100.0%
				Geom(ST)	96.4%	Geom (CH)	98.9%
2002							
HCH-CATH	24	33	2	22	21	2	93.1%
HCH-DWOR	60	80	4	169	193	3	97.5%
HCH-IMNA	31	41	0	49	60	0	100.0%
HCH-MCCA	131	164	3	232	281	6	98.0%
HCH-RAPH	117	132	7	185	210	12	94.7%
WCH	31	41	1	201	223	7	97.1%
HST	3	3	0	145	167	6	96.6%
WST	9	11	1	109	126	1	98.6%
				Geom(ST)	97.6%	Geom (CH)	96.7%
2003							
HCH-CATH	9	10	1	13	14	1	92.3%
HCH-DWOR	34	44	3	50	57	3	94.4%
HCH-IMNA	30	39	0	43	51	2	97.8%
HCH-MCCA	111	124	6	137	154	6	95.9%
HCH-RAPH	33	52	2	50	52	5	93.7%
WCH	30	29	2	51	55	4	93.3%
HST	83	105	1	81	99	3	98.1%
WST	44	53	2	52	57	2	96.5%
				Geom(ST)	97.3%	Geom (CH)	94.6%

Rear-type, species - Hatchery	LGR-T_0	BON-T_0	BON-T_0 adds	LGR-C_X	BON-C_X	BON-C_X adds	BON efficiency
2004							
HCH-CATH	11	14	0	7	7	1	95.5%
HCH-DWOR	61	121	3	46	66	1	97.9%
HCH-IMNA	26	41	1	8	12	0	98.1%
HCH-MCCA	84	113	1	25	41	0	99.4%
HCH-RAPH	70	88	2	23	25	2	96.6%
WCH	68	88	2	48	59	2	97.4%
HST	10	9	2	33	39	0	96.0%
WST	39	60	1	5	7	0	98.5%
				Geom(ST)	97.3%	Geom (CH)	97.5%
2005							
HCH-CATH	11	14	1	4	4	1	90.0%
HCH-DWOR	43	65	2	30	35	1	97.1%
HCH-IMNA	17	23	0	8	8	0	100.0%
HCH-MCCA	141	168	2	41	49	0	99.1%
HCH-RAPH	55	69	5	20	23	1	93.9%
WCH	38	49	1	20	28	0	98.7%
HST	18	29	1	43	56	1	97.7%
WST	41	52	1	17	17	5	92.0%
				Geom(ST)	94.8%	Geom (CH)	96.4%
2006							
HCH-CATH	12	23	0	23	34	0	100.0%
HCH-DWOR	52	85	0	79	130	1	99.5%
HCH-IMNA	44	59	0	55	66	1	99.2%
HCH-MCCA	164	191	3	153	186	0	99.2%
HCH-RAPH	105	147	4	69	102	3	97.3%
WCH	75	87	0	79	101	1	99.5%
HST	17	24	0	160	199	2	99.1%
WST	46	79	0	31	45	1	99.2%
				Geom(ST)	99.2%	Geom (CH)	99.1%
2007							
HCH-CATH	12	15	0	20	22	3	92.5%
HCH-DWOR	16	27	0	123	169	2	99.0%
HCH-IMNA	21	25	0	68	88	0	100.0%
HCH-MCCA	77	92	1	151	186	1	99.3%
HCH-RAPH	41	64	2	70	94	5	95.8%
WCH	30	37	0	140	171	1	99.5%
						Geom (CH)	97.6%

Table 6-3 Adult success rates for all CSS groups for the juvenile outmigration years 2000-2007. Adult success rate for the transported (T0) and in-river groups (CX), and the success rate differential (T0/CX) are each shown with their 90% confidence interval. Values were the differential is significant different from one are shown in bold.

MIGR. YEAR	Reartype Species	Hatchery	Success T_0	Success Cx	Success rate differential (T_0/Cx)
2000	HCH	CATH	NA	NA	NA
	HCH	DWOR	0.608 (0.561 - 0.655)	0.756 (0.707 - 0.801)	**0.804 (0.724 - 0.891)**
	HCH	IMNA	0.8 (0.759 - 0.84)	0.916 (0.877 - 0.954)	**0.873 (0.813 - 0.936)**
	HCH	MCCA	0.841 (0.816 - 0.866)	0.888 (0.862 - 0.916)	**0.947 (0.906 - 0.988)**
	HCH	RAPH	0.695 (0.659 - 0.728)	0.826 (0.787 - 0.863)	**0.841 (0.785 - 0.9)**
	WCH		0.562 (0.379 - 0.745)	0.841 (0.817 - 0.865)	**0.669 (0.446 - 0.888)**
	HST		0.628 (0.416 - 0.927)	0.836 (0.796 - 0.873)	0.751 (0.486 - 1.11)
	WST		0.728 (0.513 - 1.013)	0.866 (0.831 - 0.902)	0.84 (0.586 - 1.182)

MIGR. YEAR	Reartype Species	Hatchery	Success T_0	Success Cx	Success rate differential (T_0/Cx)
2001	HCH	CATH	0.611 (0.429 - 0.8)	0.667 (0 - 1)	0.917 (0.500 – N/A)
	HCH	DWOR	0.823 (0.76 - 0.885)	0.875 (0.6 - 1)	0.94 (0.782 - 1.331)
	HCH	IMNA	0.787 (0.701 - 0.868)	0.625 (0.333 - 1)	1.259 (0.825 - 2.468)
	HCH	MCCA	0.812 (0.772 - 0.85)	0.873 (0.683 - 0.98)	0.93 (0.81 - 1.189)
	HCH	RAPH	0.773 (0.732 - 0.815)	0.707 (0.495 - 0.904)	1.094 (0.845 - 1.573)
	WCH		0.684 (0.432 - 0.917)	0.888 (0.788 - 0.976)	0.77 (0.486 - 1.061)
	HST		0.619 (0.286 - 1)	0.663 (0.35 - 1)	0.933 (0.4 - 2)
	WST		0.625 (0.333 - 0.9)	0.688 (0.476 - 0.889)	0.909 (0.433 - 1.545)
2002	HCH	CATH	0.677 (0.537 - 0.814)	0.975 (0.864 - 1.091)	**0.694 (0.522 - 0.893)**
	HCH	DWOR	0.731 (0.643 - 0.826)	0.854 (0.812 - 0.892)	**0.857 (0.747 - 0.983)**
	HCH	IMNA	0.756 (0.64 - 0.864)	0.817 (0.735 - 0.896)	0.926 (0.76 - 1.096)
	HCH	MCCA	0.783 (0.727 - 0.837)	0.809 (0.767 - 0.85)	0.967 (0.881 - 1.062)
	HCH	RAPH	0.84 (0.784 - 0.895)	0.835 (0.791 - 0.876)	1.006 (0.922 - 1.099)
	WCH		0.734 (0.615 - 0.845)	0.875 (0.836 - 0.912)	**0.839 (0.695 - 0.968)**
	HST		0.966 (0.943 – N/A)	0.839 (0.795 - 0.884)	**1.152 (1.087 – N/A)**
	WST		0.806 (0.538 - 1.108)	0.853 (0.799 - 0.905)	0.946 (0.625 - 1.32)
2003	HCH	CATH	0.831 (0.597 - 1.066)	0.857 (0.677 - 1.019)	0.969 (0.636 - 1.425)
	HCH	DWOR	0.729 (0.615 - 0.851)	0.828 (0.737 - 0.907)	0.881 (0.719 - 1.075)
	HCH	IMNA	0.753 (0.644 - 0.867)	0.825 (0.728 - 0.914)	0.912 (0.756 - 1.109)
	HCH	MCCA	0.858 (0.805 - 0.911)	0.853 (0.807 - 0.903)	1.006 (0.92 - 1.095)
	HCH	RAPH	0.595 (0.486 - 0.705)	0.901 (0.811 - 0.984)	**0.66 (0.522 - 0.825)**
	WCH		0.966 (0.881 - 1.058)	0.865 (0.784 - 0.944)	1.116 (0.966 - 1.305)
	HST		0.775 (0.71 - 0.84)	0.802 (0.73 - 0.869)	0.966 (0.857 - 1.092)
	WST		0.801 (0.706 - 0.89)	0.88 (0.8 - 0.952)	0.91 (0.779 - 1.058)
2004	HCH	CATH	0.75 (0.545 - 0.929)	0.955 (0.667 - 1.313)	0.786 (0.476 - 1.227)
	HCH	DWOR	0.494 (0.417 - 0.57)	0.682 (0.587 - 0.78)	**0.723 (0.584 - 0.894)**
	HCH	IMNA	0.622 (0.488 - 0.755)	0.654 (0.422 - 0.889)	0.951 (0.643 - 1.514)
	HCH	MCCA	0.739 (0.672 - 0.806)	0.606 (0.47 - 0.735)	1.219 (0.986 - 1.593)
	HCH	RAPH	0.768 (0.69 - 0.836)	0.889 (0.744 - 1.026)	0.865 (0.716 - 1.059)
	WCH		0.752 (0.676 - 0.824)	0.792 (0.702 - 0.884)	0.95 (0.807 - 1.105)
	HST		0.909 (0.75 – 1)	0.846 (0.75 - 0.938)	1.074 (0.863 - 1.273)
	WST		0.64 (0.538 - 0.743)	0.704 (0.4 - 0.986)	0.91 (0.636 - 1.668)
2005	HCH	CATH	0.707 (0.515 - 0.889)	0.9 (0.462 - 1.789)	0.786 (0.327 - 1.857)
	HCH	DWOR	0.642 (0.547 - 0.743)	0.832 (0.717 - 0.939)	**0.772 (0.626 - 0.959)**
	HCH	IMNA	0.739 (0.583 - 0.882)	1 (1 - 1)	**0.739 (0.583 - 0.885)**
	HCH	MCCA	0.832 (0.783 - 0.878)	0.829 (0.737 - 0.912)	1.003 (0.89 - 1.14)
	HCH	RAPH	0.748 (0.659 - 0.843)	0.816 (0.676 - 0.96)	0.917 (0.742 - 1.157)
	WCH		0.766 (0.657 - 0.86)	0.705 (0.559 - 0.842)	1.086 (0.863 - 1.415)
	HST		0.606 (0.451 - 0.763)	0.75 (0.651 - 0.845)	0.808 (0.583 - 1.067)
	WST		0.725 (0.629 - 0.815)	0.92 (0.731 - 1.143)	0.788 (0.598 - 1.031)
2006	HCH	CATH	0.522 (0.348 - 0.7)	0.676 (0.556 - 0.815)	0.771 (0.5 - 1.111)
	HCH	DWOR	0.609 (0.527 - 0.694)	0.605 (0.533 - 0.67)	1.007 (0.834 - 1.207)
	HCH	IMNA	0.723 (0.62 - 0.817)	0.839 (0.755 - 0.915)	0.861 (0.725 - 1.01)
	HCH	MCCA	0.85 (0.806 - 0.892)	0.81 (0.763 - 0.858)	1.05 (0.969 - 1.132)
	HCH	RAPH	0.695 (0.635 - 0.756)	0.658 (0.578 - 0.737)	1.056 (0.908 - 1.239)
	WCH		0.857 (0.793 - 0.915)	0.779 (0.706 - 0.849)	1.1 (0.975 - 1.24)
	HST		0.702 (0.543 - 0.86)	0.797 (0.748 - 0.844)	0.881 (0.68 - 1.089)
	WST		0.578 (0.476 - 0.669)	0.683 (0.564 - 0.806)	0.845 (0.658 - 1.088)
2007	HCH	CATH	0.74 (0.56 - 0.914)	0.841 (0.689 - 0.992)	0.88 (0.629 - 1.204)
	HCH	DWOR	0.587 (0.421 - 0.729)	0.72 (0.664 - 0.78)	0.814 (0.58 - 1.017)
	HCH	IMNA	0.792 (0.65 - 0.913)	0.675 (0.585 - 0.762)	1.173 (0.943 - 1.448)
	HCH	MCCA	0.82 (0.74 - 0.892)	0.792 (0.743 - 0.843)	1.035 (0.921 - 1.153)
	HCH	RAPH	0.613 (0.512 - 0.721)	0.713 (0.628 - 0.793)	0.86 (0.701 - 1.068)
	WCH		0.796 (0.674 - 0.9)	0.783 (0.729 - 0.837)	1.016 (0.844 - 1.178)

Table 6-4 Adult success rate (%) by return year for Snake River originating CSS PIT tagged groups from the 2002-2008 return years and preliminary calculations for 2009; lower and upper 90% boot-strapped CI are shown in parentheses. Rates were calculated for the transported (T0) and in-river groups (CX), and a success rate differential (T0/CX). Values were the differential is significant different from one are shown in bold.

RETURN YEAR	Rear type Species	Hatchery	Success T0	Success Cx	Success rate differential (T0/Cx)
2002	HCH	CATH	NA	NA	NA
	HCH	DWOR	0.564 (0.497 - 0.628)	0.72 (0.649 - 0.789)	**0.783 (0.673 - 0.913)**
	HCH	IMNA	0.819 (0.773 - 0.863)	0.943 (0.904 - 0.975)	**0.868 (0.814 - 0.927)**
	HCH	MCCA	0.871 (0.845 - 0.897)	0.919 (0.889 - 0.945)	**0.949 (0.91 - 0.991)**
	HCH	RAPH	0.677 (0.633 - 0.72)	0.787 (0.738 - 0.84)	**0.86 (0.778 - 0.945)**
	WCH		0.571 (0.25 - 0.9)	0.859 (0.826 - 0.893)	0.666 (0.29 - 1.058)
	HST		0.667 (0.429 - 0.9)	0.784 (0.716 - 0.848)	0.85 (0.531 - 1.149)
	WST		0.692 (0.467 - 0.909)	0.813 (0.757 - 0.871)	0.852 (0.581 - 1.116)
2003	HCH	CATH	0.611 (0.421 - 0.789)	0.667 (0 - 1)	0.917 (0.5 – N/A)
	HCH	DWOR	0.726 (0.681 - 0.774)	0.793 (0.729 - 0.851)	0.915 (0.832 - 1.021)
	HCH	IMNA	0.765 (0.696 - 0.829)	0.767 (0.653 - 0.868)	0.997 (0.858 - 1.201)
	HCH	MCCA	0.795 (0.76 - 0.828)	0.837 (0.779 - 0.887)	0.95 (0.881 - 1.027)
	HCH	RAPH	0.756 (0.724 - 0.79)	0.865 (0.816 - 0.911)	**0.873 (0.816 - 0.938)**
	WCH		0.591 (0.409 - 0.765)	0.832 (0.8 - 0.863)	**0.71 (0.494 - 0.924)**
	HST		0.8 (0.429 - 1)	0.857 (0.803 - 0.908)	0.933 (0.492 - 1.21)
	WST		0.7 (0.417 - 1)	0.848 (0.78 - 0.915)	0.825 (0.472 - 1.144)
2004	HCH	CATH	0.686 (0.548 - 0.818)	1 (1 - 1)	**0.686 (0.548 - 0.818)**
	HCH	DWOR	0.708 (0.625 - 0.789)	0.87 (0.827 - 0.909)	**0.814 (0.711 - 0.917)**
	HCH	IMNA	0.773 (0.667 - 0.872)	0.814 (0.731 - 0.889)	0.95 (0.795 - 1.116)
	HCH	MCCA	0.771 (0.715 - 0.821)	0.799 (0.758 - 0.841)	0.965 (0.883 - 1.047)
	HCH	RAPH	0.824 (0.771 - 0.872)	0.836 (0.797 - 0.877)	0.985 (0.906 - 1.06)
	WCH		0.765 (0.636 - 0.889)	0.875 (0.836 - 0.912)	0.874 (0.728 - 1.021)
	HST		0.796 (0.709 - 0.881)	0.807 (0.743 - 0.868)	0.987 (0.854 - 1.121)
	WST		0.684 (0.5 - 0.857)	0.856 (0.798 - 0.912)	0.8 (0.582 - 1.013)
2005	HCH	CATH	0.818 (0.615 - 1)	0.882 (0.722 - 1)	0.927 (0.667 - 1.222)
	HCH	DWOR	0.717 (0.61 - 0.821)	0.825 (0.741 - 0.906)	0.87 (0.727 - 1.029)
	HCH	IMNA	0.775 (0.667 - 0.879)	0.824 (0.739 - 0.911)	0.941 (0.784 - 1.116)
	HCH	MCCA	0.878 (0.828 - 0.923)	0.879 (0.837 - 0.92)	0.999 (0.925 - 1.08)
	HCH	RAPH	0.654 (0.551 - 0.766)	0.885 (0.809 - 0.959)	**0.739 (0.608 - 0.886)**
	WCH		0.879 (0.774 - 0.968)	0.883 (0.821 - 0.939)	0.995 (0.87 - 1.124)
	HST		0.794 (0.71 - 0.873)	0.766 (0.683 - 0.851)	1.037 (0.886 - 1.214)
	WST		0.806 (0.727 - 0.886)	0.829 (0.719 - 0.929)	0.972 (0.843 - 1.162)
2006	HCH	CATH	0.769 (0.545 - 0.933)	0.778 (0.5 - 1)	0.989 (0.648 - 1.556)
	HCH	DWOR	0.536 (0.453 - 0.622)	0.677 (0.58 - 0.774)	**0.792 (0.64 - 0.989)**
	HCH	IMNA	0.649 (0.526 - 0.778)	0.714 (0.5 - 0.909)	0.908 (0.659 - 1.31)
	HCH	MCCA	0.698 (0.625 - 0.766)	0.705 (0.6 - 0.803)	0.99 (0.844 - 1.181)
	HCH	RAPH	0.722 (0.635 - 0.812)	0.867 (0.75 - 0.967)	0.833 (0.703 - 1)
	WCH		0.825 (0.735 - 0.908)	0.797 (0.71 - 0.881)	1.035 (0.899 - 1.205)
	HST		0.542 (0.36 - 0.708)	0.803 (0.721 - 0.892)	**0.674 (0.444 - 0.907)**
	WST		0.551 (0.438 - 0.667)	0.692 (0.5 - 0.9)	0.796 (0.562 - 1.207)
2007	HCH	CATH	0.75 (0.563 - 0.933)	0.8 (0.5 - 1)	0.938 (0.6 - 1.667)
	HCH	DWOR	0.539 (0.444 - 0.632)	0.9 (0.816 - 0.974)	**0.599 (0.483 - 0.722)**
	HCH	IMNA	0.667 (0.5 - 0.818)	0.889 (0.667 - 1)	0.75 (0.548 - 1.026)
	HCH	MCCA	0.836 (0.79 - 0.883)	0.795 (0.686 - 0.892)	1.051 (0.921 - 1.222)
	HCH	RAPH	0.855 (0.785 - 0.92)	0.808 (0.667 - 0.933)	1.059 (0.891 - 1.314)
	WCH		0.761 (0.667 - 0.844)	0.727 (0.6 - 0.848)	1.047 (0.85 - 1.332)
	HST		0.667 (0.5 - 0.833)	0.837 (0.785 - 0.891)	0.796 (0.591 - 1.011)
	WST		0.75 (0.662 - 0.829)	0.828 (0.7 - 0.933)	0.906 (0.767 - 1.096)

RETURN YEAR	Rear type Species	Hatchery	Success T_0	Success Cx	Success rate differential (T_0/Cx)
2008	HCH	CATH	0.522 (0.345 - 0.692)	0.697 (0.567 - 0.828)	0.749 (0.459 - 1.054)
	HCH	DWOR	0.629 (0.551 - 0.7)	0.591 (0.52 - 0.664)	1.063 (0.89 - 1.254)
	HCH	IMNA	0.727 (0.619 - 0.818)	0.828 (0.745 - 0.911)	0.879 (0.728 - 1.033)
	HCH	MCCA	0.847 (0.805 - 0.887)	0.814 (0.762 - 0.859)	1.041 (0.966 - 1.127)
	HCH	RAPH	0.663 (0.601 - 0.722)	0.657 (0.581 - 0.735)	1.008 (0.872 - 1.18)
	WCH		0.846 (0.783 - 0.908)	0.767 (0.693 - 0.835)	1.103 (0.98 - 1.255)
	HST		0.867 (0.7 - 1)	0.778 (0.72 - 0.83)	1.114 (0.894 - 1.317)
	WST		0.685 (0.614 - 0.755)	0.72 (0.641 - 0.795)	0.951 (0.818 - 1.102)
2009	HCH	CATH	0.8 (0.611 - 0.947)	0.76 (0.613 - 0.893)	1.053 (0.765 - 1.392)
	HCH	DWOR	0.581 (0.441 - 0.72)	0.723 (0.669 - 0.78)	0.804 (0.609 - 1.008)
	HCH	IMNA	0.839 (0.72 - 0.941)	0.773 (0.702 - 0.844)	1.085 (0.906 - 1.269)
	HCH	MCCA	0.827 (0.77 - 0.885)	0.813 (0.769 - 0.859)	1.017 (0.928 - 1.122)
	HCH	RAPH	0.64 (0.547 - 0.732)	0.709 (0.635 - 0.78)	0.903 (0.761 - 1.075)
	WCH		0.789 (0.694 - 0.875)	0.803 (0.758 - 0.851)	0.983 (0.852 - 1.107)
	HST		NA	NA	NA
	WST		NA	NA	NA

Table 6-5. Wild Chinook logistic regression model-selection results for CSS + LGR marked individuals. Note, Y = P(Success | X), where X is the variable in question. Models are ordered by AICc score. The entire set of models is shown. Those with a ΔAIC < 2 can be considered nearly equivalent. K is the number of estimated parameters (inclusive of variance).

Model	K	AICc	Δ AICc	*wi*
transport + Qtot_Col	3	2365.38	0.00	23.33%
transport + Qtot_Col + LGR.marking	4	2365.50	0.12	21.96%
transport + Qtot_Col + T_Col	4	2366.25	0.87	15.13%
transport + Qtot_Col + T_Col + LGR.marking	5	2366.27	0.89	14.92%
transport + Qspill_Col	3	2368.49	3.11	4.92%
transport + Qspill_Col + LGR.marking	4	2369.00	3.62	3.81%
transport	2	2369.40	4.02	3.13%
transport + Qspill_Col + T_Col	4	2369.82	4.44	2.53%
transport + LGR.marking	3	2370.28	4.90	2.01%
transport + Qspill_Col + T_Col + LGR.marking	5	2370.29	4.91	2.00%
Qtot_Col	2	2370.78	5.40	1.57%
transport + T_Col	3	2371.39	6.01	1.16%
Qtot_Col + T_Col	3	2371.51	6.13	1.09%
transport + T_Col + LGR.marking	4	2372.27	6.89	0.74%
Qtot_Col + LGR.marking	3	2372.78	7.40	0.58%
Qtot_Col + T_Col + LGR.marking	4	2373.51	8.13	0.40%
Qspill_Col	2	2374.17	8.79	0.29%
Qspill_Col + T_Col	3	2375.49	10.11	0.15%
Qspill_Col + LGR.marking	3	2376.16	10.78	0.11%
T_Col	2	2376.44	11.06	0.09%
Qspill_Col + T_Col + LGR.marking	4	2377.49	12.11	0.05%
T_Col + LGR.marking	3	2378.41	13.03	0.03%

Qtot_Col = Flow at BON. Qspill_Col = spill at BON, JDA, MCN, IHR.
T_Col = Temperature at BON.
Transport is a dummy variables denoting transport at LGR, LGS or LMN.
LGR.marking is a dummy variable denoting whether a smolt was marked at LGR or not.

Table 6-6. Hatchery Chinook logistic regression model-selection results for CSS marked individuals. Note, Y = P(Success | X), where X is the variable in question. Models are ordered by AICc score. The entire set of models is shown. Those with a ΔAIC < 2 can be considered nearly equivalent. K is the number of estimated parameters (inclusive of variance).

Model	K	AICc	Δ AICc	*wi*
transport + Qtot_Col + T_Col	4	9239.73	0.00	78.57%
transport + T_Col	3	9242.96	3.24	15.56%
transport + Qspill_Col + T_Col	4	9244.91	5.19	5.87%
Qtot_Col + T_Col	3	9266.60	26.88	0.00%
T_Col	2	9269.79	30.06	0.00%
Qspill_Col + T_Col	3	9271.79	32.06	0.00%
transport + Qtot_Col	3	9316.13	76.40	0.00%
Qtot_Col	2	9337.15	97.43	0.00%
transport + Qspill_Col	3	9342.02	102.29	0.00%
Qspill_Col	2	9359.99	120.27	0.00%
transport	2	9381.16	141.43	0.00%

See table 6-5 for variable names key.

Table 6-7. Wild steelhead logistic regression model-selection results for CSS + LGR marked individuals. Note, Y = P(Success | X), where X is the variable in question. Models are ordered by AICc score. The entire set of models is shown. Those with a ΔAIC < 2 can be considered nearly equivalent. K is the number of estimated parameters (inclusive of variance).

Model	K	AICc	Δ AICc	*wi*
transport + Qspill_Col + T_Col	4	1986.33	0.00	43.40%
transport + Qspill_Col + T_Col + LGR.marking	5	1988.33	2.00	15.99%
transport + Qspill_Col	3	1988.41	2.08	15.30%
transport + Qtot_Col + T_Col	4	1990.32	3.99	5.91%
transport + Qtot_Col	3	1990.34	4.01	5.84%
transport + Qspill_Col + LGR.marking	4	1990.38	4.05	5.72%
transport + Qtot_Col + T_Col + LGR.marking	5	1992.33	6.00	2.17%
transport + Qtot_Col + LGR.marking	4	1992.34	6.01	2.15%
transport + T_Col	3	1992.61	6.28	1.88%
transport + T_Col + LGR.marking	4	1994.61	8.28	0.69%
transport	2	1995.09	8.76	0.54%
transport + LGR.marking	3	1997.08	10.75	0.20%
Qspill_Col + T_Col	3	1999.30	12.97	0.07%
Qspill_Col + T_Col + LGR.marking	4	1999.53	13.20	0.06%
Qspill_Col	2	2001.75	15.42	0.02%
Qspill_Col + LGR.marking	3	2002.11	15.78	0.02%
Qtot_Col + T_Col + LGR.marking	4	2004.13	17.80	0.01%
Qtot_Col + T_Col	3	2004.27	17.94	0.01%
Qtot_Col + LGR.marking	3	2004.63	18.30	0.00%
Qtot_Col	2	2004.70	18.37	0.00%
T_Col + LGR.marking	3	2006.09	19.76	0.00%
T_Col	2	2006.13	19.80	0.00%

See table 6.5 for variable names key.

Table 6-8. Hatchery steelhead logistic regression model-selection results for CSS marked individuals. Note, Y = P(Success | X), where X is the variable in question. Models are ordered by AICc score. The entire set of models is shown. Those with a ΔAIC < 2 can be considered nearly equivalent. K is the number of estimated parameters (inclusive of variance).

Model	K	AICc	Δ AICc	*wi*
transport	2	650.10	0.00	39.66%
transport + Qspill_Col	3	651.89	1.78	16.27%
transport + Qtot_Col	3	652.11	2.01	14.53%
transport + T_Col	3	652.11	2.01	14.52%
transport + Qspill_Col + T_Col	4	653.83	3.73	6.15%
transport + Qtot_Col + T_Col	4	654.12	4.02	5.32%
Qspill_Col	2	657.38	7.27	1.04%
Qtot_Col	2	657.69	7.58	0.89%
T_Col	2	657.69	7.59	0.89%
Qspill_Col + T_Col	3	659.35	9.25	0.39%
Qtot_Col + T_Col	3	659.70	9.60	0.33%

See table 6-5 for variable names key.

Chapter 7

Overall Annual SAR Patterns

General

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 SARs in the 2-6% range (minimum 2%; average 4%) for 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 brood of smolts, irrespective of their route of passage through the hydrosystem.

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 survival 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 Snake River spring/summer Chinook and steelhead population aggregates may be meeting the NPCC (2009) biological objectives. Parameters estimated in the CSS allow for partitioning first year ocean survival, $s3$, from SARs, which 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 have a scientific basis in analyses by the Plan for Analyzing and Testing Hypotheses (PATH), conducted in support of the 2000 Biological Opinion. 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%. PATH analyses did not identify specific SARs necessary for steelhead survival and recovery, however, historic steelhead SARs before FCRPS completion were somewhat greater than those of spring/summer Chinook (Marmorek et al. 1998). The Interior Columbia River Technical Recovery Team (IC-TRT 2007) developed biological recovery criteria based on the Viable Salmonid Population concepts (McElhaney et al. 2000). Additional SAR objectives may be associated with the IC-TRT recovery criteria for abundance and productivity when adopted or incorporated into a Recovery Plan.

Regardless of specific future SAR objectives, the same types of data and analytical methods will be required in the future to evaluate the overall effectiveness of the hydrosystem mitigation strategy.

The NPCC 2-6% SAR objective for Chinook addresses the total adult return including jacks (ie. 1-salt male Chinook). Therefore, in this chapter we present estimates of overall SAR with jacks included and the CSS standard reporting statistic of SARs with jacks excluded. All analyses elsewhere in this and previous reports, excluding Chapter six in last year's annual report, are based on strictly adult (age 2-salt and older) Chinook; this includes the generation of SARs by study category, TIR, *D*, and adult upstream migration success rates. By using only 2-salt and older returning 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 drainage above LGR.

The primary objective in this chapter is to update the long-term SAR data series for CSS study fish. The original time series of overall annual SARs for all migration years are based on the weighting of group-specific SARs by the estimated proportion of run-at-large reflected by each group. This is the method used in all prior CSS reports. Beginning in 2006, the CSS initiated the approach of pre-assigning PIT-tagged fish into two major groups. One group (Group TWS) reflects the untagged fish passage experience under a given year's fish passage management scenario. The other group (Group BWS) has its migrants bypassed if collected at a dam throughout the season. Combining Groups TWS and BWS provides the original release group from which the standard T_0, C_0, and C_1 study categories may be obtained for migration year 2006. The overall SAR for Group TWS migrants does not require a weighting of group-specific SARs; its overall SAR is directly estimated as the number of returning adults divided by the total population (i.e., detected and estimated undetected PIT-tag population) at LGR. Using return data from the 2006 (2 and 3 salt returns) and 2007 (2 salt returns), a comparison is made between the overall annual SARs computed with the original and pre-assignment methodologies. Lastly, the overall SARs with jacks included are presented for all 14 years of PIT-tagged wild Chinook data and 11 years of PIT-tagged hatchery Chinook data (except for Catherine Creek hatchery Chinook, which has only a 7-year history). The effect of including jacks in the overall SAR estimates are presented for the wild Chinook aggregate and each of the five CSS hatchery groups.

Wild and hatchery yearling Chinook SARs with jacks and without jacks

For the 14-yr time series (1994-2007) of overall annual SAR for PIT-tagged wild Chinook, the NPCC's minimum SAR interim objective of 2% was only exceeded for smolt migration year 1999 (Figure 7-1 top left plot), with values of 2.39% without jacks and 2.55% with jacks included. Even with jacks included, there were 6 years (1994-1996 and 2003-2005) with extremely low overall SARs (< 0.55%) as compared to the 2% minimum objective (see Table 7-9 at end of chapter). The NPCC minimum SAR objective includes jacks, but their inclusion has only a minor effect on the annual wild Chinook SARs due to the wild population's (Table 7-4). Wild Chinook exhibited only negligible changes in the 90% confidence interval (shaded area) based on whether overall SARs include or exclude jacks across the 14-year time series (Figure 7-2, top left plot). Both estimates show that current annual SARs for PIT-tagged wild Chinook remain well below the NPCC minimum.

The estimated SARs (without jacks) for Snake River hatchery spring/summer Chinook only exceeded 2% for selected hatcheries in 1998, 1999, and 2000 (Figure 7-1). From 1998 to 2000, the SARs for McCall Hatchery summer Chinook were greater than 2%, Imnaha River Hatchery summer Chinook SARs were greater than 2% in two years, and Rapid River Hatchery spring Chinook SARs were greater than 2% in one year. The trend in SARs for the Snake River hatchery spring/summer Chinook tracked closely with the aggregate wild Chinook SARs during 1997- 2007 (Figure 7-1).

The spring Chinook stocks (Dworshak, Rapid River, and Catherine Creek) exhibited only negligible changes in the SAR 90% confidence intervals whether jacks were included or not (Figure 7-2). The differences between the SARS without and with jacks were significant for the McCall and Imnaha hatchery summer Chinook stocks in most years (Figure 7-2). However in most migration years, this increase for summer stocks would not change the interpretation when comparing the overall SAR to the NPCC 2-6% goal (minimum 2%; average 4%). This result does highlight that the propensity of summer run Chinook to return to freshwater as 1-ocean jacks is generally greater than that of spring run Chinook.

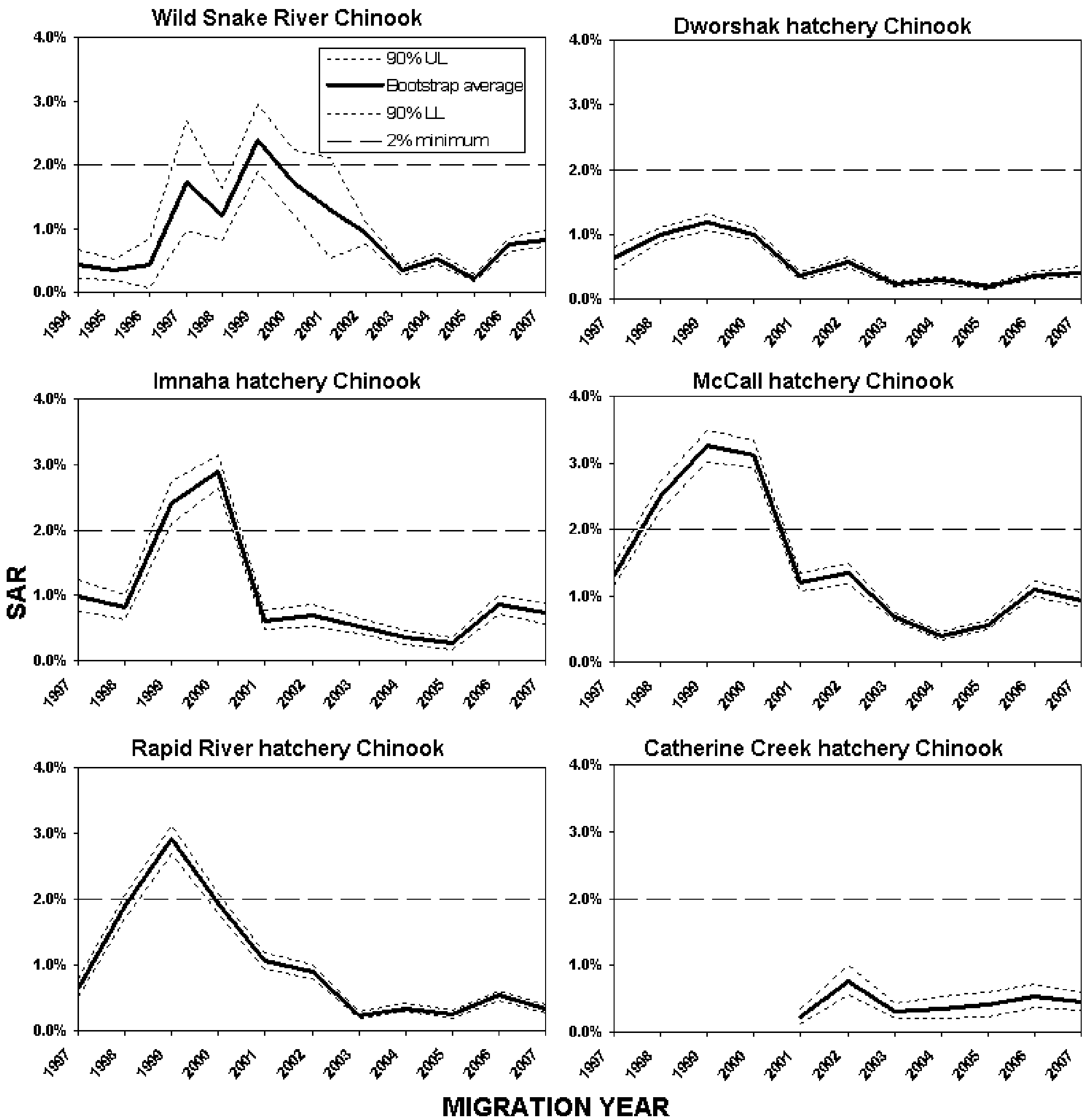


Figure 7-1 Bootstrapped SAR (with jacks excluded) and upper and lower CI for wild Chinook and 5 hatchery groups of Chinook for migration years 1997-2007. Migration year 2007 is complete through 2-ocean returns only. The NPCC (2009) minimum 2% SAR for listed wild populations is shown for reference.

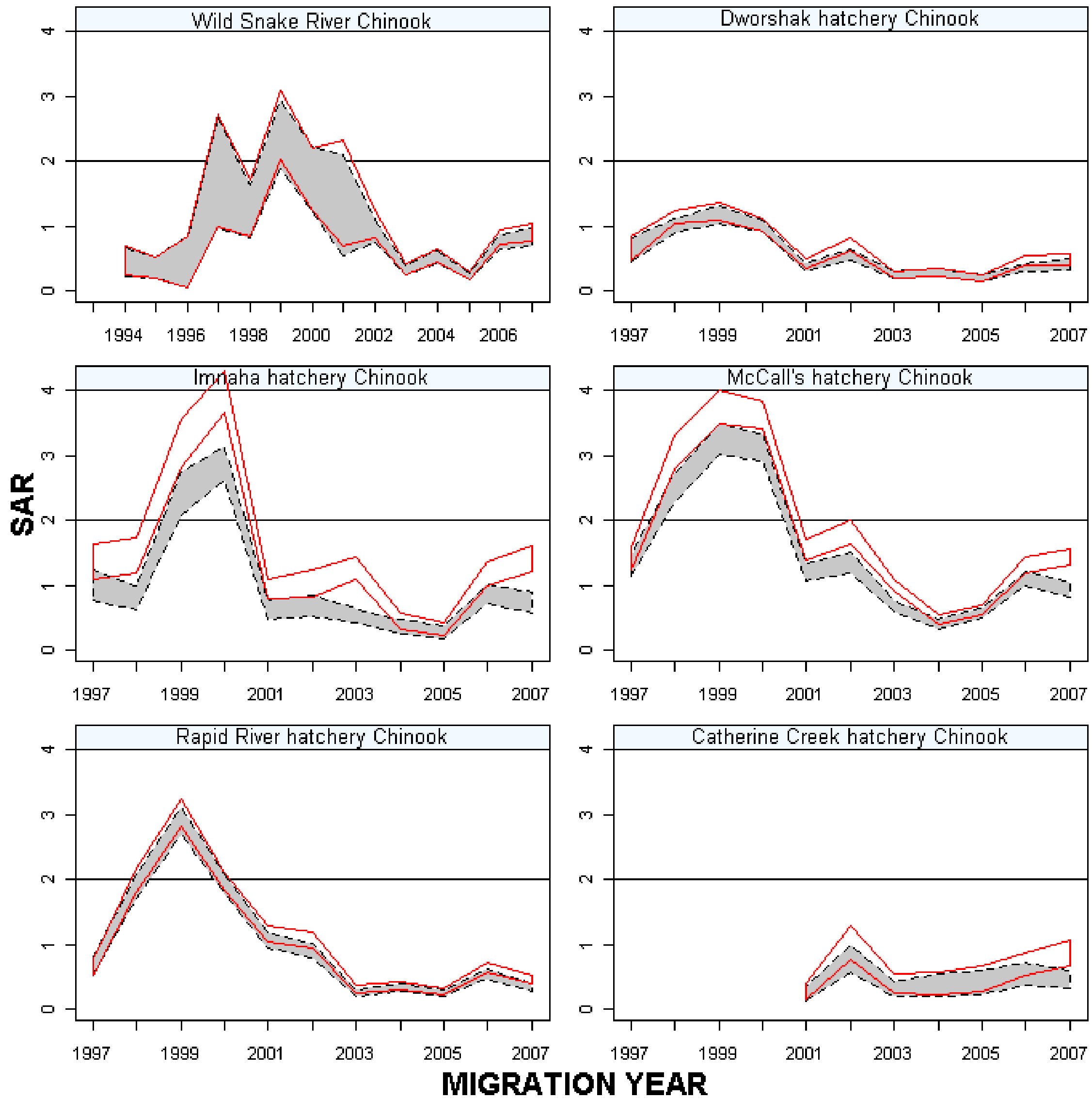


Figure 7-2 Two sets of 90% confidence intervals for Chinook overall SARs. Bootstrapped non parametric 90% confidence intervals are shown for overall SARs without jacks (dotted outline, grey fill) and with jacks (red outline, no fill). Wild Chinook and five groups of hatchery Chinook are shown. Migration year 2007 is complete through 2-ocean returns only.

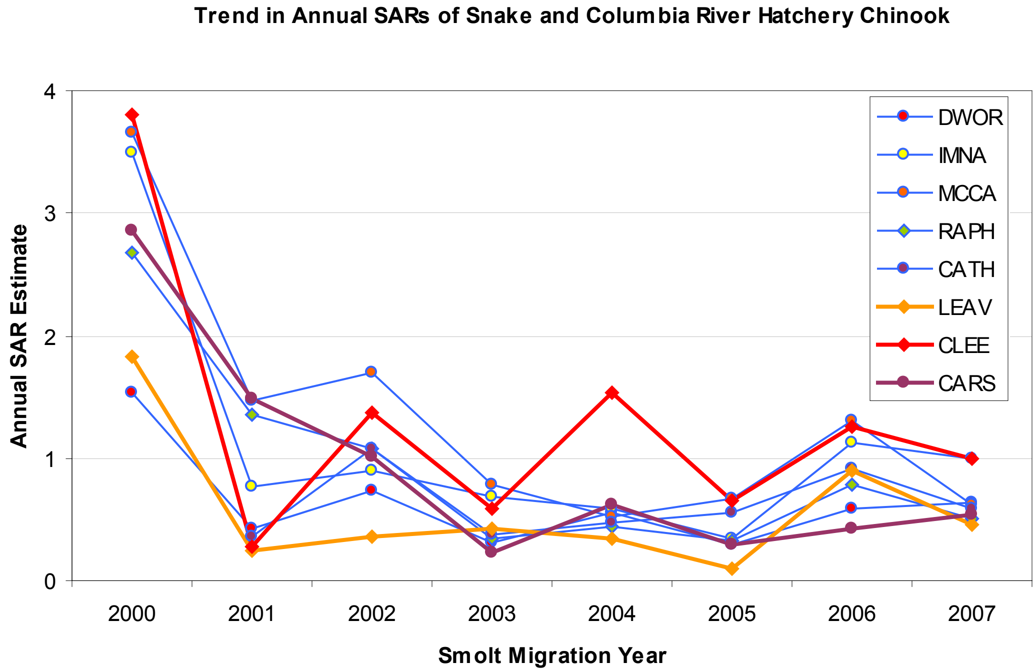
Comparison of wild and hatchery Snake River Chinook SARs with other stocks from the Columbia River basin

The trend in annual SARs for PIT-tagged wild and hatchery Chinook from the Snake River basin may be compared with that of other Chinook stocks from the Columbia River basin for migration years 2000 to 2007. For this comparison, the adult returns (no jacks) of all stocks will be indexed at Bonneville Dam. Converting the LGR-to-LGR SARs presented in Figure 7-1 for Snake River stocks into SARs indexed at Bonneville Dam may easily be accomplished by dividing the LGR-to-LGR SAR estimates presented for categories T0, C0, and C1 in Tables 7-7 (wild Chinook) and 7-8 (hatchery Chinook) by the appropriate adult success rates between Bonneville and Lower

Granite dams, which are found in Table 6.3 of Chapter 6 (*i.e.*, SAR(T_0) /SuccesssT$_0$, SAR(C_0) /SuccessCx and SAR(C_1)/SuccessCx). Then using Equation 2.11, the weighted estimates of annual SARs indexed with adults returns at Bonneville Dam are computed. The other Columbia River stocks whose annual SAR trends are being compared with the Snake River stocks include PIT-tagged wild Chinook from John Day River and PIT-tagged hatchery Chinook from Carson, Cle Elum, and Leavenworth facilities. The trend in annual SARs for the PIT-tagged spring Chinook from Cle Elum and Leavenworth hatcheries is measured using the estimated smolt starting population at McNary Dam and adults detected at Bonneville Dam. The trend in annual SARs for the PIT-tagged wild spring Chinook from John Day River is measured using the estimated smolt starting population at John Day Day and adults detected at Bonneville Dam.

The trend in annual SARs for the PIT-tagged spring Chinook from Carson NFH was initially measured using the estimated smolt starting population at Bonneville Dam and adults detected at Bonneville Dam. However, obtaining a reliable estimate of a PIT-tag smolt starting population at Bonneville Dam is difficult due to the more limited PIT-tag detection capability below Bonneville Dam compared to these groups for which the PIT-tag smolt population could be estimated at a dam above Bonneville Dam. In early CSS annual reports (Berggren *et al* 2003 and 2005a), it was found that including the PIT-tag detections from guano on the bird colonies at Rice Island (Rkm 34) and East Sand Island (Rkm 8) in addition to NOAA's trawl detections near Clatskanie, Oregon, (river km 74), allowed the estimation of Carson NFH release-to-Bonneville survival rates with higher precision and greater year-to-year stability (differing less than 10 percentage points between 1998 and 2002) than estimates obtained from the trawl detections alone. This approach relies on the unknown assumption that the birds do not capture PIT-tagged smolts above Bonneville Dam. In the last four years, 2004 to 2007, the Carson NFH release-to-Bonneville Dam survival rates estimates have been more variable year-to-year, with estimates ranging from 70% to over 100%. For this reason, the trend in annual SARs for the Carson NFH Chinook will also be computed with the PIT-tagged smolt release numbers and returning adults at Bonneville Dam.

The steady decline in SARs after smolt migration year 2000 through migration years 2003 to 2005, seen in Figures 7-1 and 7-2 for Snake River wild and hatchery spring/summer Chinook, has also been observed for other Columbia River basin spring Chinook as shown in Figure 7-3. Likewise, each of these PIT-tagged Chinook groups appear to be showing signs of improving SARs beginning with the 2006 smolt migration.



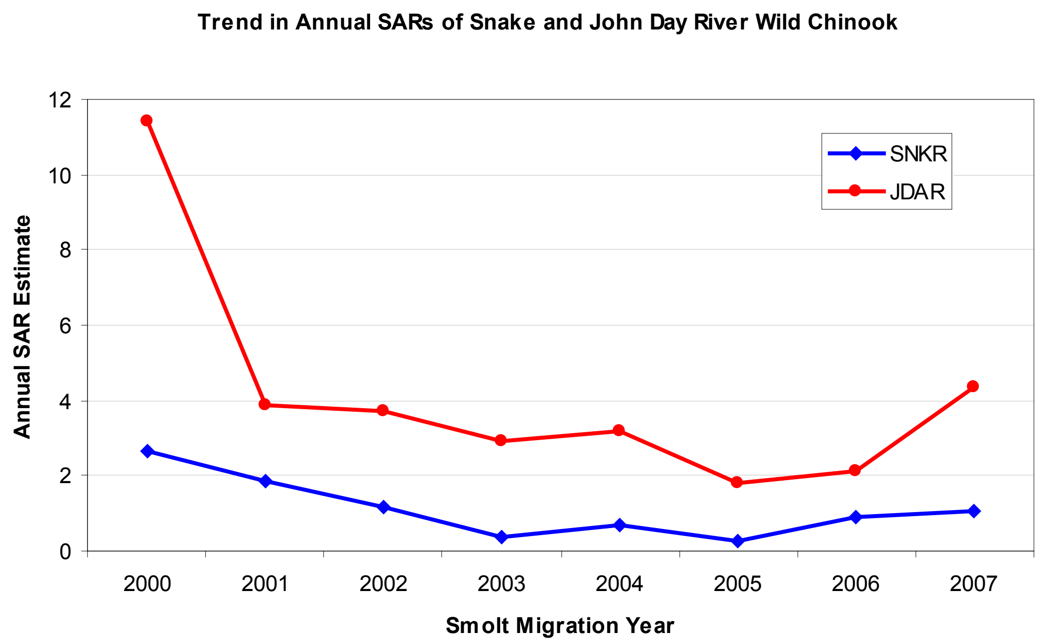


Figure 7-3 Trend in SAR from first PIT-tag monitored dam encountered as smolts to Bonneville Dam as returning adults (no jacks) for Snake River stocks compared to other Columbia River stocks; top plot for hatchery Chinook and bottom plot for wild Chinook. All Snake River stocks are plotted with a blue line. The first PIT-tag monitored dam was LGR for DWOR, IMNA, MCCA, RAPH, CATH, and SNKR; MCN for LEAV and CLEE, JDA for JDAR, and BON for CARS.

Wild and Hatchery Steelhead SARs

The estimated SARs for Snake River wild steelhead exceeded the NPCC minimum 2% SAR objective in four of ten years (1999-2002), but were consistently less than the NPCC 4% recommended average (Figure 7-4, top plot). Hatchery steelhead SARs exceeded 2% only in 2004 (Figure 7-4, lower plot), and were higher than those of wild steelhead only in the recent years of 2004 to 2006.

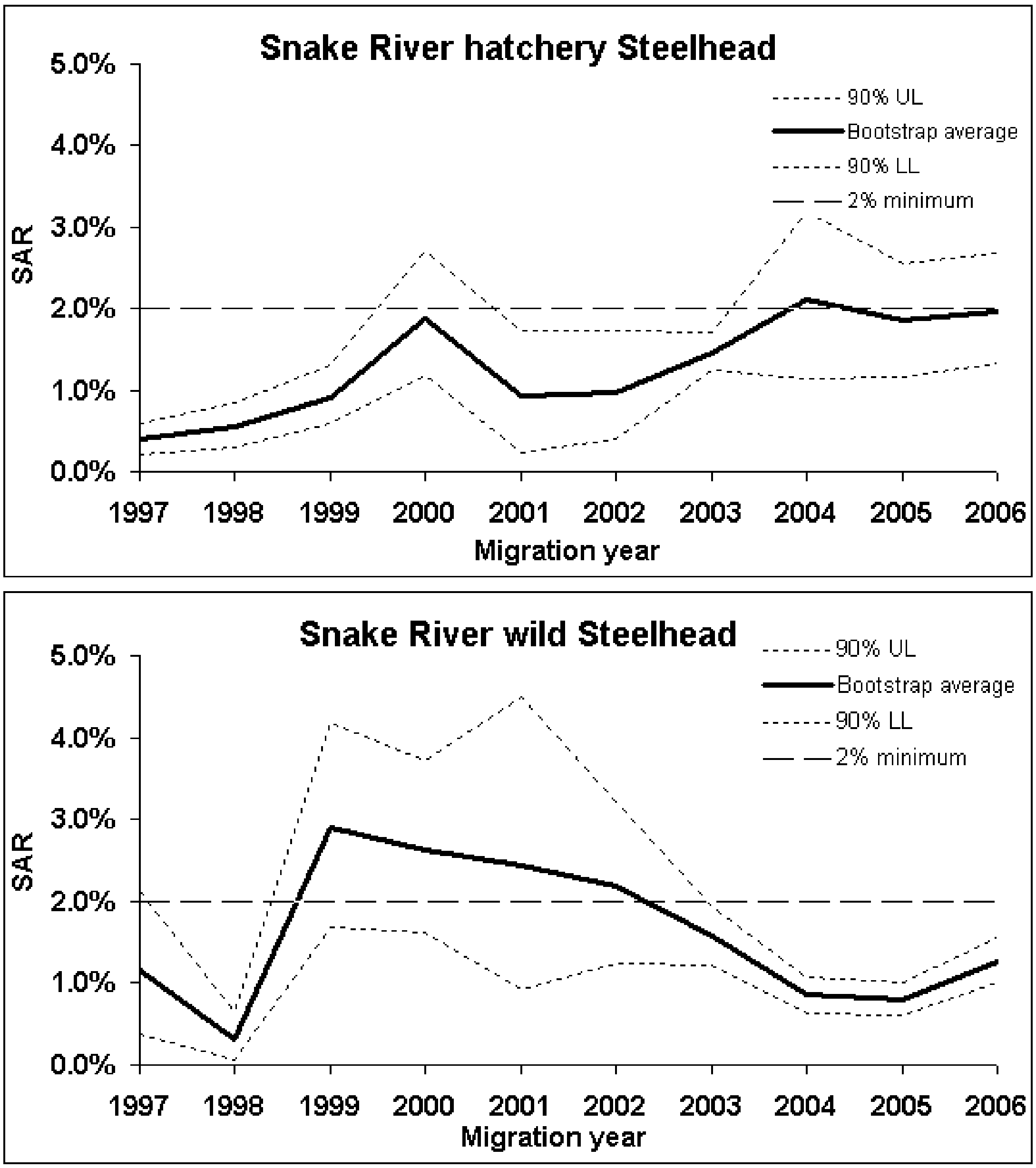


Figure 7-4 Bootstrapped annual SAR with 90% upper and lower CI for PIT-tagged aggregate of Snake River wild (top plot) and hatchery (lower plot) steelhead from smolt migration years 1997-2006. The NPCC (2009) minimum 2% SAR for listed wild populations is shown for reference.

Estimating overall SARs based on pre-assignment of fish prior to release

The overall annual SARs computed with the two methodologies are presented in Table 7-1 for PIT-tagged wild and hatchery Chinook (without jacks) from the 2006 and 2007 (2-salts only) smolt migrations and for wild steelhead from the 2006 smolt migration. Hatchery steelhead are not shown since they were not pre-assigned to monitor-mode 2006. Overall annual SARs computed directly from Group TWS (*i.e.*, SAR(TWS)) for 2006 and 2007 were more often lower in magnitude than the estimate from the original weighted SARs approach, averaging a shift of approximately 0.04 lower for wild and hatchery Chinook each year. The single year estimate for wild steelhead had a SAR(TWS) estimate that was 0.14 lower than for the original weighted SAR estimate. When shifts in point estimate were observed, there was a similar shift in the corresponding upper and lower limits of the 90% confidence intervals, indicating that precision about the estimate appears unchanged by which method was used. We anticipate greater accuracy in the estimated overall annual SAR using the pre-assignment approach since that method has fewer parameters being estimated during intermediate steps before arriving at the overall annual SAR estimate.

Table 7-1 Comparison of estimated overall annual SARs between original weighted SARs method and pre-assigned Group TWS method for adult returns from the 2006 and 2007 wild and hatchery juvenile spring/summer Chinook and 2006 wild steelhead migrations.

	Group TWS		***SAR(TWS) (with 90% CI)***			**Original Weighted SAR (%) with (90% CI)** [B]		**TWS – (Original Weighted)**
Fish Source [A]	Smolts (estimate)	Adults (count)	SAR(%)	LL	UL			
Smolt Migration Year 2006								
DWOR	29,012	104	0.36	0.30	0.42	0.36	(0.31 – 0.42)	0.00
IMNA	8,761	70	0.80	0.63	0.96	0.86	(0.71 – 1.01)	- 0.06
MCCA	21,834	232	1.06	0.95	1.19	1.10	(1.00 – 1.21)	- 0.04
RAPH	26,349	133	0.50	0.44	0.58	0.53	(0.47 – 0.61)	- 0.03
CATH	4,308	21	0.49	0.32	0.67	0.54	(0.38 – 0.72)	- 0.05
WCh	15,273	107	0.70	0.59	0.81	0.75	(0.64 – 0.86)	- 0.05
WSt	5,429	61	1.12	0.90	1.37	1.26	(1.00 – 1.55)	- 0.14
Smolt Migration Year 2007								
DWOR	28,535	100	0.35	0.29	0.41	0.41	(0.33 – 0.50)	- 0.06
IMNA	9,600	62	0.65	0.51	0.79	0.73	(057 – 0.89)	- 0.08
MCCA	19,082	169	0.89	0.78	1.01	0.92	(0.82 – 1.04)	- 0.03
RAPH	25,802	87	0.34	0.28	0.40	0.33	(0.27 – 0.39)	+ 0.01
CATH	4,698	20	0.43	0.27	0.58	0.46	(0.33 – 0.60)	- 0.03
WCh	14,930	120	0.80	0.68	0.93	0.82	(0.70 – 0.96)	- 0.02

[A] Hatchery Chinoook: DWOR =Dworshak H; IMNA=Imnaha AP; MCCA=McCall H; RAPH=Rapid River H; and CATH=Catherine Creek AP. Wild Chinook aggregate is WCh and wild steelhead aggregate is WSt.

[B] Original weighted estimate uses combined groups TWS & BWS

Comparing SARs of the TWS and BWS pre-assigned smolt groups

In addition to allowing the annual SARs to be more straightforwardly estimated, randomly pre-assigning part of a release of PIT-tagged fish to monitor-mode and the remainder to return-to-river operations over the entire migration season provides the opportunity to directly compare whether bypassing all season instead of transporting (albeit delayed) the collected smolts would have improved the annual SAR. For the aggregate PIT-tagged wild Chinook and five CSS hatchery Chinook groups from smolt migration years 2006 and 2007 (latter year with 2-salt returns only), a SAR(TWS) > SAR(BWS) was obtained for all groups except Catherine Creek hatchery Chinook in both years (Table 7-2). The parameter TIR* is defined as the ratio of SAR(TWS)/SAR(BWS). Based on the lower limit of the 90% confidence interval of TIR* being >1, a statistically significant TIR* >1 was obtained for 4 of 6 groups in 2006 and 2 of 6 groups in 2007 (Table 7-2). For steelhead, only wild stocks were pre-assigned into the TWS and BWS groups, and the results for the single migration year 2006 available was a statistically significant TIR* >1 (Table 7-2). These findings would indicate that for these two migration years under the prevailing flow and spill conditions, bypassing all the collected smolts over the entire season would not have improved the annual SAR over what the implemented delayed start of transportation strategy produced. The start of transportation at Lower Granite, Little Goose, and Lower Monumental dams was delayed in 2006 to April 20, 24, and 28, and in 2007 to May 1, 7, and 11, respectively.

Table 7-2 Comparison of estimated overall SARs (without jacks) between the 2006-2007 transportation strategy (TWS[1]) and a hypothetical non-transportation strategy (BWS[1]) for wild and hatchery juvenile spring/summer Chinook and wild steelhead migrations under the 2006-2007 spill and flow conditions. Ratio of SAR(TWS)/SAR(BWS) is TIR* -- lower limit >1 values are shaded in yellow.

Fish	*SAR(TWS) (with 90% CI)*			*SAR(BWS) (with 90% CI)*			*TIR* (with 90% CI)*		
source[2]	SAR(%)	LL	UL	SAR(%)	LL	UL	Ratio	LL [3]	UL
Smolt Migration Year 2006									
DWOR	0.36	0.30	0.42	0.25	0.18	0.32	1.44	1.05	2.05
IMNA	0.80	0.63	0.96	0.75	0.52	0.99	1.06	0.75	1.61
MCCA	1.06	0.95	1.19	0.80	0.66	0.96	1.33	1.09	1.66
RAPH	0.50	0.44	0.58	0.37	0.28	0.47	1.35	1.03	1.84
CATH	0.49	0.32	0.67	0.73	0.44	1.04	0.67	0.40	1.20
WCh	0.70	0.59	0.81	0.68	0.53	0.85	1.03	0.79	1.38
WSt	1.12	0.90	1.37	0.69	0.42	0.99	1.62	1.05	2.81
Smolt Migration Year 2007									
DWOR	0.35	0.29	0.41	0.28	0.21	0.36	1.24	0.92	1.72
IMNA	0.65	0.51	0.79	0.58	0.40	0.77	1.11	0.79	1.67
MCCA	0.89	0.78	1.01	0.62	0.48	0.74	1.44	1.13	1.85
RAPH	0.34	0.28	0.40	0.20	0.13	0.28	1.66	1.14	2.62
CATH	0.43	0.27	0.58	0.47	0.26	0.72	0.91	0.50	1.71
WCh	0.80	0.68	0.93	0.63	0.49	0.78	1.27	0.97	1.69

[1] Strategies: delayed transport with spill (TWS) vs. hypothetical bypassing of all collected fish (BWS)

[2] Hatchery Chinoook: DWOR =Dworshak H; IMNA=Imnaha AP; MCCA=McCall H; RAPH=Rapid River H; and CATH=Catherine Creek AP. Wild Chinook aggregate is WCh and wild steelhead aggregate is WSt.

[3] Lower limit >1 of non-parametric 90% confidence interval provides a one-tail (α=0.05) test of H_0: TIR*$\leq$ 1 versus H_A: TIR*>1

First Year Ocean Survival (*s3*)

Parameters estimated in CSS allow for partitioning first year ocean survival, *s3*, from the estimated SARs. The SARs used in this analysis, included jacks for spring/

summer Chinook, and used the original CSS method of weighting (see Tables 6-1 and 6-6 in Berggren et al. 2008). Estimates of *s3* 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). We back-calculated 1st year ocean survival (*s3*) estimates from 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. This method was similar to approaches used by Wilson (2003) and Zabel et al. (2006) to estimate early ocean survival rates.

Specifically, we based this *s3* estimate on the CSS PIT tagged smolt estimates at the uppermost dam in smolt year t and age-specific adult estimates at years t+1, t+2, and t+3 at the Columbia River mouth (from that smolt year). We note that:

$$s3(t) = n3(t+1)/n2(t)$$

where ni(t) is the number of individuals of age i at time t.

The n2(t) term is derived from the number of smolts as follows:

$$n2(t) = sd(t) \bullet smolts(t), \quad \text{and}$$

$$sd(t) = pT(t) \bullet sT + (1 - pT(t)) \bullet si(t)$$

where sd(t) is survival of downstream migrants through the hydrosystem, pT (t) is the portion of fish arriving at the uppermost dam that were transported, sT is the survival of transported fish, and si (t) is the survival of in-river migrants.

The sT parameter includes a "delayed differential mortality" of transported fish termed *D* (Schaller et al. 2007), accounting for the fact that transported fish generally return at lower rates than fish that migrated volitionally. Although this delayed mortality is most likely expressed during the early ocean life stage, we applied it to the downstream migration stage because it simplifies calculation of the early ocean survival term and is consistent with previous analyses (Wilson 2003, Zabel et al. 2006). Annual *D* values of wild spring/summer Chinook for migration years 1994-2005 were obtained from the CSS (Schaller et al. 2007). For steelhead calculations we used an average *D* value from CSS for 1997-2005 (Schaller et al. 2007). Fixed values were applied to all years because of wide confidence intervals on the annual estimates and large inter-annual variation. The CSS geometric mean *D* value was 1.03 (range 0.11 to 2.69).

We assigned adult recruits to smolt migration years using age structured wild adult counts at the upper dam in the Snake River. We used the wild PIT tag returns from CSS for migration years 1994-2006 for wild spring/summer Chinook and 1997-2005 for wild steelhead.

To account for variation in annual harvest rates in Columbia River fisheries and upstream passage survival during 1964-2008, we expanded the adult returns to the uppermost dam by annual harvest rates (TAC 2008) and by survival of adults migrating through the FCRPS. We used harvest rates from U.S. versus Oregon Technical Advisory Committee (TAC 2008) and upstream passage success estimates from the CSS to expand adult counts at the upper dam.

We back-calculated n3(t+1) from the number of adults returning in year t + 1 (designated nA[t + 1]), the number returning in year t + 2 (designated nA[t + 2]), and the number returning in year t + 3 (designated nA[t + 3]). These counts were then adjusted for annual ocean survival rates. We estimated n(t + 1) as:

$$n(t+1) = \{(nA(t+1)) + (nA(t+2))/(so) + (nA(t+3))/(so2)\}$$

where we assumed that adult ocean survival, so = 0.8 (Ricker 1976) and applied it according to the number of years spent in the ocean. This assumption is consistent with previous cohort based Chinook modeling studies (Pacific Salmon Commission 1988, Zabel et al. 2006).

Estimated first year ocean survival, *s3*, for wild spring/summer Chinook during 1994-2006 ranged from 0.4% in 2005 to 8.2% in 2000 and the 13-yr geometric mean was 2.2% (Table 7-3). Estimated *s3* for wild steelhead during 1997-2005 ranged from 0.6% in 1998 to 8.2% in 1999 and the 9-yr geometric mean was 2.3% (Table 7-3). Over the same 8-yr period as shown for wild steelhead, the geometric mean of *s3* was 2.5% for wild spring/summer Chinook, which is nearly 9% higher than that of wild steelhead.

Table 7-3 Estimation of first year ocean survival, *s3*, for Snake River wild spring/summer Chinook, 1994-2006, and wild steelhead, 1997-2005 based on CSS parameter estimates for SAR, in-river survival, proportion transported and *D*.

Migration year	In-river survival (si)	Proportion transported	D value	System survival (sd)	CSS SAR (lgr-lgr) excluding harvest	SAR (lgr - Col. R. mouth)	SAR (bon - Col. R. mouth)	s3
	Wild spring/summer Chinook							
1994	0.20	0.863	0.360	0.33	0.004	0.005	0.014	0.025
1995	0.41	0.805	0.420	0.41	0.004	0.004	0.009	0.016
1996	0.44	0.706	0.920	0.77	0.004	0.004	0.006	0.011
1997	0.51	0.572	0.400	0.44	0.017	0.019	0.043	0.078
1998	0.61	0.815	0.550	0.55	0.012	0.014	0.026	0.042
1999	0.59	0.863	0.720	0.69	0.024	0.029	0.042	0.056
2000	0.48	0.709	0.320	0.36	0.017	0.020	0.054	0.082
2001	0.23	0.989	2.160	2.10	0.013	0.015	0.007	0.010
2002	0.61	0.709	0.440	0.48	0.009	0.011	0.024	0.033
2003	0.60	0.694	0.680	0.65	0.003	0.004	0.006	0.009
2004	0.40	0.929	0.450	0.44	0.005	0.006	0.013	0.019
2005	0.48	0.926	1.070	1.01	0.002	0.003	0.003	0.004
2006	0.57	0.667	0.540	0.54	0.006	0.007	0.014	0.026
geometric mean	0.4480	0.7792	0.5955	0.5878	0.0072	0.0083	0.0141	0.022
	Wild steelhead							
1997	0.52	0.715	1.034	0.87	0.012	0.017	0.020	0.022
1998	0.54	0.892	1.034	0.96	0.003	0.005	0.005	0.006
1999	0.45	0.869	1.034	0.94	0.028	0.043	0.045	0.053
2000	0.30	0.846	1.034	0.90	0.027	0.037	0.041	0.046
2001	0.038	0.992	1.034	1.01	0.025	0.034	0.034	0.038
2002	0.52	0.675	1.034	0.85	0.021	0.028	0.033	0.037
2003	0.37	0.723	1.034	0.83	0.016	0.021	0.025	0.029
2004	0.18	0.974	1.034	0.99	0.009	0.012	0.012	0.013
2005	0.27	0.930	1.034	0.96	0.008	0.011	0.011	0.013
geometric mean	0.288	0.839	1.034	0.923	0.013	0.019	0.021	0.023

Discussion

The trend in SARs across years for hatchery spring/summer Chinook are similar to those for the aggregate wild Chinook population in smolt migration years 1997-2007 suggesting similar factors influence their survival during the smolt migration and estuary and ocean life stages. There were differences among Chinook hatcheries within a single year such as Dworshak NFH which showed generally poorer SARs than Rapid River, McCall and Imnaha; conversely, the McCall and Imnaha hatcheries typically had among the highest SARs within a year.

In summary, it appears that both Snake River spring/summer Chinook and steelhead wild populations are still not consistently meeting the NPCC 2-6% SAR objective. The 10-year CSS retrospective report found that the SARs for these populations were strongly related to water travel time; an index that influences the smolt migration rate, and is indirectly related to spill and other hydrosystem factors. Although Snake River hatchery Chinook exhibited a generally more positive response to transportation and relatively lower levels of differential mortality than wild populations, annual SARs of wild and hatchery Snake River 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 Chinook SAR information following future years of low escapements, in addition to providing valuable management information for the specific hatcheries.

Parameters estimated in CSS, including in-river survival, transport proportions and *D*, allow for partitioning of the SARs to estimate first year ocean survival, *s3*. The time series of SARs and *s3* 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).

Supporting tables

Wild and hatchery Chinook returning age composition

Table 7-4 Age composition of returning PIT-tagged wild Chinook jacks and adults detected at Lower Granite Dam that were PIT-tagged during the 10-month period from July 25 to May 20 for each migration year between 1994 and 2007.

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	47	8.0	69.8	22.2
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	42 (1[C])	2.3	64.3	33.4 [C]
2005	4	38	24	6.1	57.6	36.4
2006 [A]	12	124	36	7.0	72.1	20.9
2007 [A B]	22	171	NA	--	--	--
	Average (1994 – 2006)			4.4	65.8	29.8

[A] Smolt migration year 2006 and 2007 data is combined groups TWS & BWS
[B] Incomplete adult returns through 8/3/2009 at GRA; not included in average
[C] Number of age 4-salts is shown in parenthesis; percent for combined 3- and 4-salt adults

Table 7-5 Age composition of returning PIT-tagged hatchery Summer Chinook adults and jacks detected at Lower Granite Dam that migrated as smolts in 1997 to 2007.

Hatchery	Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
MCCA	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 B]	67	301	25	17.0	76.6	6.4
	2007 [A B]	145	228	NA	--	--	--
	Average (1997 – 2006)				17.7	72.2	10.1
IMNA	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	63.8	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 B]	91	89	NA	--	--	--
	Average (1997 – 2006)				31.6	63.2	5.3

[A] Smolt migration year 2006 and 2007 data is combined groups TWS & BWS
[B] Incomplete adult returns through 8/3/2009 at GRA; not included in average
[C] Number of age 4-salts is shown in parenthesis; percent for combined 3- and 4-salt adults

Table 7-6 Age composition of returning PIT-tagged hatchery Spring Chinook adults and jacks detected at Lower Granite Dam that migrated as smolts in 1997 to 2007.

Hatchery	Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
RAPH	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	76.2	5.0
	2007 [A B]	48	111	NA	--	--	--
	Average (1997 – 2006)				9.0	78.7	12.3
DWOR	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 B]	40	139	NA	--	--	--
	Average (1997 – 2006)				8.2	75.9	15.9

Hatchery	Smolt Migr Year	Jacks 1-salt	Adults 2-salt	Adults 3-salt	Percent 1-salt	Percent 2-salt	Percent 3-salt
CATH	2001	2	13	0	13.3	86.7	0.0
	2002	11	45	1	19.3	79.0	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 B]	26	32	NA	--	--	--
	Average (1997 – 2006)				14.9	79.4	5.7

[A] **Smolt migration year 2006 and 2007 data is combined groups TWS & BWS**

[B] **Incomplete adult returns through 8/3/2009 at GRA; not included in average.**

Wild and hatchery Chinook without jacks

Table 7-7 Study-specific SARs and weights (estimated proportion of run-at-large reflected by each study category) used to estimate the annual SARs for wild Chinook with jacks excluded.

Smolt Migr Year	Population proportion In study category [A] T_0	C_0	C_1	SAR for study category (%) sar(T_0)	sar(C_0)	sar(C_1)	Weighted $SAR_{LGR\text{-}to\text{-}LGR}$ (%)	(90% CI)
1994	0.863	0.137		0.45	0.28		0.43	(0.22 – 0.66)
1995	0.805	0.141	0.054	0.35	0.37	0.25	0.35	(0.20 – 0.52)
1996	0.706	0.255	0.039	0.50	0.26	0.13	0.42	(0.06 – 0.84)
1997	0.572	0.239	0.189	1.74	2.35	0.93	1.73	(0.97 – 2.68)
1998	0.815	0.185		1.18	1.36		1.21	(0.82 – 1.64)
1999	0.863	0.137		2.43	2.13		2.39	(1.89 – 2.94)
2000	0.709	0.269	0.022	1.43	2.39	2.34	1.71	(1.22 – 2.24)
2001	0.989	0.011		1.28	0.14 [B]		1.27	(0.54 – 2.11)
2002	0.709	0.273	0.018	0.80	1.22	0.99	0.92	(0.75 – 1.10)
2003	0.692	0.294	0.014	0.34	0.33	0.17	0.34	(0.26 – 0.41)
2004	0.928	0.071	0.001	0.53	0.49	0.22	0.52	(0.43 – 0.63)
2005	0.926	0.040	0.035	0.23	0.11 [C]		0.22	(0.17 – 0.28)
2006 [D]	0.667	0.159	0.174	0.77	0.97	0.51	0.75	(0.64 – 0.86)
2007 [D E]	0.381	0.488	0.131	0.93	0.81	0.59	0.82	(0.70 – 0.96)

[A] **Estimated proportion of total smolt population (tagged and untagged) at LGR in each study category.**

[B] **In-river SAR uses SAR(C_1) with the C_0 population proportion in the weighted SAR computation.**

[C] **In-river SAR is combination of groups C_0 and C_1**

[D] **Smolt migration year 2006 and 2007 use combined groups TWS & BWS data**

[E] **Incomplete with 2-salt returns through August 3, 2009**

Smolt Migr Year	Hatchery Code [A]	Population proportion In study category [B] T_0	C_0	C_1	SAR for study category (%) sar(T_0)	sar(C_0)	sar(C_1)	Weighted $SAR_{LGR\text{-}to\text{-}LGR}$ (%)	(90% CI)
1997	DWOR	0.481	0.313	0.205	0.83	0.47	0.36	0.62	(0.44 - ,0.81)
	IMNA	0.515	0.272	0.213	1.16	0.86	0.69	0.98	(0.76 – 1.23)
	MCCA	0.509	0.307	0.184	1.51	1.09	1.10	1.31	(1.15 – 1.46)
	RAPH	0.539	0.272	0.189	0.79	0.45	0.53	0.65	(0.52 – 0.79)
1998	DWOR	0.714	0.286		0.90	1.25		1.00	(0.90 – 1.11)
	IMNA	0.848	0.152		0.85	0.55		0.81	(0.63 – 1.00)
	MCCA	0.856	0.144		2.69	1.38		2.50	(2.28 – 2.73)
	RAPH	0.857	0.143		2.00	1.20		1.88	(1.71 – 2.07)
1999	DWOR	0.735	0.265		1.18	1.19		1.18	(1.05 – 1.32)
	IMNA	0.777	0.223		2.69	1.43		2.41	(2.09 – 2.74)
	MCCA	0.725	0.275		3.59	2.40		3.26	(3.02 – 3.49)
	RAPH	0.797	0.203		3.04	2.37		2.91	(2.69 – 3.13)
2000	DWOR	0.660	0.340		1.00	1.01		1.00	(0.92 – 1.10)
	IMNA	0.686	0.314		3.11	2.41		2.89	(2.63 – 3.15)
	MCCA	0.580	0.420		3.88	2.06		3.12	(2.92 – 3.33)
	RAPH	0.679	0.321		2.10	1.59		1.94	(1.79 – 2.08)
2001	DWOR	0.978	0.022		0.36		0.04 [C]	0.36	(0.29 – 0.43)
	IMNA	0.976	0.024		0.62		0.06 [C]	0.61	(0.48 – 0.77)
	MCCA	0.972	0.028		1.23		0.04 [C]	1.20	(1.07 – 1.34)
	RAPH	0.974	0.026		1.08		0.05 [C]	1.06	(0.94 – 1.18)
	CATH	0.964	0.036		0.23		0.04 [C]	0.22	(0.12 – 0.34)
2002	DWOR	0.569	0.431		0.62	0.50		0.57	(0.48 – 0.65)
	IMNA	0.662	0.338		0.80	0.45		0.68	(0.52 – 0.85)
	MCCA	0.678	0.322		1.49	1.03		1.34	(1.19 – 1.50)
	RAPH	0.665	0.335		1.01	0.67		0.90	(0.79 – 1.01)
	CATH	0.706	0.294		0.89	0.49		0.77	(0.56 – 1.00)
2003	DWOR	0.535	0.465		0.26	0.21		0.24	(0.19 – 0.29)
	IMNA	0.549	0.451		0.58	0.48		0.53	(0.42 – 0.65)
	MCCA	0.537	0.463		0.79	0.54		0.68	(0.60 – 0.76)
	RAPH	0.550	0.450		0.25	0.23		0.24	(0.19 – 0.29)
	CATH	0.550	0.450		0.36	0.25		0.31	(0.20 – 0.43)
2004	DWOR	0.842	0.150	0.008	0.28	0.32	0.18	0.29	(0.23 – 0.34)
	IMNA	0.887	0.103	0.010	0.38	0.23	0.11	0.36	(0.25 – 0.46)
	MCCA	0.927	0.060	0.013	0.40	0.25	0.12	0.39	(0.33 – 0.46)
	RAPH	0.889	0.098	0.014	0.36	0.23	0.12	0.34	(0.28 – 0.41)
	CATH	0.896	0.096	0.008	0.38	0.20	0.32	0.36	(0.20 – 0.54)
2005	DWOR	0.836	0.079	0.085	0.20		0.14 [D]	0.19	(0.15 – 0.24)
	IMNA	0.856	0.056	0.089	0.28		0.16 [D]	0.27	(0.17 – 0.37)
	MCCA	0.860	0.059	0.081	0.62		0.20 [D]	0.57	(0.50 – 0.64)
	RAPH	0.869	0.049	0.082	0.27		0.12 [D]	0.25	(0.20 – 0.31)
	CATH	0.862	0.058	0.080	0.44		0.18 [D]	0.40	(0.22 – 0.60)
2006 [E]	DWOR	0.657	0.329	0.014	0.35	0.39	0.20	0.36	(0.31 – 0.43)
	IMNA	0.725	0.220	0.055	0.77	1.25	0.48	0.86	(0.71 – 1.01)
	MCCA	0.664	0.277	0.059	1.16	1.03	0.67	1.10	(1.00 – 1.21)
	RAPH	0.753	0.220	0.027	0.58	0.42	0.33	0.53	(0.47 – 0.61)
	CATH	0.682	0.256	0.061	0.41	0.92	0.44	0.54	(0.38 – 0.72)
2007 [E F]	DWOR	0.270	0.694	0.036	0.68	0.31	0.32	0.41	(0.33 – 0.50)
	IMNA	0.371	0.548	0.081	0.96	0.61	0.47	0.73	(0.57 – 0.89)
	MCCA	0.313	0.617	0.070	1.46	0.070	0.050	0.92	(0.82 – 1.04)
	RAPH	0.408	0.523	0.069	0.45	0.25	0.25	0.33	(0.27 – 0.39)
	CATH	0.439	0.464	0.097	0.54	0.37	0.52	0.46	(0.33 – 0.60)

[A] Hatchery coding: DWOR=Dworshak H; IMNA=Imnaha AP; MCCA=McCall H; RAPH=Rapid River H; and CATH=Catherine Creek AP.

[B] Estimated proportion of total smolt population (tagged and untagged) at LGR in each study category.

[C] In-river SAR uses SAR(C_1) with the C_0 population proportion in the weighted SAR computation.

[D] In-river SAR is combination of groups C_0 and C_1

[E] Smolt migration year 2006 and 2007 use combined groups TWS & BWS data

[F] Incomplete with 2-salt returns through August 3, 2009

Wild and hatchery Chinook with jacks

Table 7-9 Study-specific SARs and weights (estimated proportion of run-at-large reflected by each study category) used to estimate the annual SARs for wild Chinook with jacks included.

Smolt Migr Year	Population proportion In study category [A]			SAR for study category (%)			Weighted $SAR_{LGR\text{-}to\text{-}LGR}$ (%) (90% CI)	
	T_0	C_0	C_1	$sar(T_0)$	$sar(C_0)$	$sar(C_1)$		
1994	0.863	0.137		0.50	0.28		0.47	(0.24 – 0.70)
1995	0.805	0.141	0.054	0.35	0.37	0.26	0.35	(0.19 – 0.52)
1996	0.706	0.255	0.039	0.50	0.26	0.17	0.43	(0.06 – 0.85)
1997	0.572	0.239	0.189	1.74	2.50	0.98	1.78	(0.99 – 2.73)
1998	0.815	0.185		1.18	1.56		1.25	(0.84 – 1.70)
1999	0.863	0.137		2.60	2.19		2.55	(2.03 – 3.09)
2000	0.709	0.269	0.022	1.43	2.43	2.37	1.72	(1.25 – 2.20)
2001	0.989	0.011		1.46	0.15 [B]		1.45	(0.70 – 2.32)
2002	0.709	0.273	0.018	0.90	1.38	1.07	1.04	(0.83 – 1.24)
2003	0.692	0.294	0.014	0.34	0.33	0.20	0.34	(0.26 – 0.42)
2004	0.928	0.071	0.001	0.54	0.49	0.23	0.54	(0.44 – 0.64)
2005	0.926	0.040	0.035	0.25	0.12 [C]		0.24	(0.18 – 0.30)
2006 [D]	0.667	0.159	0.174	0.83	1.06	0.55	0.81	(0.71 – 0.94)
2007 [D E]	0.381	0.488	0.131	1.02	0.90	0.68	0.92	(0.78 – 1.05)

[A] Estimated proportion of total smolt population (tagged and untagged) at LGR in each study category.

[B] In-river SAR uses SAR(C_1) with the C_0 population proportion in the weighted SAR computation.

[C] In-river SAR is combination of groups C_0 and C_1

[D] Smolt migration year 2006 and 2007 use combined groups TWS & BWS data

E Incomplete with 2-salt returns through August 3, 2009

Table 7-10 Study-specific SARs and weights (estimated proportion of run-at-large reflected by each study category) used to estimate the annual SARs for hatchery Chinook with jacks included.

Smolt Migr Year	Hatchery Code [A]	Population proportion In study category [B]			SAR for study category (%)			Weighted $SAR_{LGR\text{-}to\text{-}LGR}$ (%) (90% CI)
		T_0	C_0	C_1	sar(T_0)	sar(C_0)	sar(C_1)	
1997	DWOR	0.481	0.313	0.205	0.83	0.51	0.36	0.63 (0.46 – 0.84)
	IMNA	0.515	0.272	0.213	1.72	0.99	0.90	1.35 (1.10 – 1.64)
	MCCA	0.509	0.307	0.184	1.63	1.17	1.20	1.41 (1.25 – 1.58)
	RAPH	0.539	0.272	0.189	0.79	0.45	0.56	0.65 (0.52 – 0.78)
1998	DWOR	0.714	0.286		1.03	1.44		1.14 (1.04 – 1.25)
	IMNA	0.848	0.152		1.56	0.95		1.46 (1.20 – 1.73)
	MCCA	0.856	0.144		3.27	1.87		3.07 (2.80 – 3.32)
	RAPH	0.857	0.143		2.08	1.39		1.98 (1.80 – 2.18)
1999	DWOR	0.735	0.265		1.22	1.24		1.22 (1.08 – 1.36)
	IMNA	0.777	0.223		3.59	1.85		3.20 (2.82 – 3.57)
	MCCA	0.725	0.275		4.08	2.82		3.73 (3.48 – 4.02)
	RAPH	0.797	0.203		3.18	2.50		3.04 (2.82 – 3.25)
2000	DWOR	0.660	0.340		1.01	1.02		1.01 (0.92 – 1.12)
	IMNA	0.686	0.314		4.26	3.41		3.99 (3.66 – 4.31)
	MCCA	0.580	0.420		4.49	2.44		3.63 (3.41 – 3.84)
	RAPH	0.679	0.321		2.12	1.62		1.96 (1.82 – 2.1)
2001	DWOR	0.978	0.022		0.43	0.04 [C]		0.42 (0.35 – 0.49)
	IMNA	0.976	0.024		1.00	0.06 [C]		0.98 (0.80 – 1.17)
	MCCA	0.972	0.028		1.58	0.05 [C]		1.55 (1.39 – 1.71)
	RAPH	0.974	0.026		1.19	0.05 [C]		1.17 (1.04 – 1.29)
	CATH	0.964	0.036		0.27	0.04 [C]		0.26 (0.14 – 0.40)
	DWOR	0.569	0.431		0.80	0.62		0.72 (0.63 – 0.81)
	IMNA	0.662	0.338		1.15	0.75		1.02 (0.83 – 1.23)
2002	MCCA	0.678	0.322		2.05	1.33		1.82 (1.64 – 2.00)
	RAPH	0.665	0.335		1.19	0.83		1.07 (0.95 – 1.19)
	CATH	0.706	0.294		1.15	0.65		1.00 (0.76 – 1.28)
	DWOR	0.535	0.465		0.27	0.23		0.25 (0.20 – 0.30)
	IMNA	0.549	0.451		1.35	1.15		1.26 (1.08 – 1.43)
2003	MCCA	0.537	0.463		1.11	0.88		1.00 (0.91 – 1.09)
	RAPH	0.550	0.450		0.35	0.26		0.31 (0.26 – 0.37)
	CATH	0.550	0.450		0.44	0.34		0.40 (0.25 – 0.54)
	DWOR	0.842	0.150	0.008	0.28	0.32	0.19	0.29 (0.23 – 0.34)
	IMNA	0.887	0.103	0.010	0.46	0.38	0.13	0.45 (0.33 – 0.58)
2004	MCCA	0.927	0.060	0.013	0.48	0.46	0.14	0.47 (0.40 – 0.55)
	RAPH	0.889	0.098	0.014	0.37	0.23	0.12	0.36 (0.29 – 0.42)
	CATH	0.896	0.096	0.008	0.38	0.59	0.32	0.40 (0.22 – 0.58)
	DWOR	0.836	0.079	0.085	0.21	0.14 [D]		0.20 (0.16 – 0.25)
	IMNA	0.856	0.056	0.089	0.35	0.18 [D]		0.32 (0.23 – 0.43)
2005	MCCA	0.860	0.059	0.081	0.67	0.23 [D]		0.61 (0.54 – 0.69)
	RAPH	0.869	0.049	0.082	0.29	0.13 [D]		0.27 (0.22 – 0.33)
	CATH	0.862	0.058	0.080	0.52	0.22 [D]		0.48 (0.27 – 0.68)
	DWOR	0.657	0.329	0.014	0.48	0.49	0.28	0.48 (0.41 – 0.55)
	IMNA	0.725	0.220	0.055	1.08	1.60	0.74	1.18 (1.00 – 1.37)
2006 [E]	MCCA	0.664	0.277	0.059	1.40	1.23	0.81	1.32 (1.19 – 1.43)
	RAPH	0.753	0.220	0.027	0.67	0.53	0.45	0.64 (0.56 – 0.72)
	CATH	0.682	0.256	0.061	0.51	1.17	0.61	0.69 (0.51 – 0.88)
	DWOR	0.270	0.694	0.036	0.73	0.39	0.47	0.48 (0.40 – 0.57)
2007	IMNA	0.371	0.548	0.081	1.65	1.33	0.94	1.42 (1.22 – 1.62)
[E F]	MCCA	0.313	0.617	0.070	1.84	1.30	0.85	1.44 (1.31 – 1.57)
	RAPH	0.408	0.523	0.069	0.61	0.35	0.41	0.46 (0.39 – 0.53)
	CATH	0.439	0.464	0.097	1.03	0.77	0.65	0.87 (0.68 – 1.06)

[A] Hatchery coding: DWOR=Dworshak H; IMNA=Imnaha AP; MCCA=McCall H; RAPH=Rapid River H; and CATH=Catherine Creek AP.

[B] Estimated proportion of total smolt population (tagged and untagged) at LGR in each study category.

[C] In-river SAR uses SAR(C_1) with the C_0 population proportion in the weighted SAR computation.

[D] In-river SAR is combination of groups C_0 and C_1

[E] Smolt migration year 2006 and 2007 use combined groups TWS & BWS data

[F] Incomplete with 2-salt returns through August 3, 2009

Wild and hatchery steelhead returning age composition

Table 7-11 Age composition of returning PIT-tagged wild steelhead adults detected at Lower Granite Dam that were PIT-tagged during the 12-month period from July 1 to June 30 for each migration year between 1997 and 2006.

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	51	2	38.4	59.3	2.3
2000	132	131	3	49.6	49.3	1.1
2001	5	14	2	23.8	66.7	9.5
2002	59	60	1	49.2	50.0	0.8
2003	38	63	0	37.6	62.4	0
2004	26	21	0	55.3	44.7	0
2005	17	42	1	28.3	70.0	1.7
2006 [A]	37	42	0	46.8	53.2	0
	Average			42.4	56.0	1.5

[A] Smolt migration year 2006 data is combined groups TWS & BWS

Table 7-12 Age composition of returning PIT-tagged hatchery steelhead adults detected at Lower Granite Dam that migrated as smolts in 1997 to 2006.

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	0.6
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	76	0	57.3	42.7	0
	Average			55.4	44.5	0.2

Wild and hatchery steelhead overall SARs

Table 7-13 Study-specific SARs and weights (estimated proportion of run-at-large reflected by each study category) used to estimate the annual SARs for wild steelhead.

Smolt Migr Year	Population proportion In study category [A]			SAR for study category (%)			Weighted $SAR_{LGR\text{-}to\text{-}LGR}$ (%) (90% CI)	
	T_0	C_0	C_1	sar(T_0)	sar(C_0)	sar(C_1)		
1997	0.715	0.122	0.163	1.45	0.66	0.23	1.16	(0.37 – 2.12)
1998	0.892	0.108		0.21	1.07		0.30	(0.07 – 0.66)
1999	0.869	0.131		3.07	1.35		2.84	(1.68 – 4.19)
2000	0.846	0.144	0.009	2.79	1.92	1.82	2.66	(1.62 – 3.72)
2001	0.992	0.008		2.49	0.07 [B]		2.47	(0.97 – 4.49)
2002	0.675	0.309	0.016	2.84	0.67	0.94	2.14	(1.24 – 3.21)
2003	0.723	0.262	0.015	1.99	0.45	0.52	1.57	(1.22 – 1.94)
2004	0.974	0.026	0.000	0.87	0.06 [C]		0.85	(0.63 – 1.08)
2005	0.931	0.014	0.055	0.84	0.17 [C]		0.80	(0.60 – 1.01)
2006 [D]	0.803	0.077	0.120	1.34	1.37	0.64	1.26	(1.00 – 1.55)

[A] Estimated proportion of total smolt population (tagged and untagged) at LGR in each study category.
[B] In-river SAR uses SAR(C_1) with the C_0 population proportion in the weighted SAR computation.
[C] In-river SAR is combination of groups C_0 and C_1
[D] Incomplete until 3-salt returns (if any) occur after 7/1/2009 at GRA.

Table 7-14 Study-specific SARs and weights (estimated proportion of run-at-large reflected by each study category) used to estimate the annual SARs for hatchery steelhead.

Smolt Migr Year	Population proportion In study category [A]			SAR for study category (%)			Weighted SARLGR-to-LGR (%) (90% CI)	
	T_0	C_0	C_1	sar(T_0)	sar(C_0)	sar(C_1)		
1997	0.608	0.140	0.252	0.52	0.24	0.17	0.39	(0.22 – 0.59)
1998	0.873	0.127		0.51	0.89		0.56	(0.30 – 0.85)
1999	0.848	0.150	0.002	0.90	1.04	0.59	0.92	(0.59 – 1.30)
2000	0.817	0.183		2.10	0.95		1.89	(1.18 – 2.70)
2001	0.979	0.019	0.003	0.94	0.016 [B]		0.92	(0.24 – 1.74)
2002	0.700	0.300		1.06	0.70		0.95	(0.40 – 1.72)
2003	0.690	0.305	0.005	1.81	0.68	0.37	1.46	(1.24 – 1.68)
2004	0.973	0.023	0.004	2.13	0.21 [C]		2.08	(1.15 – 3.19)
2005	0.890	0.019	0.091	2.03	0.24 [C]		1.83	(1.17 – 2.55)
2006 [D]	0.787	0.118	0.095	2.13	1.42	1.23	1.96	(1.33 – 2.67)

[A] Estimated proportion of total smolt population (tagged and untagged) at LGR in each study category.
[B] In-river SAR uses SAR(C_1) with the C_0 population proportion in the weighted SAR computation.
[C] In-river SAR is combination of groups C_0 and C_1
[D] Incomplete until 3-salt returns (if any) occur after 7/1/2009 at GRA.

Wild and hatchery Chinook overall SARs of Snake River and other Columbia River basin stocks indexed at Bonneville Dam

Table 7-15 Estimates of annual SARs (%) of PIT-tagged wild and hatchery sp/su Chinook of Snake River and other Columbia River basin stocks, 2000 to 2007. SARs based on adults (no jacks) detected at Bonneville Dam, and smolt numbers estimated at starting location behind the @ symbol where LGR = Lower Granite Dam; JDA = John Day Dam; MCN = McNary Dam; BON = Bonneville Dam; and REL = release site.

	Smolt Migration Year							
Fish Groups[1]	2000	2001	2002	2003	2004	2005	2006	2007
Wild Chinook								
Snake R @LGR	2.63	1.85	1.17	0.36	0.70	0.29	0.91	1.05
John Day R @JDA	11.39	3.90	3.72	2.93	3.19	1.82	2.10	4.37
Hatchery Chinook								
Snake R								
DWOR @LGR	1.54	0.43	0.73	0.31	0.55	0.29	0.59	0.63
IMNA @LGR	3.49	0.77	0.89	0.69	0.58	0.35	1.13	1.00
MCCA @LGR	3.65	1.47	1.70	0.79	0.53	0.67	1.31	0.62
RAPH @LGR	2.67	1.36	1.07	0.35	0.44	0.33	0.78	0.51
CATH @LGR	N.A.	0.36	1.08	0.37	0.48	0.56	0.92	0.58
Upper Columbia R								
LEAV @MCN	1.83	0.24	0.36	0.43	0.34	0.09	0.89	0.45
CLEE @MCN	3.81	0.28	1.37	0.59	1.54	0.66	1.25	0.99
Lower Columbia R								
CARS @BON	3.30	1.78	1.22	0.27	N.A	0.32	0.60	N.A.
CARS @REL	2.85	1.49	1.01	0.23	0.62	0.30	0.42	0.54

[1] Abbreviations: DWOR = Dworshak NFH; IMNA = Imnaha River Acclimation Pond; MCCA = McCall Hatchery; RAPH = Rapid River Hatchery; CATH = Catherine Creek Acclimation Pond; LEAV = Leavenworth NFH; CLEE = Cle Elum Hatchery; CARS = Carson NFH.

Table 7-16. Carson NFH spring Chinook estimated starting population of PIT-tag smolts at Bonneville Dam with estimate of BON-to-BON SARs, as well as estimated SAR from release to BON as adults without jacks, 2000 to 2007.

Smolt migr. yr	PIT-tag release number	Est. Population at BON (90% CI)	Adults detected at BON	BON-to-BON SAR % (90% CI)	REL-to-BON SAR % (90% CI)
2000	14,992	12,945 (11,015 – 15,531)	427	3.30 (2.71 – 3.91)	2.85 (2.62 – 3.07)
2001	14,978	12,506 (11,244 – 14,150)	223	1.78 (1.50 – 2.05)	1.49 (1.32 – 1.65)
2002	14,983	12,349 (10,096 – 15,432)	151	1.22 (0.94 – 1.54)	1.01 (0.88 – 1.14)
2003	14,983	12,709 (10,855 – 15,275)	34	0.27 (0.19 – 0.36)	0.23 (0.17 – 0.29)
2004	14,973	N.A. survival est. > 1	93	N.A	0.62 (0.51 – 0.73)
2005	14,958	14,053 (11,878 – 17,070)	45	0.32 (0.23 – 0.42)	0.30 (0.23 – 0.37)
2006	14,971	10,509 (8.926 – 12,583)	63	0.60 (0.45 – 0.77)	0.42 (0.33 – 0.51)
2007	14,943	N.A. survival est. > 1	80	N.A	0.54 (0.43 – 0.63)

Table 7-17. Cle Elum Hatchery[1] spring Chinook estimated starting population of PIT-tag smolts at McNary Dam with estimate of MCN-to-BON SARs, as well as estimated SAR from release to BON as adults without jacks, 2000 to 2007.

Smolt migr. yr	PIT-tag release number	Est. Population at MCN (90% CI)	Adults detected at BON	MCN-to-BON SAR % (90% CI)	REL-to-BON SAR % (90% CI)
2000	38,467	13,794 (13,147 – 14,575)	526	3.81 (3.47 – 4.14)	1.37 (1.27 – 1.47)
2001	39,799	9,228 (9,050 – 9,410)	26	0.28 (0.19 – 0.37)	0.07 (0.05 – 0.09)
2002	39,419	11,728 (11,439 – 12,011)	161	1.37 (1.18 – 1.56)	0.41 (0.35 – 0.46)
2003	39,985	11,962 (11,647 – 12,278)	71	0.59 (0.48 – 0.71)	0.18 (0.14 – 0.21)
2004	40,015	7,982 (7,635 – 8,336)	123	1.54 (1.31 – 1.79)	0.31 (0.26 – 0.35)
2005	39,997	5,784 (5,543 – 6,030)	38	0.66 (0.48 – 0.83)	0.10 (0.07 – 0.12)
2006	39,987	10,141 (9,787 – 10,495)	127	1.25 (1.07 – 1.44)	0.32 (0.27 – 0.36)
2007	40,006	12,675 (12,361 – 13,002)	126	0.99 (0.85 – 1.16)	0.31 (0.27 – 0.36)

[1] Aggregate of Cle Elum Hatchery's releases from three acclimation ponds in Yakima River: Clark Flat AP (Rkm 270); Jack Creek AP (Rkm 284); and Easton AP (Rkm 325)

Table 7-18. Leavenworth NFH spring Chinook estimated starting population of PIT-tag smolts at McNary Dam with estimate of MCN-to-BON SARs, as well as estimated SAR from release to BON as adults without jacks, 2000 to 2007.

Smolt migr. yr	PIT-tag release number	Est. Population at MCN (90% CI)	Adults detected at BON	MCN-to-BON SAR % (90% CI)	REL-to-BON SAR % (90% CI)
2000	7,387	4,360 (3,958 – 4,831)	80	1.83 (1.48 – 2.22)	1.08 (0.89 – 1.29)
2001	7,600	3,808 (3,708 – 3,914)	9	0.24 (0.13 – 0.38)	0.12 (0.07 – 0.18)
2002	317,271	178,609 (176,832 – 180,567)	647	0.36 (0.34 – 0.39)	0.20 (0.19 – 0.22)
2003	240,558	153,594 (452,152 – 155,084)	653	0.43 (0.40 – 0.45)	0.27 (0.25 – 0.29)
2004	216,600	104,754 (102,845 – 106,695)	365	0.34 (0.31 – 0.37)	0.16 (0.15 – 0.18)
2005	14,825	7,880 (7,544 – 8,208)	7	0.09 (0.04 – 0.15)	0.05 (0.02 – 0.07)
2006	14,700	8,183 (7,857 – 8,534)	73	0.89 (0.72 – 1.09)	0.50 (0.40 – 0.60)
2007	14,969	8,882 (8,611 – 9,161)	40	0.45 (0.34 – 0.57)	0.27 (0.20 – 0.34)

Table 7-19. John Day River wild spring Chinook[1] estimated starting population of PIT-tag smolts at John Day Dam with estimate of JDA-to-BON SARs, as well as estimated SAR from release to BON as adults without jacks, 2000 to 2007.

Smolt migr. yr	PIT-tag release number	Est. Population at MCN (90% CI)	Adults detected at BON	MCN-to-BON SAR % (90% CI)	REL-to-BON SAR % (90% CI)
2000	1,851	1,255 (1,137 – 1,381)	143	11.39 (9.58 – 13.33)	7.73 (6.70 – 8.75)
2001	3,881	2,721 (2,617 – 2,835)	106	3.90 (3.24 – 4.50)	2.73 (2.29 – 3.17)
2002	3,999	2,555 (2,279 – 2,894)	95	3.72 (3.01 – 4.43)	2.38 (2.00 – 2.75)
2003	6,122	4,203 (3,919 – 4,512)	123	2.93 (2.46 – 3.42)	2.01 (1.72 – 2.32)
2004	4,372	2,755 (2,381 – 3,282)	88	3.19 (2.50 – 4.01)	2.01 (1.69 – 2.38)
2005	5,337	3,907 (3,687 – 4,160)	71	1.82 (1.46 – 2.20)	1.33 (1.09 – 1.61)
2006	2,757	2,188 (1,963 –2,483)	46	2.10 (1.56 – 2.70)	1.67 (1.31 – 2.10)
2007	3,463	2,606 (2,431 – 2,797)	114	4.37 (3.71 – 5.11)	3.29 (2.83 – 3.78)

[1] John Day River release sites include JDAR1, JDAR2, JDARNF, JDARMF and JDARSF; wild Chinook were PIT-tagged and released between Feb 1 and May 20 for migration years 2000 – 2003 and 2006 – 2007 and between Oct 1 of prior year and May 20 for migration years 2004 – 2005.

Wild and hatchery Chinook of other Columbia River basin stocks returning age composition at Bonneville Dam

Table 7-20 Age composition of returning PIT-tagged wild spring Chinook from John Day River basin detected at Bonneville Dam from smolt migration years 2000 to 2007.

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	NA	--	--	--
Average (2000 – 2006)				5.3	78.5	16.2

A One 4-salt return was included in the 3-salt percentage.

Table 7-21 Age composition of returning PIT-tagged Carson NFH spring Chinook detected at Bonneville Dam from smolt migration years 2000 to 2007.

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
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		4.5	95.5	0.0
2007	12	80		--	--	--
Average (2000 – 2006)				2.4	86.7	10.9

A One 4-salt return was included in the 3-salt percentage.

Table 7-22 Age composition of returning PIT-tagged Cle Elum Hatchery[1] spring Chinook at Bonneville Dam from smolt migration years 2000 to 2007.

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		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		--	--	--
Average (2000 – 2006)				17.0	80.1	2.9

[1] **Aggregate of Cle Elum Hatchery's releases from three acclimation ponds in Yakima River: Clark Flat AP (Rkm 270); Jack Creek AP (Rkm 284); and Easton AP (Rkm 325)**

Table 7-23 Age composition of returning PIT-tagged Leavenworth NFH spring Chinook at Bonneville Dam from smolt migration years 2000 to 2007.

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		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		--	--	--
Average (2000 – 2006)				6.3	76.5	17.2

[A] **One 5-salt return was included in the 3-salt percentage.**

Chapter 8

Variability of run-at-large juvenile population abundance estimates used in run-reconstruction LGR-to-LGR SARs and the implications on estimated precision

Introduction

Run-reconstruction SARs require the estimation of both the number of smolts during the outmigration as well as the number of those smolts that return as adults. In this chapter, we develop methods to estimate the number of smolts in the run-at-large at Lower Granite Dam, along with estimates of the precision of those smolt estimates. Using daily PIT-tag detection probability estimates and collection estimates from the Smolt Monitoring Program (SMP), we developed annual estimates of the abundance of juvenile wild yearling spring/summer Chinook at Lower Granite Dam (LGR) and their associated confidence intervals.

The CSS ten-year report (Schaller et al. 2007) reported that SARs for Snake River wild PIT-tagged spring/summer Chinook averaged 19% less than SARs based on run-reconstruction methods. However, because run-reconstruction methods contained many assumptions, Schaller et al. (2007) could not conclusively determine whether an actual bias existed in either method. The ISAB/ISRP (2007) review of the CSS ten-year report and the ISAB/ISRP tagging report (ISAB/ISRP 2009) recommended that the CSS conduct a comprehensive study to determine why the PIT-tagged Snake River wild spring/summer Chinook are producing lower SARs than the unmarked wild Chinook. However, because of the numerous challenges inherent in estimating run-reconstruction SARs and properly characterizing the statistical precision of those SARs of unmarked wild Chinook, it should be noted that it remains unclear whether run-reconstruction SARs indeed are or are not lower than PIT-tag SARs.

Recently, Knudsen et al. (2009) reported that SARs estimated utilizing PIT-tags could be biased low due to a combination of PIT-tag loss and tag-induced mortality compared to SARs utilizing coded-wire tags (CWTs). Many of the analyses in the CSS focus on comparisons between similarly tagged groups. The potential bias reported by Knudsen et al. (2009) should not affect those comparisons because both groups would presumably express any bias equally. However, the potential bias could play a role when comparing CSS SARs with run-reconstruction SARs. Because the results of Knudsen et al. (2009) are of interest to a wide variety of researchers employing PIT-tags across the Columbia and Snake River basins, the USFWS is working towards implementing a basin-wide independent PIT-tag bias study in an effort to evaluate and test the repeatability of the Knudsen et al. (2009) results.

The run-reconstruction SARs utilize a different estimation methodology than the CSS. Run-reconstruction estimates of wild smolt abundance rely on detection probabilities from PIT-tags and Smolt Monitoring Program (SMP) wild collection estimates. In monitoring the number of number of unmarked smolts, the SMP attempts to correct for unclipped hatchery smolts through the detection of coded-wire-tagged individuals.

Run-reconstruction estimates of wild adult abundance rely on window counts of unclipped adults and jacks using a visually-based, minimum 22” fork length criterion. Some level of uncertainty results from determining age-composition and assigning the returning adults to particularly brood years. Other uncertainties in adult abundance include the implicit or explicit assumptions about fallback/re-ascension rates and expansions for passage during the non-counting hours. Finally, the unclipped adults and jacks contain an unknown number of unclipped hatchery fish.

To partially address the ISAB/ISRP recommendation above, the CSS has begun to investigate one of the component uncertainties inherent in the run-reconstruction SARs, the estimation of wild smolt abundance. The estimation of juvenile abundance at Lower Granite Dam provides an important component of the overall estimation of run-reconstruction SARs. However, uncertainties in juvenile abundance estimates are not currently incorporated in the run-reconstruction SARs. This analysis provides an estimate of the uncertainty in juvenile abundance estimates for use in calculating overall variances associated with run-reconstruction SARs. Here we report these variances for wild Chinook. We are currently working on expanding this approach for wild steelhead and expect to present those results in later reports.

The estimates of juvenile abundance at Lower Granite Dam utilize methods described by Sanford and Smith (2002) and Copeland et al. (2008). Sanford and Smith (2002) used PIT-tags to estimate daily detection probabilities at dams. Copeland et al. (2008) used these estimated detection probabilities as well as daily collection estimates from the SMP to estimate daily and seasonal abundance at Lower Granite Dam. Using these estimates of juvenile abundance, along with estimates of adult returns, Copeland et al. (2008) calculated LGR-to-LGR SARs. In the Copeland et al. (2008) analysis, adult counts by migration year were estimated by using adult returns from ladder counts (e.g., adult counts by return year) and incorporating fin-ray-based aging data from carcasses collected on spawning grounds. These estimates of adult numbers at LGR were then divided by juvenile population abundance estimates for each juvenile migration year. However, the SARs Copeland et al. (2008) reported used binomial confidence intervals, without attempting to incorporate the variance from the smolt estimation process. Here we provide variance estimates for the smolt portion of these SAR calculations for wild Chinook that may be used to develop confidence intervals for run-reconstruction SARs using variances from both juvenile and adult components of the ratio estimate.

Methods

Dataset description

Wild spring/summer Chinook salmon juveniles PIT tagged for the CSS from migration years 1994 to 2006 were used in this analysis. These tagged fish originate from above Lower Granite Dam and are the same groups used in other CSS reports (Schaller et al. 2007). Once tag groups were identified for each year, all tag detection information at Little Goose Dam and/or Lower Granite Dam between March 26 (the date the bypass is started up each year) and June 30 were included in the dataset. Fish detected between these dates typically encompassed over 99% of the run-at-large sampled by the SMP and therefore, should be representative of the seasonal population. Seasonal PIT-tag population estimates generated from this analysis were compared to those derived by CSS which used CJS single release capture/recapture methods (see Chapter 2) which might potentially include detections through October at these dams. However, detected smolts after June 30 were typically a small portion of the PIT-tagged population (less than 0.1 percent per year).

Seasonal population estimation was calculated in three analytical steps. First, daily estimated PIT-tag detection probabilities were calculated using the methods described below. Second, daily collection estimates and variances were derived from SMP data. Third, daily abundance estimates were then calculated using the estimated collection divided by the estimated dam detection probabilities. The estimated daily abundance estimates were bootstrapped 1,000 times for each year to develop average annual estimates and population variances using a nonparametric bootstrapping approach (Efron and Tibshirani 1993), where the data are re-sampled with replacement to create 1,000 simulated populations. Annual estimates of run-at-large population size and associated variance estimates were calculated for each year. Estimates of annual PIT-tag populations were also calculated and those data were compared to the annual estimates generated by CSS using the CJS single release capture/recapture methodology.

PIT-tag estimates of daily detection probability at Lower Granite Dam

PIT-tags that were detected at Little Goose Dam (LGS) were divided into those seen at Lower Granite Dam (LGR) X_{11} and those unseen at Lower Granite Dam X_{01}. The X_{11} tags were tallied for each date between March 26 and June 30 at Little Goose Dam. For each i^{th} date at LGS the number tagged fish previously detected at Lower Granite Dam were tallied for each date at LGR, *j*. For any day *j*, at LGR, the total number of fish detected at that dam that were also detected at Little Goose Dam was the sum of daily counts:

$$N_{jX_1} = \sum_{i=1}^{n} X_{11}$$

For fish not detected at LGR but subsequently detected at LGS, the daily passage number $\hat{N}_{X0}$ had to be estimated. In order to estimate the daily number of undetected fish passing LGR, we assumed the passage timing of undetected fish was identical to that of fish detected at both dams. The distribution of daily passage proportion P_{ij} at Lower Granite Dam for fish detected on the i^{th} date at Little Goose Dam and j^{th} day at Lower Granite Dam was represented by:

$$P_{ij} = X_{1j} \Big/ \sum_{j=1}^{n} X_{1j} \qquad .$$

The calculation of all P_{ij} was designated as the daily passage proportion matrix **P** for fish detected at both sites. Assuming travel time distribution for fish undetected at Lower Granite Dam was the same as that of fish detected at both dams, the X_{01} fish passage distribution at Lower Granite Dam would have been identical to the proportional passage distribution *P* of the X_{11} fish. A vector containing the count of X_{01} fish at LGS for each

i^{th} date was multiplied by matrix **P** to generate an intermediate matrix that distributed the X_{01} fish using the X_{11} passage proportions. This intermediate matrix ($P \bullet X_{01}$) contains the estimated daily passage of X_{01} fish at LGR. The estimated count of X_{01} fish on each j^{th} date at Lower Granite, $\hat{N}_{jX01}$, was the sum of each column of the $P \bullet X_{01}$ matrix.

Once the number detected and undetected was estimated for each j^{th} date at Lower Granite Dam, an uncorrected estimate of detection probability was calculated as

$$N_{jX_{11}} \Big/ (N_{jX_1} + \hat{N}_{jX_0}) \quad .$$

This number was corrected for the proportion of PIT-tagged fish that were removed on the j^{th} date at Lower Granite Dam, R_j. These fish were either transported or removed for research. The final estimated detection probability $\hat{p}_{cj}$ for each date corrected for removed fish (R_j) was calculated:

$$\hat{p}_{c_j} = N_{jX_{11}} \Big/ (N_{jX_1} + (1 - R_j) \bullet \hat{N}_{jX_0}) \quad .$$

For each bootstrap iteration, regression analysis was used to fill in dates between March 26 and June 30 when PIT-tag data were insufficient to provide estimates of detection probability following methods described by Sanford and Smith (2002). Daily detection probability was regressed against spill percentage and the estimated intercept and slope values were used to generate missing detection probability estimates within a season. Typically, most missing dates were late in the year. This was done for all 1,000 iterations for each year. Average daily detection probabilities $\overline{p}_{c_i}$ and associated population variance estimates $V[p_{c_i}]$ were generated from the 1,000 daily estimated bootstrap detection probabilities for each date of each year.

Estimating Annual Populations at Lower Granite Dam

Annual Run-at-large and PIT-tag populations were estimated for each year using the estimated daily detection probabilities described above. The fish that were in the bypass were considered the catchable portion of the population, such that the SMP sample was a second phase sample. In effect, we estimated the bypassed or catchable portion of fish using the SMP sample and used the distinct PIT tag estimation process to determine what portion of the population was catchable following methods described by Seber (1973). To estimate the catchable portion of the population, often referred to as collection, the daily sample data from the SMP were used. Sample rates and sample counts were used to estimate daily collection, $\hat{N}_{c_i}$. The daily collection from the bypass was estimated as

$$\hat{N}_{c_i} = n_{s_i} / p_{byp\,i}$$

where n_{s_i} was the sample count of wild or unmarked yearling Chinook and p_{byp_i} was the nominal sample rate. The sample data were assumed to follow a binomial distribution, so that the variance in daily collection was calculated using the delta method (Seber 1973). The variance in the sample was calculated as

$$V\left[\hat{N}_{c_i}\right] = n_{s_i} \bullet (1 - p_{byp_i}) / p_{byp_i}.$$

The daily collection estimate was divided by the PIT tag detection probability to estimate the daily population using the formula $\hat{N}_{T_i} = \hat{N}_{c_i} / p_{ci}$. From Seber (1973) the variance for each daily population estimate was calculated

$$V\left[\hat{N}_{T_i}\right] = V\left[\hat{N}_{c_i}\right] / p_{ci}^{2} + (\hat{N}_{T_i}^{2} / p_{ci}^{2}) \bullet V\left[p_{c_i}\right].$$

Seasonal population estimates ($\hat{N}_{\bullet}$) were the sum of the daily estimated populations or $\sum \hat{N}_{T_i}$. Seasonal variances were calculated as the sum of the daily variances $\sum V\left[\hat{N}_{T_i}\right]$. Ninety-five percent confidence intervals for annual run-at-large estimates were calculated as $\hat{N}_{\bullet} \pm 1.96 \bullet \sqrt{\sum V\left[\hat{N}_{T_i}\right]}$. We assumed the covariance term was negligible and negative so that the resulting confidence intervals would not be altered greatly by including covariance and because it was not included, would be conservative.

Results

The annual run-at-large wild spring/summer Chinook population estimates at Lower Granite Dam are shown in Table 8-1. Estimates varied considerably from year to year, with a low $\hat{N}_{\bullet}$ estimate of 145,658 smolts in migration year 1997 and a high estimated population of 1,723,989 in 2005. The annual $\hat{N}_{\bullet}$ estimates of juvenile population size at Lower Granite Dam were very similar to those reported by Copeland et al. (2008; see Table 8.1). In seven of the 11 years compared, the Copeland et al. (2008) population estimate was contained within the 90% confidence intervals calculated for the $\hat{N}_{\bullet}$ estimates. The relative difference between the two methods was compared by taking the ratio of the Copeland et al. population estimates divided by the $\hat{N}_{\bullet}$ estimates and then taking a geometric mean of the differences. Overall, the difference averaged 4% with the geometric mean of 1.04 indicating that on average the Copeland method resulted in a slightly higher juvenile population estimate at Lower Granite Dam than the $\hat{N}_{\bullet}$ estimation method described in this Chapter. The largest differences between the two estimates were in the years 1996 and 1997 where the $\hat{N}_{\bullet}$ estimate was 20% and 11% higher (respectively). Removing those two years from the comparison resulted in a geometric mean difference of 2%.

Table 8-1 Annual smolt population of wild spring/summer Chinook estimated for Lower Granite Dam from 1994 to 2006. 90% confidence intervals are also shown.

Juvenile Migration Year	Copeland Population [1]	$\hat{N}_{\bullet}$ Annual Smolt Population	$\sqrt{\sum V\left[\hat{N}_{T_i}\right]}$	Lower 90% CI	Upper 90% CI
1994		646,712	25,059	621,653	671,771
1995		1,553,923	36,446	1,517,476	1,590,369
1996	419,826	350,458	18,250	332,208	368,708
1997	161,157	145,658	12,799	132,859	158,457
1998	599,159	578,181	17,677	560,504	595,859
1999	1,560,298	1,579,026	44,571	1,534,455	1,623,598
2000	1,344,382	1,277,779	48,794	1,228,985	1,326,573
2001	490,534	491,149	12,962	478,187	504,110
2002	1,128,539	1,094,672	50,033	1,044,639	1,144,704
2003	1,455,845	1,427,391	41,695	1,385,696	1,469,085
2004	1,517,956	1,489,620	34,721	1,454,900	1,524,341
2005	1,734,464	1,723,989	30,477	1,693,512	1,754,466
2006	1,225,679	1,164,097	40,647	1,123,450	1,204,744

1 Source: Copeland et al. 2008
2 1994-1998 populations do not include jacks

To determine what impact the 4% average difference in juvenile populations would have on a comparison of SAR's, adult count data from Copeland et al. (2008) and the juvenile population estimates ($\hat{N}_{\bullet}$) were used to derive SAR's and those were compared to SARs reported by Copeland et al. (2008; see Table 8-2). The results showed little difference in SARs for most years, with the geometric mean difference at 4%. By comparison the CSS SARs derived from PIT-tags (including jacks) showed a geometric mean difference of 35% (the geomean of the ratios of Copeland et al SARs divided by CSS PIT-tag SARs for the years 1996 to 2004 was 1.35).

Table 8-2 Comparison of SARs from Copeland et al. 2008, CSS PIT-tag SARs and SARs using Copeland adult counts and juvenile population estimates presented in Table 8-1 ($\hat{N}_{\bullet}$). Confidence intervals for SAR using $\hat{N}_{\bullet}$ are the 90% juvenile CI's from Table 8.1 divided by the Copeland adult population.

Juvenile Migr. Year	Brood Year	Copeland Adult Population [1]	SAR from Copeland [1] (90% CI)	SAR using Copeland Adult and $\hat{N}$ (90% CI) [2]	SAR from CSS PIT tags (90% CI)
1996[4]	1994	1,312	0.31 (0.30-0.33)	0.37 (0.36-0.39)	0.43 (0.06 – 0.85)
1997[4]	1995	2,823	1.75 (1.69-1.82)	1.94 (1.78-2.12)	1.78 (0.99 – 2.73)
1998[4]	1996	8,966	1.5 (1.47-1.53)	1.55 (1.50-1.60)	1.25 (0.84 – 1.70)
1999	1997	57,720	3.7 (3.67-3.73)	3.66 (3.56-3.76)	2.55 (2.03 – 3.09)
2000	1998	40,995	3.05 (3.02-3.08)	3.21 (3.09-3.34)	1.72 (1.25 – 2.20)
2001	1999	9,084	1.85 (1.81-1.89)	1.85 (1.80-1.90)	1.45 (0.70 – 2.32)
2002	2000	22,877	2.03 (2.00-2.05)	2.09 (2.00-2.19)	1.04 (0.83 – 1.24)
2003	2001	8,732	0.6 (0.59-0.61)	0.61 (0.59-0.63)	0.34 (0.26 – 0.42)
2004	2002	12,245	0.81 (0.79-0.82)	0.82 (0.80-0.84)	0.54 (0.44 – 0.64)
2005	2003	5,037	0.29 (0.28-0.30)	0.29 (0.29-0.30)	
2006	2004	1,462[3]	0.12 (0.11-0.13)	0.13 (0.12-0.13)	

1 Source: Copeland et al. (2008)
2 SAR Confidence intervals use 90% juvenile population divided into Copeland adult count.
3 Included only 1-ocean adult returns.
4 1994-1998 estimates do not include jacks.

Discussion and Conclusions

Overall, the estimates of juvenile population abundance we derived were similar to estimates reported by Copeland et al. (2008). Variance estimates showed that sample sizes were adequate to provide relatively precise estimates of juvenile population abundance. The levels of uncertainty in juvenile population abundances we derived were similar to the levels of uncertainty used in Copeland et al. (2008) to derive SARs. However, by incorporating the uncertainty in the collection sample, we derived SARs with confidence intervals that were in most cases wider than those reported by Copeland et al. (2008). We believe that incorporating both sources of error (i.e., error due to detection probability and error due to the collection sample) provides a better sense of overall uncertainty in the estimates of juvenile population abundance for use in run-at-large SARs.

Differences between run-reconstruction SARs and those reported by CSS were more notable. Run-reconstruction SARs were on average 35% higher than those derived from PIT-tags in the CSS. Four of nine Copeland et al. (2008) SARs reported in Table 8-2 and four of nine of the $\hat{N}_{\bullet}$ derived SARs fall within the confidence bounds of the CSS estimates. However, as mentioned in the introduction, it was these differences that led the ISAB to suggest that the CSS review and compare the differences between run-reconstruction and PIT-tag based SAR calculations.

The incorporation of juvenile population estimation uncertainty is just part of the analysis that we are undertaking. In the future, we will be investigating the adult component of run-reconstruction SARs to examine sources of uncertainty in those estimates. Incorporating adult estimation uncertainty is likely to dramatically increase the levels of uncertainty in the run-reconstruction SARs. We are aware that the run-reconstruction SARs are very sensitive to estimated adult numbers and we are also aware of some unresolved issues regarding adult counts as described in the introduction to this chapter, which we will explore in future reports.

At this point we have shown that some increased uncertainty in run-reconstruction SARs is due to uncertainty in juvenile population abundance. We anticipate that additional uncertainty will be incorporated into the SARs as we investigate adult count estimates. However, both CSS PIT-tag derived SARs and the run-reconstruction SARs were below the NPCC goal of achieving smolt-to-adult return rates in the 2-6 percent range (minimum 2 percent; average 4 percent) for listed Snake River and upper Columbia salmon and steelhead (NPCC 2009). Only two run-reconstruction SARs for wild spring/summer Chinook met the minimum threshold of 2% out of the 9 completed migration years reported by Copeland et al. (2008).

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Appendix A

Timing plots at Bonneville Dam of returning adult Chinook and steelhead

PIT-tag spring/summer Chinook adult returns (with jacks) at Bonneville Dam

The PIT-tagged adult run timing data of spring Chinook versus summer Chinook at Bonneville Dam for Chinook originating above Lower Granite Dam is characterized along with that of Chinook originating in the middle and upper Columbia River areas in a series of graphs in this appendix. For this analysis, FPC staff compiled all available detections at the Bonneville Dam fish ladders for hatchery and wild Chinook with spring and summer run designations. Wild Chinook PIT-tagged at the Clearwater River trap, which are denoted in PTAGIS as "unknown" run, were added to the Snake River wild spring Chinook group since tagging at that site only targets yearling spring Chinook and steelhead. Fish tagged at hatcheries and released at dams for research purposes were not used except in the case of hatchery summer Chinook in the upper Columbia River (discussed below). All PIT-tagged yearling Chinook released into the Imnaha River in the Snake River basin were considered as summer stock. Yearling Chinook PIT-tagged in the Imnaha River are considered summer Chinook when tagged by Nez Perce Tribe researchers, whereas they are considered spring Chinook when tagged by ODFW researchers. The CSS considers the Imnaha River Chinook as summer Chinook since the adult return timing matches closely that of McCall Hatchery summer stock and the higher jack rate of Imnaha hatchery Chinook is more like that of McCall Hatchery summer Chinook than any other CSS spring Chinook hatchery group (see page 21 of CSS 2002 Annual Report).

The Chinook return data are stratified into the following three geographic regions, (i) middle Columbia (Bonneville Dam to confluence with Snake River), (ii) Snake River, and (iii) upper Columbia (confluence with Snake to below Chief Joseph Dam). Table A-1 shows that in the middle Columbia River most returning adults of hatchery origin were from Carson NFH and of wild origin were from the John Day River. Sizeable PIT-tagging programs occurred at both those locations in the years covered in this analysis.

srrt	river	rel_site	2002	2003	2004	2005	2006	2007	2008	Grand Total
11H	Wind	CARS	305	334	167	39	82	54	83	1064
	Hood	HOODMF & HOODWF							41	41
	Klickitat	KLIH							3	3
	Warm Spr	WSPH & WARMSR			38	2	1		12	53
	Umatilla	IMQP & UMAR & TMFFBY	31	19	15	13	16	13	11	118
	WallaWalla	WALLAR & WALLSF						4	1	5
11H Total			336	353	220	54	99	71	151	1284
11W	Hood	HOODR					1			1
	John Day	JDAR1	110	113	103	125	59	50	34	594
	John Day	JDAR2	1				16	14	8	39
	John Day	JDARMF		3			11	16	19	49
	John Day	JDARNF & JDARSF	8	10	3		3	1	4	29
	Umatilla	IMQP & UMAR & TMFFBY	1	4	5	4				14
	WallaWalla	WALLAR			6	6	5			17
11W Total			120	130	117	135	95	81	65	743
Middle Columbia Basin Total			456	483	337	189	194	152	216	2027

Table A-1 Number PIT-tagged hatchery and wild spring Chinook adults (with jacks) detected at Bonneville Dam ladders by return year for fish release sites in middle Columbia River drainage.

Table A-2 shows that in the upper Columbia River most returning spring Chinook adults of hatchery origin were from Leavenworth NFH or Cle Elm Hatchery's releases at Clark Flat, Easton, and Jack Creek acclimation ponds and of wild origin were from the Yakima River. Sizeable PIT-tagging programs occurred at both those locations in the years covered in this analysis. For summer Chinook, the large scale releases of PIT-tagged Wells Hatchery summer Chinook yearlings in the forebays and tailraces of Priest Rapids, Wannapum, Rock Island, Rocky Reach, and Wells dams between 2000 and 2008 provided ample numbers of returning adults (with jacks) in each of return years 2002 to 2008 for determining run timing for upper Columbia River summer Chinook (Table 2). Without these fish, the total available adults (with jacks) across all seven return years would have been only 29 fish from Wells Hatchery on-site PIT-tag releases and 23 fish from its Okanogan River releases.

srrt	river	rel_site	2002	2003	2004	2005	2006	2007	2008	Grand Total
11H	Yakima	YAKIMR & YAKIM1	128	5	2	2		6	16	159
	Yakima	CHANDL	19	3				3	6	31
	Yakima	CLARFP	211	39	55	25	48	26	82	486
	Yakima	EASTOP	163	41	51	25	30	21	56	387
	Yakima	JACKCP	105	35	86	48	48	31	49	402
	Yakima	ROSAD	28	2	1	6	4	6	11	58
	Wenatchee	LEAV	44	73	650	601	395	68	74	1905
	Wenatchee	CHIP							20	20
	Entiat	ENTH		5	128	134	136	21	6	430
	Methow	METH			46	60	6			112
	Methow	CHEWUP			7	16	33	1		57
	Methow	TWISPP & TWISPR				44	62	2	4	112
	Methow	WINT	38	24	82	11	17	6	9	187
11H Total			736	227	1108	972	779	191	333	4346
11W	Yakima	YAKIMR & YAKIM1	93	93	49	66	50	21	26	398
	Yakima	ROSAD	66	13	56	52	47	11	9	254
	Yakima	CHANDL	22	43	12	15	39	18	9	158
	Wenatchee	WENATT & PESHAR					1	1	9	11
	Wenatchee	CHIWAT & CHIWAR				5	2	2	14	23
	Entiat	ENTIAR				2	4	7	8	21
	Methow	METHR & METTRP & TWISPR						2	3	5
11W Total			181	149	117	140	143	62	78	870
12H	Mainstem	COLR & COLR7	95	235	391	103	6			830
	Mainstem	PRDTAL			38	174	291	303	73	879
	Mainstem	WAN & WANTAL			38	173	326	255	32	824
	Mainstem	RIS & RI2BYP & RISTAL	379	687	545	570	771	365	145	3462
	Mainstem	RRE & RRETAL	335	729	443	394	491	129	23	2544
	Mainstem	WELTAL				18	43	71	21	153

Table A-2 Number PIT-tagged hatchery and wild spring Chinook adults (with jacks) and hatchery Wells stock summer Chinook adults (with jacks) detected at Bonneville Dam ladders by return year for fish release sites in upper Columbia River drainage.

Table A-3 shows that in the Snake River most returning spring Chinook adults of hatchery origin were from Rapid River and Dworshak hatcheries. Sizeable PIT-tagging programs occurred at both those locations in the years covered in this analysis due to tagging specifically for the CSS plus additional research programs in some years. The spring Chinook wild stocks are mostly spread across numerous tributaries within the Clearwater, Grande Ronde, and Salmon River drainages.

srrt	river	rel_site	2002	2003	2004	2005	2006	2007	2008	Grand Total
11H	Tucannon	CURP			1	1			5	7
	Clearwater	DWORNF & DWORMS & (*note)	289	413	282	100	163	192	477	1916
	Clearwater	KOOS & CLEARC	11	3	6	1	2	2	7	32
	Clearwater	LOLOC	1	4	4					9
	Clearwater	PAPOOC & PETEKC & SQUAWC			2	1				3
	Clearwater	POWP	5	2	2			15	97	121
	Clearwater	MEADOC & NEWSOC		1	10	1	3	2	5	22
	Clearwater	CROOKR & CROOKP		1	1			11	94	107
	Clearwater	REDP & REDR		2		1		6	95	104
	Grande Ronde	GRNTRP & GRANDR	11	4	9	3	1	4	10	42
	Grande Ronde	LOOKGC & LOOH	6	5	1	1	6		5	24
	Grande Ronde	LOSTIP	52	58	98	42	16	27	42	335
	Grande Ronde	CATHEP	12	34	57	27	24	29	85	268
	Grande Ronde	GRANDP	2		3	4		2	8	19
	Salmon	RAPH	520	770	1147	456	124	180	527	3724
	Salmon	YANKFK						1	2	3
	Salmon	SAWTRP & SAWT	5	1	2				41	49
11H Total			914	1298	1625	638	339	471	1500	6785
11W	Tucannon	TUCR			1	2			2	5
	Clearwater	CLWTRP & CLWR			5	2	2	3	2	14
	Clearwater	LOLOC	4	6		1	3	2	10	26
	Clearwater	CLEARC	2	3	2		1			8
	Clearwater	CFCTRP	3	4	1	1	1	3	6	19
	Clearwater	COLTKC & WHITSC	1	1	3		1		1	7
	Clearwater	PAPOOC & SQUAWC & FISTRP		1	1	1		1	4	8
	Clearwater	MEADOC	5	3	7	1	2	3	34	55
	Clearwater	NEWSOC	2	6	1	1		1	5	16
	Clearwater	CROTRP & AMERR		4	2	1	1	3		11
	Clearwater	REDTRP	3	7	2		2		4	18
	Grande Ronde	GRNTRP & GRANDR	19	23	13	7	12	11	36	121
	Grande Ronde	MINAMR	1	6	5	2	2	2	4	22
	Grande Ronde	LOOKGC		1	11	4		1	1	18
	Grande Ronde	LOSTIR	14	15	10	4	5	5	9	62
	Grande Ronde	CATHEC	3	7	4	2	3	2	6	27
	Grande Ronde	GRAND2	3	5		4	6	2	6	26
	Salmon	CHAMWF & RPDTRP			1			2		3
	Salmon	BIG2C	1	3	3	2			1	10
	Salmon	CAMASC & LOONC & SULFUC	6	4					2	12
	Salmon	MARTRP & MARSHC	7	12	9	3		1	1	33
	Salmon	ELKC & CAPEHC & BEARVC	1	7	2	2				12
	Salmon	LEMHIW & LEMHIR	8	11	7	2	3	3	6	40
	Salmon	SALEFT & SALREF & HERDC	2	2					4	8
	Salmon	YANKWF & VALEYC	1	7	1	1		1	2	13
	Salmon	SAWTRP	5	9	13	9	10	10	21	77
11W Total			91	147	104	52	54	56	167	671
Snake River Basin Spring Chinook Total			1005	1445	1729	690	393	527	1667	7456
*note -- Dworshak NFH on-site releases include rel_site DWOR and CLWR in addition to DWORNF and DWORMS										

Table A-3 Number PIT-tagged hatchery and wild spring Chinook adults (with jacks) detected at Bonneville Dam ladders by return year for fish release sites in Snake River drainage.

Table A-4 shows that in the Snake River most returning summer Chinook adults of hatchery origin were from Imnaha and McCall hatcheries. Sizeable PIT-tagging programs occurred at both those locations in the years covered in this analysis due to tagging specifically for the CSS plus additional research programs using fish from McCall Hatchery in some years. The Snake River summer Chinook wild stock adults were mostly from the Imnaha River Trap located 6 km above the Imnaha River mouth, and from several locations in the South Fork Salmon River, plus a few also from Pahsimeroi River in the upper portion of the Salmon River drainage.

srrt	river	rel_site	2002	2003	2004	2005	2006	2007	2008	Grand Total
12H	Imnaha	IMNAHW	359	205	181	102	58	86	212	1203
	Imnaha	IMNTRP & IMNAHR	46	24	10	1				81
	SF Salmon	JOHNSC	17	16	17	15	7	28	53	153
	SF Salmon	KNOXB	760	634	579	292	187	299	555	3306
	SF Salmon	SALRSF & SFSTRP & STOLP		2			1			3
	Pahsimeroi	PAHP	7		3	1	1			12
12H Total			1189	881	790	411	254	413	820	4758
12W	Imnaha	IMNAHR & IMNAHW	21	23	4	2			3	53
	Imnaha	IMNTRP	82	81	47	28	38	26	25	327
	SF Salmon	JOHTRP & JOHNSC	27	41	31	6	8	11	39	163
	SF Salmon	LSFTRP & SALRSF	14	33	4					51
	SF Salmon	SECESR & SECTRP & LAKEC	21	33	13	3	2	4	15	91
	SF Salmon	SFSTRP & KNOXB	10	24	2	2	4	3	7	52
	Pahsimeroi	PAHTRP	6	3	1		4	3	5	22
12W Total			181	238	102	41	56	47	94	759
Snake River Basin Summer Chinook Total			1370	1119	892	452	310	460	914	5517

Table A-4 Number PIT-tagged hatchery and wild summer Chinook adults (with jacks) detected at Bonneville Dam ladders by return year for fish release sites in Snake River drainage.

The counting of returning Chinook adults and jacks as spring run ends at Bonneville Dam on May 31, and it switches to summer run on the following day. The seven-year average cumulative proportion for return years 2002 to 2008 at Bonneville Dam through May 31 was between 94% and 98% for middle Columbia River, Snake River, and upper Columbia River PIT-tagged hatchery spring Chinook (Table A-5). For middle and upper Columbia PIT-tagged wild spring Chinook it was near 93%, while Snake River PIT-tagged wild spring Chinook dropped to approximately 86%. The PIT-tagged Wells Hatchery summer Chinook averaged only 2% detections at Bonneville Dam before the start of counting of run-at-large Chinook as summer run. The Snake River PIT-tagged summer Chinook had a seven-year average cumulative proportion detected through May 31 of approximately 37% for hatchery fish and 49% for wild fish. Therefore, a large proportion of the returning PIT-tagged summer Chinook adults and jacks from the Snake River basin are passing the Bonneville Dam adult counting windows before the official start of the summer run counting season. The full distribution of the cumulative proportion of PIT-tagged wild and hatchery spring and summer Chinook adults (with jacks) detected at Bonneville Dam are graphed for each return year separately in Figures A-1 to A-7.

	MC-1H	MC-1W	SN-1H	SN-1W	SN-2H	SN-2W	UC-1H	UC-1W	UC-2H
5/31/02	1.000	0.933	0.963	0.846	0.293	0.486	0.977	0.950	0.004
5/31/03	0.997	0.969	0.979	0.939	0.462	0.559	0.960	0.993	0.013
5/31/04	0.995	0.983	0.971	0.846	0.601	0.696	0.988	0.957	0.024
5/31/05	1.000	0.956	0.964	0.808	0.436	0.561	0.989	0.943	0.061
5/31/06	1.000	0.895	0.962	0.889	0.185	0.357	0.985	0.930	0.004
5/31/07	1.000	0.889	0.945	0.875	0.278	0.447	0.890	0.919	0.025
5/31/08	0.834	0.862	0.956	0.808	0.307	0.351	0.835	0.782	0.010
Avg.	**0.975**	**0.927**	**0.963**	**0.859**	**0.366**	**0.494**	**0.946**	**0.925**	**0.020**

Table A-5 Cumulative proportion of PIT-tagged wild and hatchery spring and summer Chinook detected at Bonneville Dam by May 31 of 2002 through 2008, which is the last day of designating returning adults and jacks as spring Chinook at the Bonneville Dam fishway counting window.

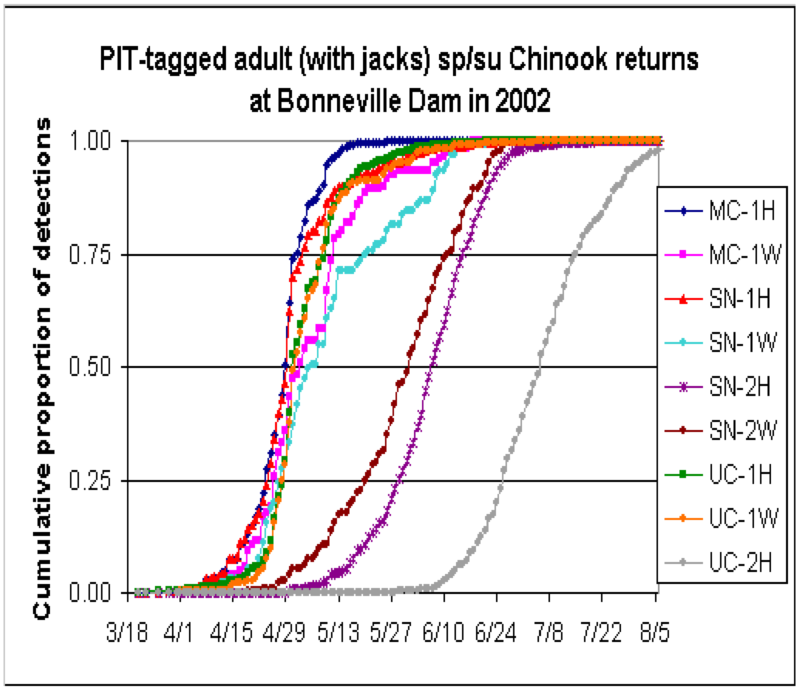

Figure A-1 Return year 2002 timing at Bonneville Dam of hatchery and wild spring and summer Chinook adults (with jacks) from Snake and Columbia rivers. (Legend: MC is middle Columbia from Bonneville Dam to confluence of Snake River, SN is Snake River, and UC is upper Columbia from confluence with Snake River to Chief Joseph Dam; 1 is spring run and 2 is summer run; H is hatchery fish and W is wild fish.)

Table on next page shows the breakdown by river of origin and release site for the PIT-tagged returning adults (including jacks) that compose each cumulative curve in above figure.

basin	srrt	river	rel_site	2002
MC	11H	Wind	CARS	305
		Umatilla	IMQP & UMAR & TMFFBY	31
	11H Total			336
	11W	John Day	JDAR1	110
		John Day	JDAR2	1
		John Day	JDARNF & JDARSF	8
		Umatilla	IMQP & UMAR & TMFFBY	1
	11W Total			120
SN	11H	Clearwater	DWORNF & DWORMS	289
		Clearwater	KOOS & CLEARC	11
		Clearwater	LOLOC	1
		Clearwater	POWP	5
		Grande Ronde	GRNTRP & GRANDR	11
		Grande Ronde	LOOKGC & LOOH	6
		Grande Ronde	LOSTIP	52
		Grande Ronde	CATHEP	12
		Grande Ronde	GRANDP	2
		Salmon	RAPH	520
		Salmon	SAWTRP & SAWT	5
	11H Total			914
	11W	Clearwater	LOLOC	4
		Clearwater	CLEARC	2
		Clearwater	CFCTRP	3
		Clearwater	COLTKC & WHITSC	1
		Clearwater	MEADOC	5
		Clearwater	NEWSOC	2
		Clearwater	REDTRP	3
		Grande Ronde	GRNTRP & GRANDR	19
		Grande Ronde	MINAMR	1
		Grande Ronde	LOSTIR	14
		Grande Ronde	CATHEC	3
		Grande Ronde	GRAND2	3
		Salmon	BIG2C	1
		Salmon	CAMASC & LOONC & SULFUC	6
		Salmon	MARTRP & MARSHC	7
		Salmon	ELKC & CAPEHC & BEARVC	1
		Salmon	LEMHIW & LEMHIR	8
		Salmon	SALEFT & SALREF & HERDC	2
		Salmon	YANKWF & VALEYC	1
		Salmon	SAWTRP	5
	11W Total			91
	12H	Imnaha	IMNAHW	359
		Imnaha	IMNTRP & IMNAHR	46
		SF Salmon	JOHNSC	17
		SF Salmon	KNOXB	760
		Pahsimeroi	PAHP	7
	12H Total			1189
	12W	Imnaha	IMNAHR & IMNAHW	21
		Imnaha	IMNTRP	82
		SF Salmon	JOHTRP & JOHNSC	27
		SF Salmon	LSFTRP & SALRSF	14
		SF Salmon	SECESR & SECTRP & LAKEC	21
		SF Salmon	SFSTRP & KNOXB	10
		Pahsimeroi	PAHTRP	6
	12W Total			181
UC	11H	Yakima	YAKIMR & YAKIM1	128
		Yakima	CHANDL	19
		Yakima	CLARFP	211
		Yakima	EASTOP	163
		Yakima	JACKCP	105
		Yakima	ROSAD	28
		Wenatchee	LEAV	44
		Methow	WINT	38
	11H Total			736
	11W	Yakima	YAKIMR & YAKIM1	93
		Yakima	ROSAD	66
		Yakima	CHANDL	22
	11W Total			181
	12H	Mainstem	COLR & COLR7	95
		Mainstem	RIS & RI2BYP & RISTAL	379
		Mainstem	RRE & RRETAL	335
		Okanogan	OKANR	7
	12H Total			816

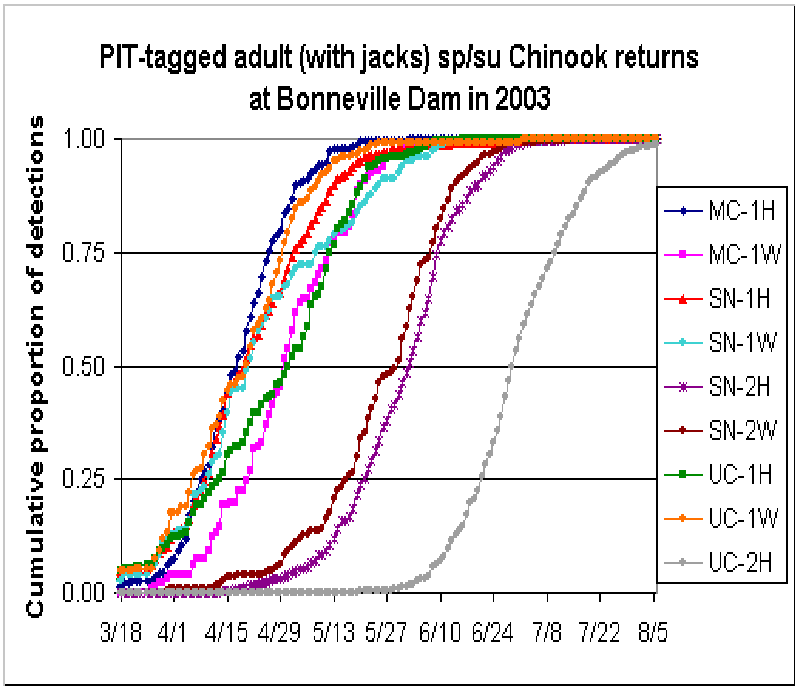

Figure A-2 Return year 2003 timing at Bonneville Dam of hatchery and wild spring and summer Chinook adults (with jacks) from Snake and Columbia rivers. (Legend: MC is middle Columbia from Bonneville Dam to confluence of Snake River, SN is Snake River, and UC is upper Columbia from confluence with Snake River to Chief Joseph Dam; 1 is spring run and 2 is summer run; H is hatchery fish and W is wild fish.)

Table on next page shows the breakdown by river of origin and release site for the PIT-tagged returning adults (including jacks) that compose each cumulative curve in above figure.

basin	srrt	river	rel_site	2003
MC	11H	Wind	CARS	334
		Umatilla	IMQP & UMAR & TMFFBY	19
	11H Total			353
	11W	John Day	JDAR1	113
		John Day	JDARMF	3
		John Day	JDARNF & JDARSF	10
		Umatilla	IMQP & UMAR & TMFFBY	4
	11W Total			130
SN	11H	Clearwater	DWORNF & DWORMS & CLWR	413
		Clearwater	KOOS & CLEARC	3
		Clearwater	LOLOC	4
		Clearwater	POWP	2
		Clearwater	MEADOC & NEWSOC	1
		Clearwater	CROOKR & CROOKP	1
		Clearwater	REDP & REDR	2
		Grande Ronde	GRNTRP & GRANDR	4
		Grande Ronde	LOOKGC & LOOH	5
		Grande Ronde	LOSTIP	58
		Grande Ronde	CATHEP	34
		Salmon	RAPH	770
		Salmon	SAWTRP & SAWT	1
	11H Total			1298
	11W	Clearwater	LOLOC	6
		Clearwater	CLEARC	3
		Clearwater	CFCTRP	4
		Clearwater	COLTKC & WHITSC	1
		Clearwater	PAPOOC & SQUAWC & FISTRP	1
		Clearwater	MEADOC	3
		Clearwater	NEWSOC	6
		Clearwater	CROTRP & AMERR	4
		Clearwater	REDTRP	7
		Grande Ronde	GRNTRP & GRANDR	23
		Grande Ronde	MINAMR	6
		Grande Ronde	LOOKGC	1
		Grande Ronde	LOSTIR	15
		Grande Ronde	CATHEC	7
		Grande Ronde	GRAND2	5
		Salmon	BIG2C	3
		Salmon	CAMASC & LOONC & SULFUC	4
		Salmon	MARTRP & MARSHC	12
		Salmon	ELKC & CAPEHC & BEARVC	7
		Salmon	LEMHIW & LEMHIR	11
		Salmon	SALEFT & SALREF & HERDC	2
		Salmon	YANKWF & VALEYC	7
		Salmon	SAWTRP	9
	11W Total			147
	12H	Imnaha	IMNAHW	205
		Imnaha	IMNTRP & IMNAHR	24
		SF Salmon	JOHNSC	16
		SF Salmon	KNOXB	634
		SF Salmon	SALRSF & SFSTRP & STOLP	2
	12H Total			881
	12W	Imnaha	IMNAHR & IMNAHW	23
		Imnaha	IMNTRP	81
		SF Salmon	JOHTRP & JOHNSC	41
		SF Salmon	LSFTRP & SALRSF	33
		SF Salmon	SECESR & SECTRP & LAKEC	33
		SF Salmon	SFSTRP & KNOXB	24
		Pahsimeroi	PAHTRP	3
	12W Total			238
UC	11H	Yakima	YAKIMR & YAKIM1	5
		Yakima	CHANDL	3
		Yakima	CLARFP	39
		Yakima	EASTOP	41
		Yakima	JACKCP	35
		Yakima	ROSAD	2
		Wenatchee	LEAV	73
		Entiat	ENTH	5
		Methow	WINT	24
	11H Total			227
	11W	Yakima	YAKIMR & YAKIM1	93
		Yakima	ROSAD	13
		Yakima	CHANDL	43
	11W Total			149
	12H	Mainstem	COLR & COLR7	235
		Mainstem	RIS & RI2BYP & RISTAL	687
		Mainstem	RRE & RRETAL	729
		Mainstem	WELH	3
		Okanogan	OKANR	15
	12H Total			1669

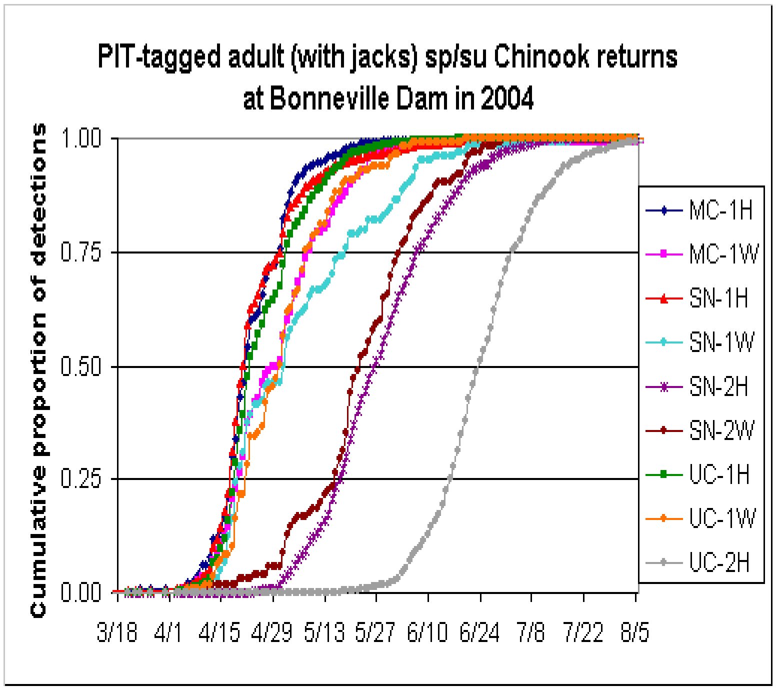

Figure A-3 Return year 2004 timing at Bonneville Dam of hatchery and wild spring and summer Chinook adults (with jacks) from Snake and Columbia rivers. (Legend: MC is middle Columbia from Bonneville Dam to confluence of Snake River, SN is Snake River, and UC is upper Columbia from confluence with Snake River to Chief Joseph Dam; 1 is spring run and 2 is summer run; H is hatchery fish and W is wild fish.)

Table on next page shows the breakdown by river of origin and release site for the PIT-tagged returning adults (including jacks) that compose each cumulative curve in above figure.

basin	srrt	river	rel_site	2004
MC	11H	Wind	CARS	167
		Warm Spr	WSPH & WARMSR	38
		Umatilla	IMQP & UMAR & TMFFBY	15
	11H Total			220
	11W	John Day	JDAR1	103
		John Day	JDARNF & JDARSF	3
		Umatilla	IMQP & UMAR & TMFFBY	5
		WallaWalla	WALLAR	6
	11W Total			117
SN	11H	Tucannon	CURP	1
		Clearwater	DWORNF & DWORMS	282
		Clearwater	KOOS & CLEARC	6
		Clearwater	LOLOC	4
		Clearwater	PAPOOC & PETEKC & SQUAWC	2
		Clearwater	POWP	2
		Clearwater	MEADOC & NEWSOC	10
		Clearwater	CROOKR & CROOKP	1
		Grande Ronde	GRNTRP & GRANDR	9
		Grande Ronde	LOOKGC & LOOH	1
		Grande Ronde	LOSTIP	98
		Grande Ronde	CATHEP	57
		Grande Ronde	GRANDP	3
		Salmon	RAPH	1147
		Salmon	SAWTRP & SAWT	2
	11H Total			1625
	11W	Tucannon	TUCR	1
		Clearwater	CLWTRP & CLWR	5
		Clearwater	CLEARC	2
		Clearwater	CFCTRP	1
		Clearwater	COLTKC & WHITSC	3
		Clearwater	PAPOOC & SQUAWC & FISTRP	1
		Clearwater	MEADOC	7
		Clearwater	NEWSOC	1
		Clearwater	CROTRP & AMERR	2
		Clearwater	REDTRP	2
		Grande Ronde	GRNTRP & GRANDR	13
		Grande Ronde	MINAMR	5
		Grande Ronde	LOOKGC	11
		Grande Ronde	LOSTIR	10
		Grande Ronde	CATHEC	4
		Salmon	CHAMWF & RPDTRP	1
		Salmon	BIG2C	3
		Salmon	MARTRP & MARSHC	9
		Salmon	ELKC & CAPEHC & BEARVC	2
		Salmon	LEMHIW & LEMHIR	7
		Salmon	YANKWF & VALEYC	1
		Salmon	SAWTRP	13
	11W Total			104
	12H	Imnaha	IMNAHW	181
		Imnaha	IMNTRP & IMNAHR	10
		SF Salmon	JOHNSC	17
		SF Salmon	KNOXB	579
		Pahsimeroi	PAHP	3
	12H Total			790
	12W	Imnaha	IMNAHR & IMNAHW	4
		Imnaha	IMNTRP	47
		SF Salmon	JOHTRP & JOHNSC	31
		SF Salmon	LSFTRP & SALRSF	4
		SF Salmon	SECESR & SECTRP & LAKEC	13
		SF Salmon	SFSTRP & KNOXB	2
		Pahsimeroi	PAHTRP	1
	12W Total			102
UC	11H	Yakima	YAKIMR & YAKIM1	2
		Yakima	CLARFP	55
		Yakima	EASTOP	51
		Yakima	JACKCP	86
		Yakima	ROSAD	1
		Wenatchee	LEAV	650
		Entiat	ENTH	128
		Methow	METH	46
		Methow	CHEWUP	7
		Methow	WINT	82
	11H Total			1108
	11W	Yakima	YAKIMR & YAKIM1	49
		Yakima	ROSAD	56
		Yakima	CHANDL	12
	11W Total			117
	12H	Mainstem	COLR & COLR7	391
		Mainstem	PRDTAL	38
		Mainstem	WAN & WANTAL	38
		Mainstem	RIS & RI2BYP & RISTAL	545
		Mainstem	RRE & RRETAL	443
		Mainstem	WELH	7
		Okanogan	OKANR	1
	12H Total			1463

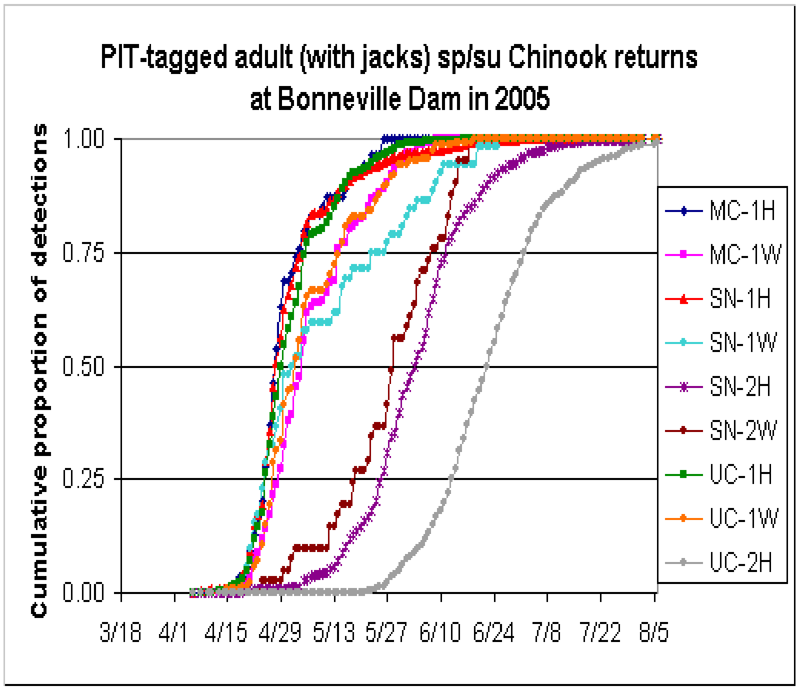

Figure A-4 Return year 2005 timing at Bonneville Dam of hatchery and wild spring and summer Chinook adults (with jacks) from Snake and Columbia rivers. (Legend: MC is middle Columbia from Bonneville Dam to confluence of Snake River, SN is Snake River, and UC is upper Columbia from confluence with Snake River to Chief Joseph Dam; 1 is spring run and 2 is summer run; H is hatchery fish and W is wild fish.)

Table on next page shows the breakdown by river of origin and release site for the PIT-tagged returning adults (including jacks) that compose each cumulative curve in above figure.

basin	srrt	river	rel_site	2005
MC	11H	Wind	CARS	39
		Warm Spr	WSPH & WARMSR	2
		Umatilla	IMQP & UMAR & TMFFBY	13
	11H Total			54
	11W	John Day	JDAR1	125
		Umatilla	IMQP & UMAR & TMFFBY	4
		WallaWalla	WALLAR	6
	11W Total			135
SN	11H	Tucannon	CURP	1
		Clearwater	DWORNF & DWOR	100
		Clearwater	KOOS & CLEARC	1
		Clearwater	PAPOOC & PETEKC & SQUAWC	1
		Clearwater	MEADOC & NEWSOC	1
		Clearwater	REDP & REDR	1
		Grande Ronde	GRNTRP & GRANDR	3
		Grande Ronde	LOOKGC & LOOH	1
		Grande Ronde	LOSTIP	42
		Grande Ronde	CATHEP	27
		Grande Ronde	GRANDP	4
		Salmon	RAPH	456
	11H Total			638
	11W	Tucannon	TUCR	2
		Clearwater	CLWTRP & CLWR	2
		Clearwater	LOLOC	1
		Clearwater	CFCTRP	1
		Clearwater	PAPOOC & SQUAWC & FISTRP	1
		Clearwater	MEADOC	1
		Clearwater	NEWSOC	1
		Clearwater	CROTRP & AMERR	1
		Grande Ronde	GRNTRP & GRANDR	7
		Grande Ronde	MINAMR	2
		Grande Ronde	LOOKGC	4
		Grande Ronde	LOSTIR	4
		Grande Ronde	CATHEC	2
		Grande Ronde	GRAND2	4
		Salmon	BIG2C	2
		Salmon	MARTRP & MARSHC	3
		Salmon	ELKC & CAPEHC & BEARVC	2
		Salmon	LEMHIW & LEMHIR	2
		Salmon	YANKWF & VALEYC	1
		Salmon	SAWTRP	9
	11W Total			52
	12H	Imnaha	IMNAHW	102
		Imnaha	IMNTRP & IMNAHR	1
		SF Salmon	JOHNSC	15
		SF Salmon	KNOXB	292
		Pahsimeroi	PAHP	1
	12H Total			411
	12W	Imnaha	IMNAHR & IMNAHW	2
		Imnaha	IMNTRP	28
		SF Salmon	JOHTRP & JOHNSC	6
		SF Salmon	SECESR & SECTRP & LAKEC	3
		SF Salmon	SFSTRP & KNOXB	2
	12W Total			41
UC	11H	Yakima	YAKIMR & YAKIM1	2
		Yakima	CLARFP	25
		Yakima	EASTOP	25
		Yakima	JACKCP	48
		Yakima	ROSAD	6
		Wenatchee	LEAV	601
		Entiat	ENTH	134
		Methow	METH	60
		Methow	CHEWUP	16
		Methow	TWISPP & TWISPR	44
		Methow	WINT	11
	11H Total			972
	11W	Yakima	YAKIMR & YAKIM1	66
		Yakima	ROSAD	52
		Yakima	CHANDL	15
		Wenatchee	CHIWAT & CHIWAR	5
		Entiat	ENTIAR	2
	11W Total			140
	12H	Mainstem	COLR & COLR7	103
		Mainstem	PRDTAL	174
		Mainstem	WAN & WANTAL	173
		Mainstem	RIS & RI2BYP & RISTAL	570
		Mainstem	RRE & RRETAL	394
		Mainstem	WELTAL	18
		Mainstem	WELH	6
	12H Total			1438

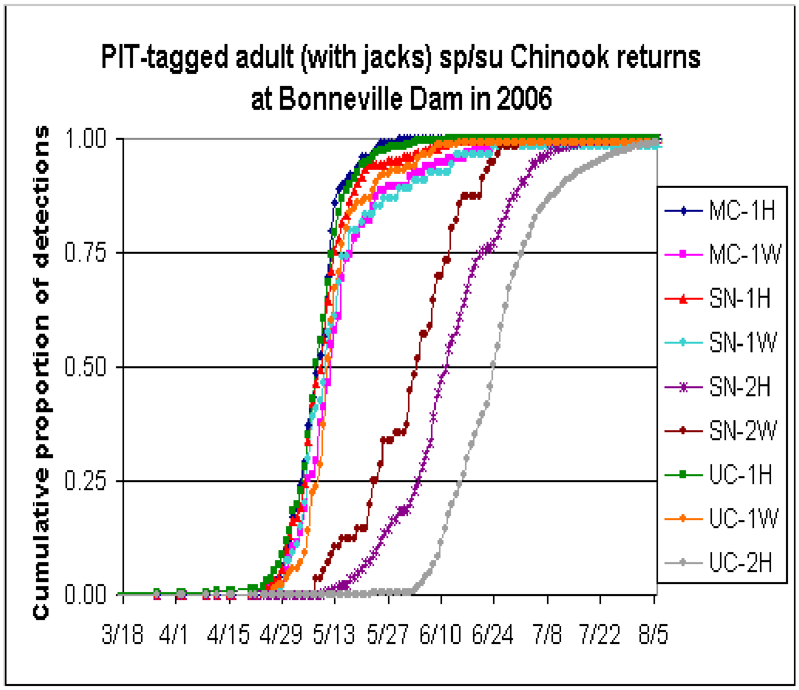

Figure A-5 Return year 2006 timing at Bonneville Dam of hatchery and wild spring and summer Chinook adults (with jacks) from Snake and Columbia rivers. (Legend: MC is middle Columbia from Bonneville Dam to confluence of Snake River, SN is Snake River, and UC is upper Columbia from confluence with Snake River to Chief Joseph Dam; 1 is spring run and 2 is summer run; H is hatchery fish and W is wild fish.)

Table on next page shows the breakdown by river of origin and release site for the PIT-tagged returning adults (including jacks) that compose each cumulative curve in above figure.

basin	srrt	river	rel_site	2006
MC	11H	Wind	CARS	82
		Warm Spr	WSPH & WARMSR	1
		Umatilla	IMQP & UMAR & TMFFBY	16
	11H Total			99
	11W	Hood	HOODR	1
		John Day	JDAR1	59
		John Day	JDAR2	16
		John Day	JDARMF	11
		John Day	JDARNF & JDARSF	3
		WallaWalla	WALLAR	5
	11W Total			95
SN	11H	Clearwater	DWORNF & DWOR	163
		Clearwater	KOOS & CLEARC	2
		Clearwater	MEADOC & NEWSOC	3
		Grande Ronde	GRNTRP & GRANDR	1
		Grande Ronde	LOOKGC & LOOH	6
		Grande Ronde	LOSTIP	16
		Grande Ronde	CATHEP	24
		Salmon	RAPH	124
	11H Total			339
	11W	Clearwater	CLWTRP & CLWR	2
		Clearwater	LOLOC	3
		Clearwater	CLEARC	1
		Clearwater	CFCTRP	1
		Clearwater	COLTKC & WHITSC	1
		Clearwater	MEADOC	2
		Clearwater	CROTRP & AMERR	1
		Clearwater	REDTRP	2
		Grande Ronde	GRNTRP & GRANDR	12
		Grande Ronde	MINAMR	2
		Grande Ronde	LOSTIR	5
		Grande Ronde	CATHEC	3
		Grande Ronde	GRAND2	6
		Salmon	LEMHIW & LEMHIR	3
		Salmon	SAWTRP	10
	11W Total			54
	12H	Imnaha	IMNAHW	58
		SF Salmon	JOHNSC	7
		SF Salmon	KNOXB	187
		SF Salmon	SALRSF & SFSTRP & STOLP	1
		Pahsimeroi	PAHP	1
	12H Total			254
	12W	Imnaha	IMNTRP	38
		SF Salmon	JOHTRP & JOHNSC	8
		SF Salmon	SECESR & SECTRP & LAKEC	2
		SF Salmon	SFSTRP & KNOXB	4
		Pahsimeroi	PAHTRP	4
	12W Total			56
UC	11H	Yakima	CLARFP	48
		Yakima	EASTOP	30
		Yakima	JACKCP	48
		Yakima	ROSAD	4
		Wenatchee	LEAV	395
		Entiat	ENTH	136
		Methow	METH	6
		Methow	CHEWUP	33
		Methow	TWISPP & TWISPR	62
		Methow	WINT	17
	11H Total			779
	11W	Yakima	YAKIMR & YAKIM1	50
		Yakima	ROSAD	47
		Yakima	CHANDL	39
		Wenatchee	WENATT & PESHAR	1
		Wenatchee	CHIWAT & CHIWAR	2
		Entiat	ENTIAR	4
	11W Total			143
	12H	Mainstem	COLR & COLR7	6
		Mainstem	PRDTAL	291
		Mainstem	WAN & WANTAL	326
		Mainstem	RIS & RI2BYP & RISTAL	771
		Mainstem	RRE & RRETAL	491
		Mainstem	WELTAL	43
		Mainstem	WELH	2
	12H Total			1930

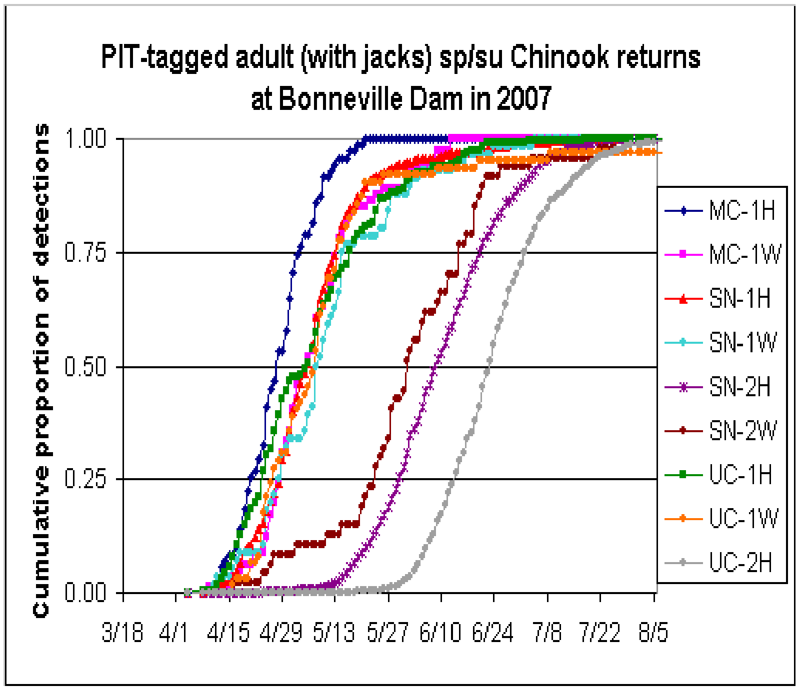

Figure A-6 Return year 2007 timing at Bonneville Dam of hatchery and wild spring and summer Chinook adults (with jacks) from Snake and Columbia rivers. (Legend: MC is middle Columbia from Bonneville Dam to confluence of Snake River, SN is Snake River, and UC is upper Columbia from confluence with Snake River to Chief Joseph Dam; 1 is spring run and 2 is summer run; H is hatchery fish and W is wild fish.)

Table on next page shows the breakdown by river of origin and release site for the PIT-tagged returning adults (including jacks) that compose each cumulative curve in above figure.

basin	srrt	river	rel_site	2007
MC	11H	Wind	CARS	54
		Umatilla	IMQP & UMAR & TMFFBY	13
		WallaWalla	WALLAR & WALLSF	4
	11H Total			71
	11W	John Day	JDAR1	50
		John Day	JDAR2	14
		John Day	JDARMF	16
		John Day	JDARNF & JDARSF	1
	11W Total			81
SN	11H	Clearwater	DWORNF & DWOR	192
		Clearwater	KOOS & CLEARC	2
		Clearwater	POWP	15
		Clearwater	MEADOC & NEWSOC	2
		Clearwater	CROOKR & CROOKP	11
		Clearwater	REDP & REDR	6
		Grande Ronde	GRNTRP & GRANDR	4
		Grande Ronde	LOSTIP	27
		Grande Ronde	CATHEP	29
		Grande Ronde	GRANDP	2
		Salmon	RAPH	180
		Salmon	YANKFK	1
	11H Total			471
	11W	Clearwater	CLWTRP & CLWR	3
		Clearwater	LOLOC	2
		Clearwater	CFCTRP	3
		Clearwater	PAPOOC & SQUAWC & FISTRP	1
		Clearwater	MEADOC	3
		Clearwater	NEWSOC	1
		Clearwater	CROTRP & AMERR	3
		Grande Ronde	GRNTRP & GRANDR	11
		Grande Ronde	MINAMR	2
		Grande Ronde	LOOKGC	1
		Grande Ronde	LOSTIR	5
		Grande Ronde	CATHEC	2
		Grande Ronde	GRAND2	2
		Salmon	CHAMWF & RPDTRP	2
		Salmon	MARTRP & MARSHC	1
		Salmon	LEMHIW & LEMHIR	3
		Salmon	YANKWF & VALEYC	1
		Salmon	SAWTRP	10
	11W Total			56
	12H	Imnaha	IMNAHW	86
		SF Salmon	JOHNSC	28
		SF Salmon	KNOXB	299
	12H Total			413
	12W	Imnaha	IMNTRP	26
		SF Salmon	JOHTRP & JOHNSC	11
		SF Salmon	SECESR & SECTRP & LAKEC	4
		SF Salmon	SFSTRP & KNOXB	3
		Pahsimeroi	PAHTRP	3
	12W Total			47
	11H	Yakima	YAKIMR & YAKIM1	6
		Yakima	CHANDL	3
		Yakima	CLARFP	26
		Yakima	EASTOP	21
		Yakima	JACKCP	31
		Yakima	ROSAD	6
		Wenatchee	LEAV	68
		Entiat	ENTH	21
		Methow	CHEWUP	1
		Methow	TWISPP & TWISPR	2
		Methow	WINT	6
	11H Total			191
	11W	Yakima	YAKIMR & YAKIM1	21
		Yakima	ROSAD	11
		Yakima	CHANDL	18
		Wenatchee	WENATT & PESHAR	1
		Wenatchee	CHIWAT & CHIWAR	2
		Entiat	ENTIAR	7
		Methow	METHR & METTRP & TWISPR	2
	11W Total			62
	12H	Mainstem	PRDTAL	303
		Mainstem	WAN & WANTAL	255
		Mainstem	RIS & RI2BYP & RISTAL	365
		Mainstem	RRE & RRETAL	129
		Mainstem	WELTAL	71
		Mainstem	WELH	4
	12H Total			1127

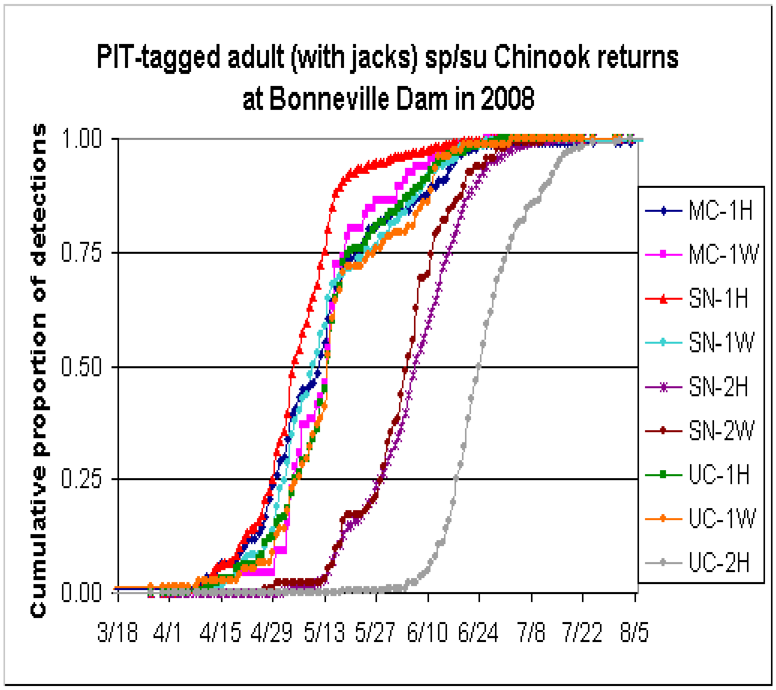

Figure A-7 Return year 2008 timing at Bonneville Dam of hatchery and wild spring and summer Chinook adults (with jacks) from Snake and Columbia rivers. (Legend: MC is middle Columbia from Bonneville Dam to confluence of Snake River, SN is Snake River, and UC is upper Columbia from confluence with Snake River to Chief Joseph Dam; 1 is spring run and 2 is summer run; H is hatchery fish and W is wild fish.)

Table on next page shows the breakdown by river of origin and release site for the PIT-tagged returning adults (including jacks) that compose each cumulative curve in above figure.

basin	srrt	river	rel_site	2008
MC	11H	Wind	CARS	83
		Hood	HOODMF & HOODWF	41
		Klickitat	KLIH	3
		Warm Spr	WSPH & WARMSR	12
		Umatilla	IMQP & UMAR & TMFFBY	11
		WallaWalla	WALLAR & WALLSF	1
	11H Total			151
	11W	John Day	JDAR1	34
		John Day	JDAR2	8
		John Day	JDARMF	19
		John Day	JDARNF & JDARSF	4
	11W Total			65
SN	11H	Tucannon	CURP	5
		Clearwater	DWORNF & DWOR	477
		Clearwater	KOOS & CLEARC	7
		Clearwater	POWP	97
		Clearwater	MEADOC & NEWSOC	5
		Clearwater	CROOKR & CROOKP	94
		Clearwater	REDP & REDR	95
		Grande Ronde	GRNTRP & GRANDR	10
		Grande Ronde	LOOKGC & LOOH	5
		Grande Ronde	LOSTIP	42
		Grande Ronde	CATHEP	85
		Grande Ronde	GRANDP	8
		Salmon	RAPH	527
		Salmon	YANKFK	2
		Salmon	SAWTRP & SAWT	41
	11H Total			1500
	11W	Tucannon	TUCR	2
		Clearwater	CLWTRP & CLWR	2
		Clearwater	LOLOC	10
		Clearwater	CFCTRP	6
		Clearwater	COLTKC & WHITSC	1
		Clearwater	PAPOOC & SQUAWC & FISTRP	4
		Clearwater	MEADOC	34
		Clearwater	NEWSOC	5
		Clearwater	REDTRP	4
		Grande Ronde	GRNTRP & GRANDR	36
		Grande Ronde	MINAMR	4
		Grande Ronde	LOOKGC	1
		Grande Ronde	LOSTIR	9
		Grande Ronde	CATHEC	6
		Grande Ronde	GRAND2	6
		Salmon	BIG2C	1
		Salmon	CAMASC & LOONC & SULFUC	2
		Salmon	MARTRP & MARSHC	1
		Salmon	LEMHIW & LEMHIR	6
		Salmon	SALEFT & SALREF & HERDC	4
		Salmon	YANKWF & VALEYC	2
		Salmon	SAWTRP	21
	11W Total			167
	12H	Imnaha	IMNAHW	212
		SF Salmon	JOHNSC	53
		SF Salmon	KNOXB	555
	12H Total			820
	12W	Imnaha	IMNAHR & IMNAHW	3
		Imnaha	IMNTRP	25
		SF Salmon	JOHTRP & JOHNSC	39
		SF Salmon	SECESR & SECTRP & LAKEC	15
		SF Salmon	SFSTRP & KNOXB	7
		Pahsimeroi	PAHTRP	5
	12W Total			94
UC	11H	Yakima	YAKIMR & YAKIM1	16
		Yakima	CHANDL	6
		Yakima	CLARFP	82
		Yakima	EASTOP	56
		Yakima	JACKCP	49
		Yakima	ROSAD	11
		Wenatchee	LEAV	74
		Wenatchee	CHIP	20
		Entiat	ENTH	6
		Methow	TWISPP & TWISPR	4
		Methow	WINT	9
	11H Total			333
	11W	Yakima	YAKIMR & YAKIM1	26
		Yakima	ROSAD	9
		Yakima	CHANDL	9
		Wenatchee	WENATT & PESHAR	9
		Wenatchee	CHIWAT & CHIWAR	14
		Entiat	ENTIAR	8
		Methow	METHR & METTRP & TWISPR	3
	11W Total			78
	12H	Mainstem	PRDTAL	73
		Mainstem	WAN & WANTAL	32
		Mainstem	RIS & RI2BYP & RISTAL	145
		Mainstem	RRE & RRETAL	23
		Mainstem	WELTAL	21
		Mainstem	WELH	7
	12H Total			301

PIT-tagged spring and summer Chinook adults by age of return at Bonneville Dam

The timing distribution of jacks and 2-salt and 3-salt adults at Bonneville Dam for the PIT-tagged spring and summer Chinook was graphed to determine if the general pattern of older aged fish returning earlier was consistent across the key wild Chinook and hatchery stocks shown in Tables A-1 to A-4. For each group of interest, the PIT-tag detections at the Bonneville Dam fishway ladders from return years 2003 to 2008 were pooled and a tally by serial date was taken on each returning age class (return year 2002 is omitted since 3-salt returns with 400 kHz tags are not detectable). Table A-5 shows that by May 31, over 95% of the spring Chinook jacks, 2-salt, and 3-salt returns of Carson, Leavenworth, Catherine Creek, Dworshak, and Rapid River hatcheries had passed Bonneville Dam prior to the facility starting to count returning adults as summer Chinook stock on June 1. Likewise, over 94% of the spring Chinook 2-salts and 3-salt wild spring Chinook from the John Day and Yakima rivers and Cle Elum Hatchery spring Chinook passed Bonneville Dam during the spring Chinook counting season. The adult timing distribution for wild Snake River spring Chinook is more protracted with approximately 35% jacks, 15% 2-salts, and 8% 3-salts passing after May 31. Many summer run wild and hatchery Chinook returning adults from the Snake River basin pass during the spring Chinook counting season (i.e., 36-52% 2-salts and 53-68% 3-salts depending on group). On the other hand, only 13-21% of the summer Chinook jacks pass before the start of the summer Chinook counting season. The timing plots are presented in Figures A-8 to A-12b.

Table A.6 Cumulative proportion of PIT-tagged wild and hatchery spring and summer Chinook detected at Bonneville Dam by May 31 (based on pooled 2003-2008 returns), which is the last day of designating returning adults and jacks as spring Chinook at the Bonneville Dam fishway counting windows.

Basin	Group	Jacks	2-Salts	3-Salts
Wild Chinook Stocks				
Middle Columbia	John Day R - Sp (JD-11W)	0.783	0.944	0.969
Upper Columbia	Yakima R - Sp (YK-11W)	0.894	0.945	0.994
Snake River	Snake R - Sp (SN-11W)	0.649	0.850	0.919
Snake River	Snake R - Su (SN-12W)	0.154	0.517	0.555
Hatchery Spring Chinook Stocks				
Middle Columbia	Carson NFH (CARS)	0.960	0.996	0.994
Upper Columbia	Cle Elum H (CLEE[1])	0.733	0.948	1.000
Upper Columbia	Leavenworth H (LEAV)	0.977	0.999	0.995
Snake River	Catherine Ck AP (CATH[2])	1.000	0.995	1.000
Snake River	Dworshak NFH (DWOR[3])	0.972	0.992	0.997
Snake River	Rapid River H (RAPH)	0.987	0.999	0.998
Hatchery Summer Chinook Stocks				
Snake River	McCall H (MCCA[4])	0.213	0.493	0.531
Snake River	Imnaha R AP (IMNA[5])	0.129	0.360	0.683

[1] **Cle Elum H rel_sites are CLARFP, EASTOP, and JACKCP in Table 2.**
[2] **Catherine Ck AP rel_site is CATHEP in Table 3.**
[3] **Dworshak NFH rel_sites are CLWR, DWOR, DWORNF, and DWORMS in Table 3.**
[4] **McCall H rel_site is KNOXB in Table 4.**
[5] **Imnaha R AP rel_sites is IMNAHW in Table 4.**

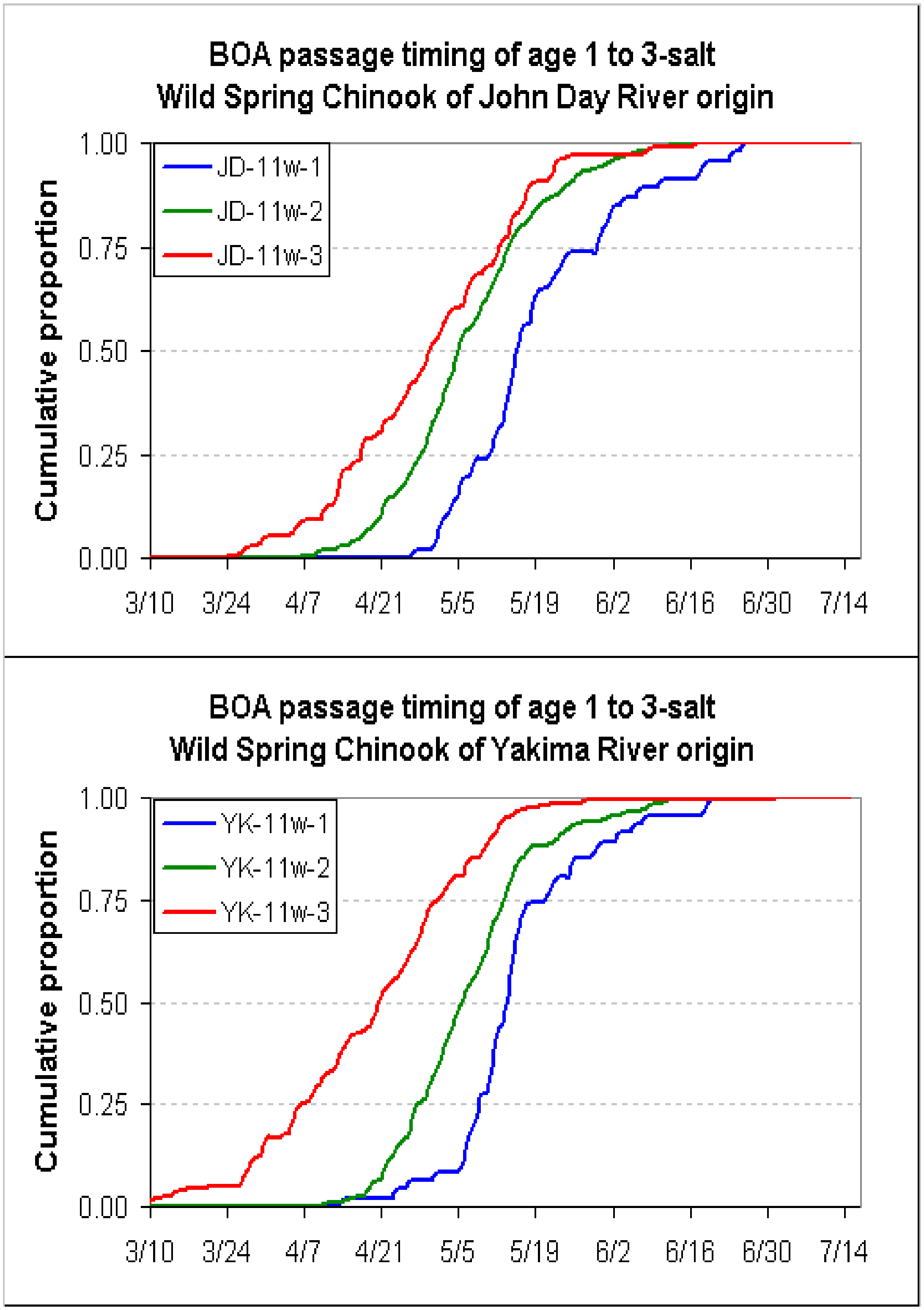

Figure A-8 Timing of PIT-tagged wild spring Chinook of John Day River (top plot) and Yakima River (bottom plot) origins at Bonneville Dam (pooled 2003-2008 returns).

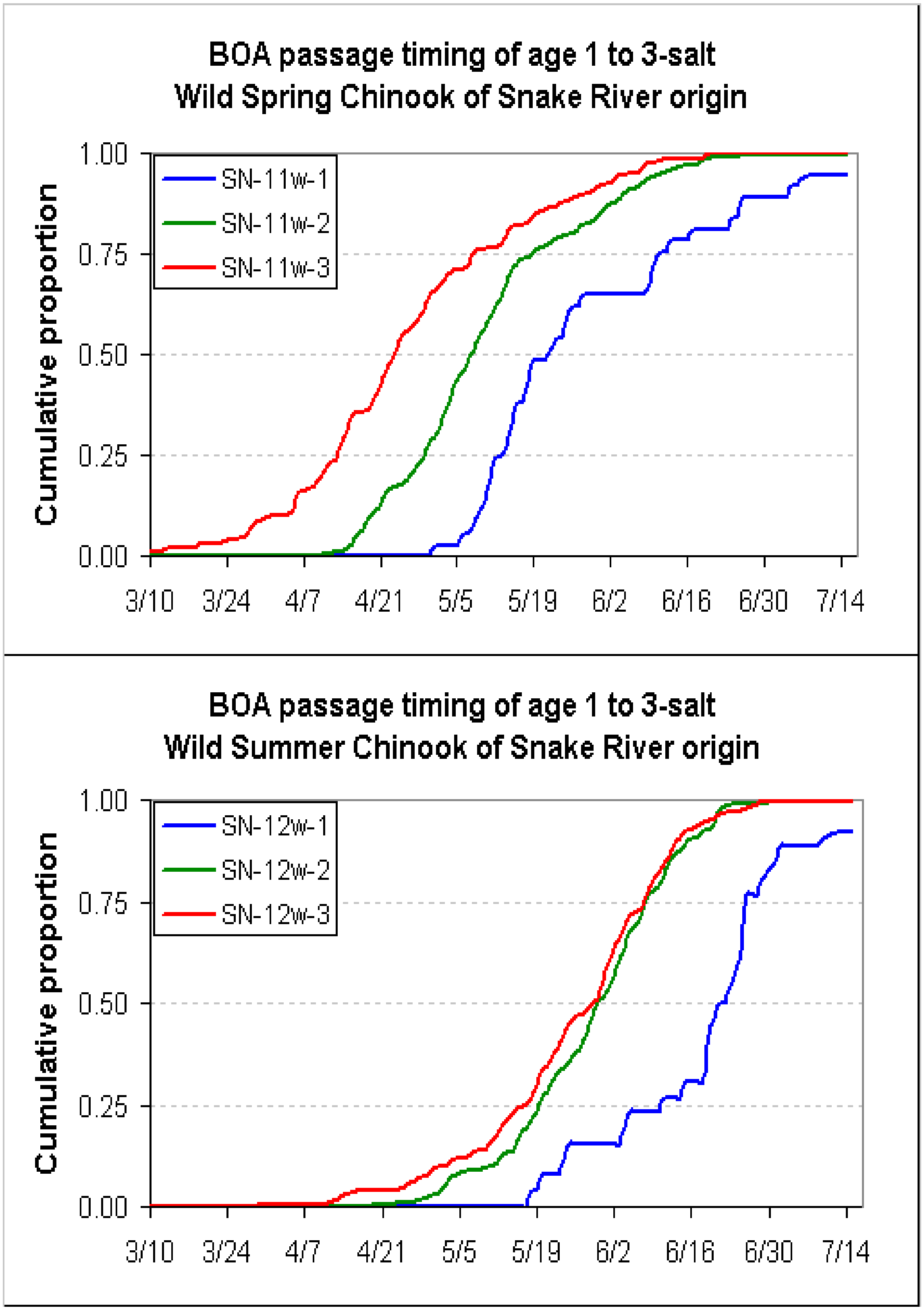

Figure A-9 Timing of PIT-tagged wild spring (top plot) and summer (bottom plot) Chinook of Snake River origins at Bonneville Dam (pooled 2003-2008 returns).

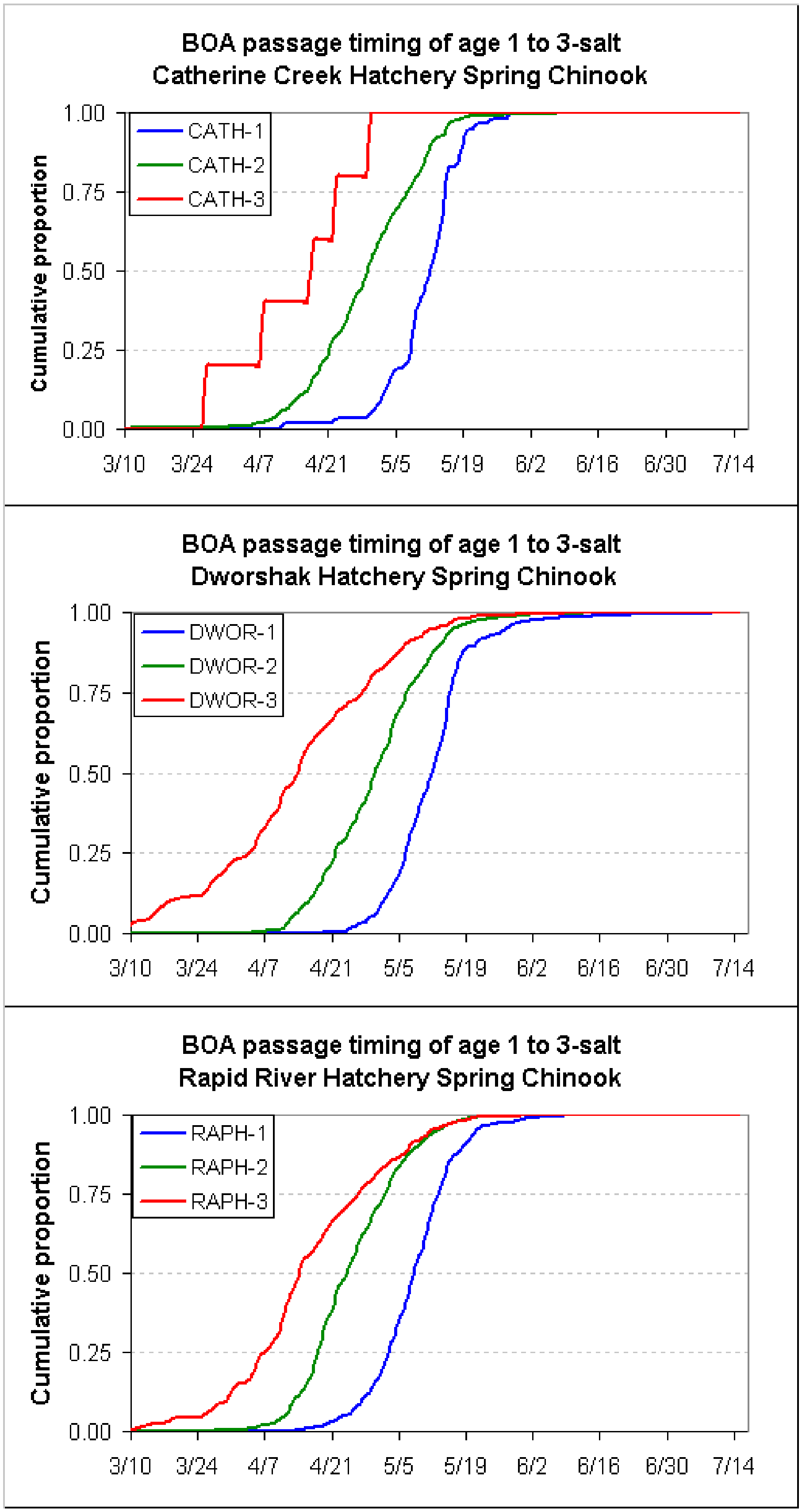

Figure A-10 Timing of PIT-tagged spring Chinook from Snake River basin hatcheries at Bonneville Dam (pooled 2003-2008 returns).

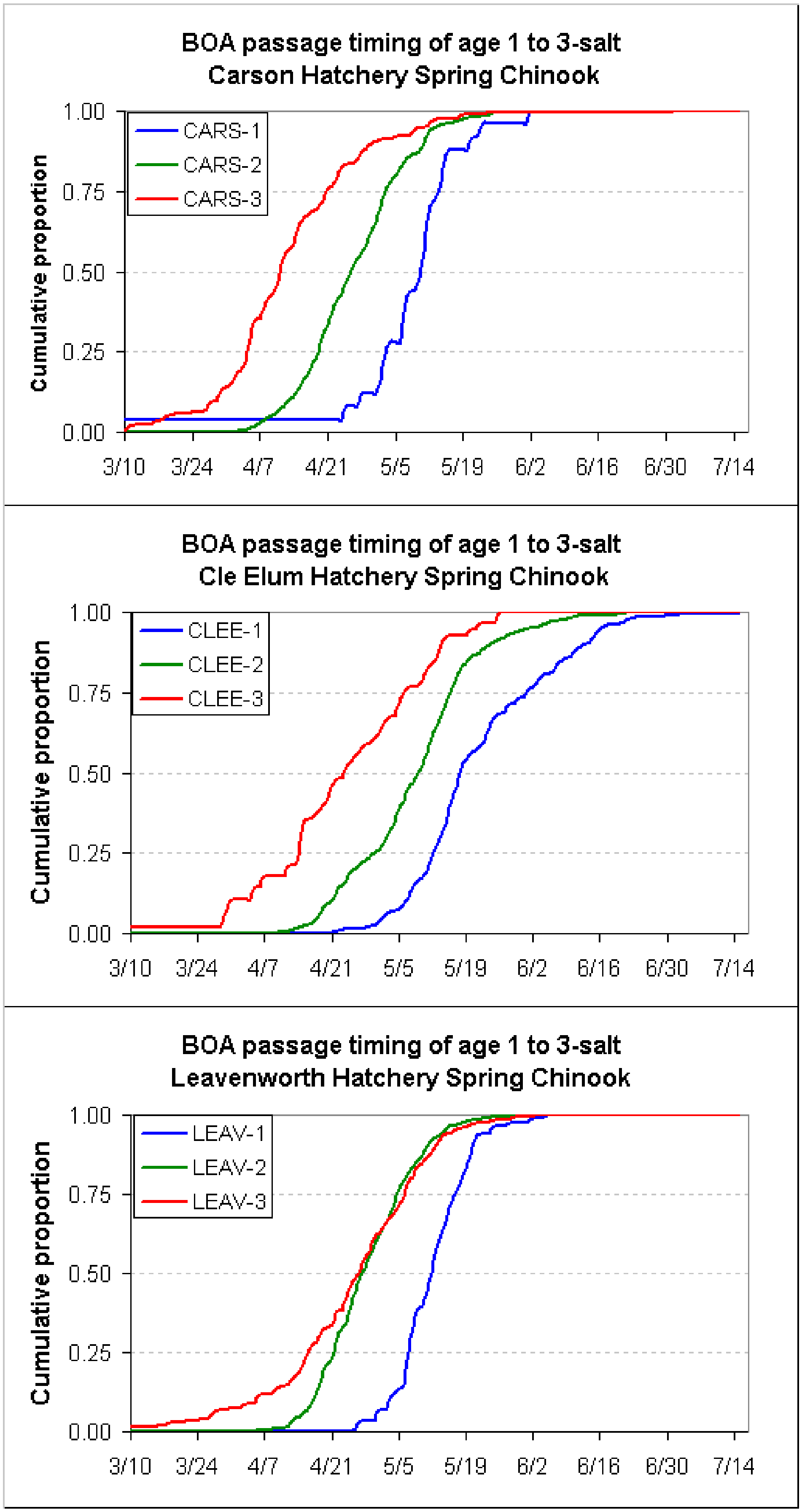

Figure A-11 Timing of PIT-tagged spring Chinook from middle and upper Columbia River basin hatcheries at Bonneville Dam (pooled 2003-2008 returns).

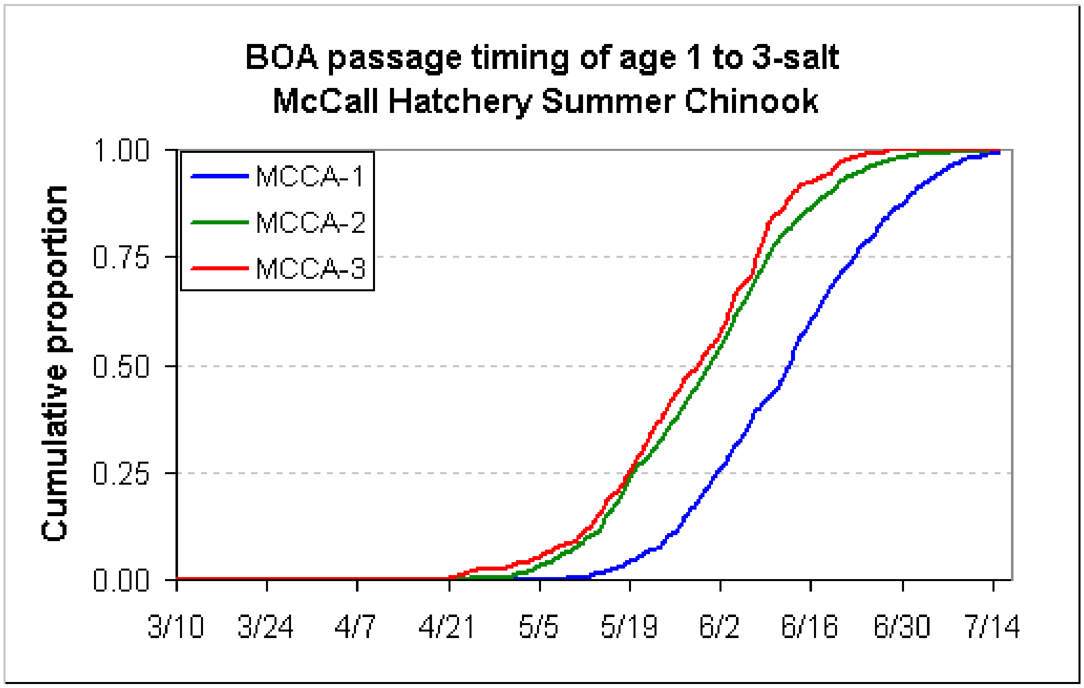

Figure A-12a Timing of PIT-tagged summer Chinook from Snake River basin hatcheries at Bonneville Dam (pooled 2003-2008 returns).

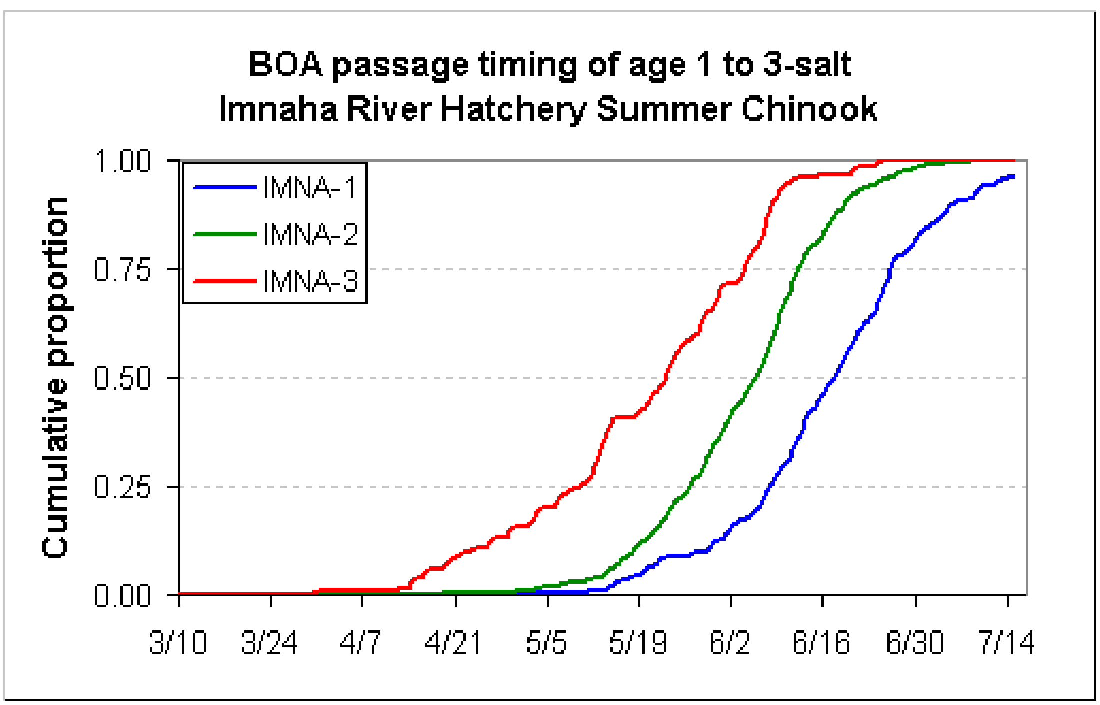

Figure A-12b Timing of PIT-tagged summer Chinook from Snake River basin hatcheries at Bonneville Dam (pooled 2003-2008 returns).

PIT-tagged hatchery and wild summer steelhead adult returns at Bonneville Dam

The PIT-tagged adult run timing data of wild and hatchery summer steelhead at Bonneville Dam for steelhead originating above Lower Granite Dam is characterized along with that of steelhead originating in the middle and upper Columbia River areas in the following series of graphs. For this analysis, FPC staff compiled all available detections at the Bonneville Dam fish ladders for hatchery and wild steelhead. Fish tagged at hatcheries and released at dams for research purposes were not used. The steelhead return data are stratified into the following three geographic regions, (i) middle Columbia (Bonneville Dam to confluence with Snake River), (ii) Snake River, and (iii) upper Columbia (confluence with Snake to below Chief Joseph Dam). Hatchery steelhead of Snake River origin were further stratified into A-run and B-run stocks.

Table A-7 shows the number of PIT-tagged wild steelhead adults at Bonneville Dam detected for return years 2002 to 2008 grouped by the tributaries comprising each basin for which return timing is plotted in Figures A-14 and A-16. The tributaries of the Snake River basin have a longer time series of PIT-tag adult returns, and fewer return years dominated by just one or two tributaries as has occurred in the middle and upper Columbia River basins.

Table A-7 Number PIT-tagged wild summer steelhead adults detected at Bonneville Dam ladders by return year for fish release sites in middle and upper Columbia River and Snake River drainage.

Basin	Drainage	2002	2003	2004	2005	2006	2007	2008	Grand Total
MC	Deschutes R.						38	67	105
	Hood R.					1	3		4
	John Day R.	1	5	2	67	117	109	246	547
	Umatilla R.	17	10	11	3	10	17	21	89
	Walla Walla R.			2	2	3	6	6	19
	Wind R.	1	9	3	2	11	11	22	59
MC Total		**19**	**24**	**18**	**74**	**142**	**184**	**362**	**823**
SN	Asotin Ck					1	12	23	36
	Clearwater R.	87	24	30	36	29	50	77	333
	Grande Ronde R.	16	19	26	35	15	33	36	180
	Imnaha R.	22	39	42	38	14	34	125	314
	mainstem (Lewiston)	11	16	15	4		2	8	56
	Salmon R.	35	17	22	17	21	19	48	179
	Tucannon R.	9	19	32	35	25	38	16	174
SN Total		**180**	**134**	**167**	**165**	**105**	**188**	**333**	**1,272**
UC	Entiat R.					3	8	7	18
	Methow R.						6	13	19
	Wenatchee R.						2	8	10
	Yakima R.		24	22	15	12	18	15	106
UC Total			**24**	**22**	**15**	**15**	**34**	**43**	**153**
Grand Total		199	182	207	254	262	406	738	2,248

Table A-8 shows the number of PIT-tagged hatchery steelhead adults at Bonneville Dam detected for return years 2002 to 2008 grouped by the tributaries comprising each basin for which return timing is plotted in Figures A-13 and A-15. The large numbers of PIT-tagged adults in the upper Columbia River basin returning in 2004 to 2007 are due primarily to the three-year McNary Dam transportation evaluation. For that study over 400,000 hatchery steelhead were being PIT-tagged and released annually in the upper Columbia River basin.

Table A.8 Number PIT-tagged hatchery summer steelhead adults detected at Bonneville Dam ladders by return year for fish release sites in middle and upper Columbia River and Snake River drainage, with Snake River origin steelhead split into A-run (Basin = SN) and B-run (Basin = SN-B) stocks.

Basin	Drainage	2002	2003	2004	2005	2006	2007	2008	Grand Total
MC	Hood R.					10	49	102	161
	Umatilla R.	35	47	13	9	12	59	80	255
	Walla Walla R.	5	2		33	32	23	297	392
MC Total		**40**	**49**	**13**	**42**	**54**	**131**	**479**	**808**
SN	Grande Ronde R.	28	29	22	19	102	163	148	511
	Imnaha R.	24	26	45	31	36	33	33	228
	mainstem (HCD)	1	2	16	5	2	5	5	36
	mainstem (Lewiston)		1						1
	mainstem (LYFE)	2							2
	Salmon R.	6	33	48	27	15	52	53	234
	Tucannon R.	4	4	10	59	79	544	422	1,122
SN Total		**65**	**95**	**141**	**141**	**234**	**797**	**661**	**2,134**
SN-B	Clearwater R.	50	8	21	36	34	48	176	373
	Salmon R.	1	1	3	5	1	5	2	18
SN-B Total		**51**	**9**	**24**	**41**	**35**	**53**	**178**	**391**
UC	mainstem (RINH)			1,858	2,869	2,673	209	1	7,610
	mainstem (WELH)	488		357	634	4			1,483
	Methow R.			740	1,866	3,087	469	23	6,185
	Okanogan R.			115	350	462	73	17	1,017
	Wenatchee R.			387	407	357	313	466	1,930
UC Total		**488**		**3,457**	**6,126**	**6,583**	**1,064**	**507**	**18,225**
Grand Total		644	153	3,635	6,350	6,906	2,045	1,825	21,558

A very similar return timing at Bonneville Dam is shown in Figurs A-13 and A-15 for the PIT-tagged Snake River A-run hatchery steelhead and hatchery steelhead from the middle and upper Columbia River. These figures show a very distinct later timing of the PIT-tagged Snake River B-run stocks. All hatchery production in the Clearwater River is B-run steelhead, while only select sites in the Salmon River have B-run steelhead planted. All but two of the 18 returning B-run adults originating in the Salmon River were from the Squaw Creek acclimation pond as well as direct stream releases in Squaw Creek.

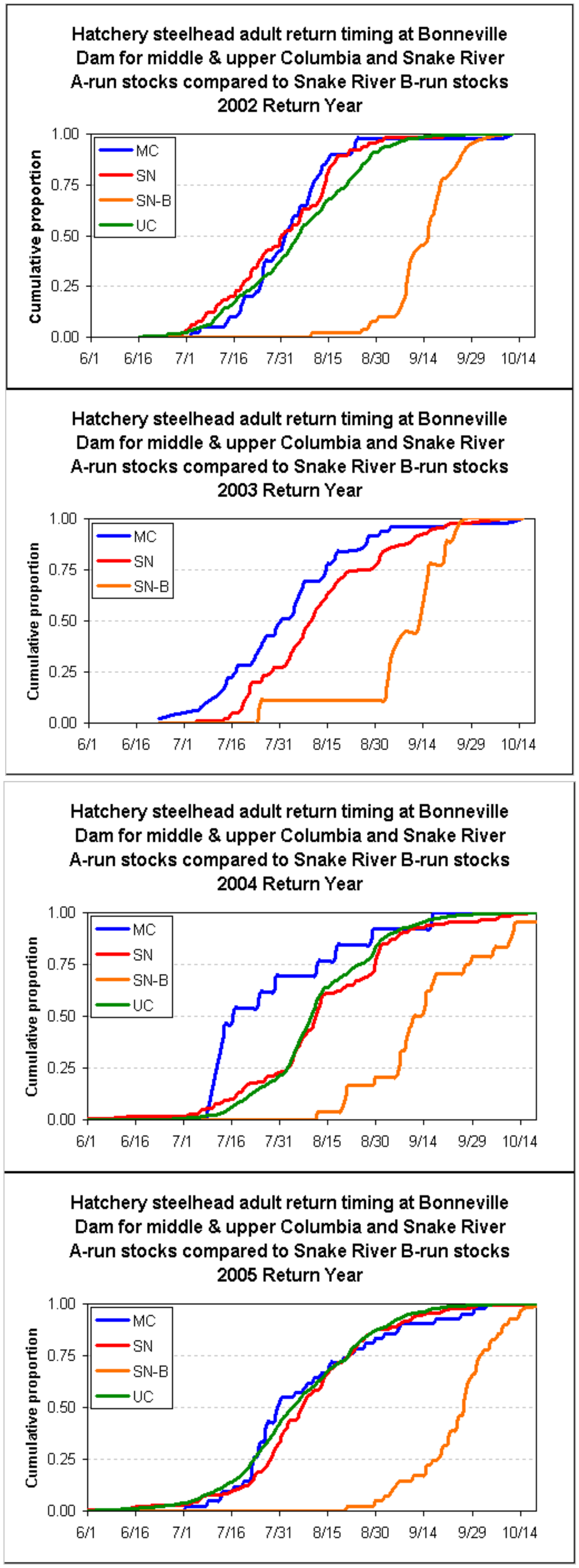

Figure A-13 Timing of PIT-tagged hatchery summer steelhead adults by basin of origin at Bonneville Dam for return years 2002-2005.

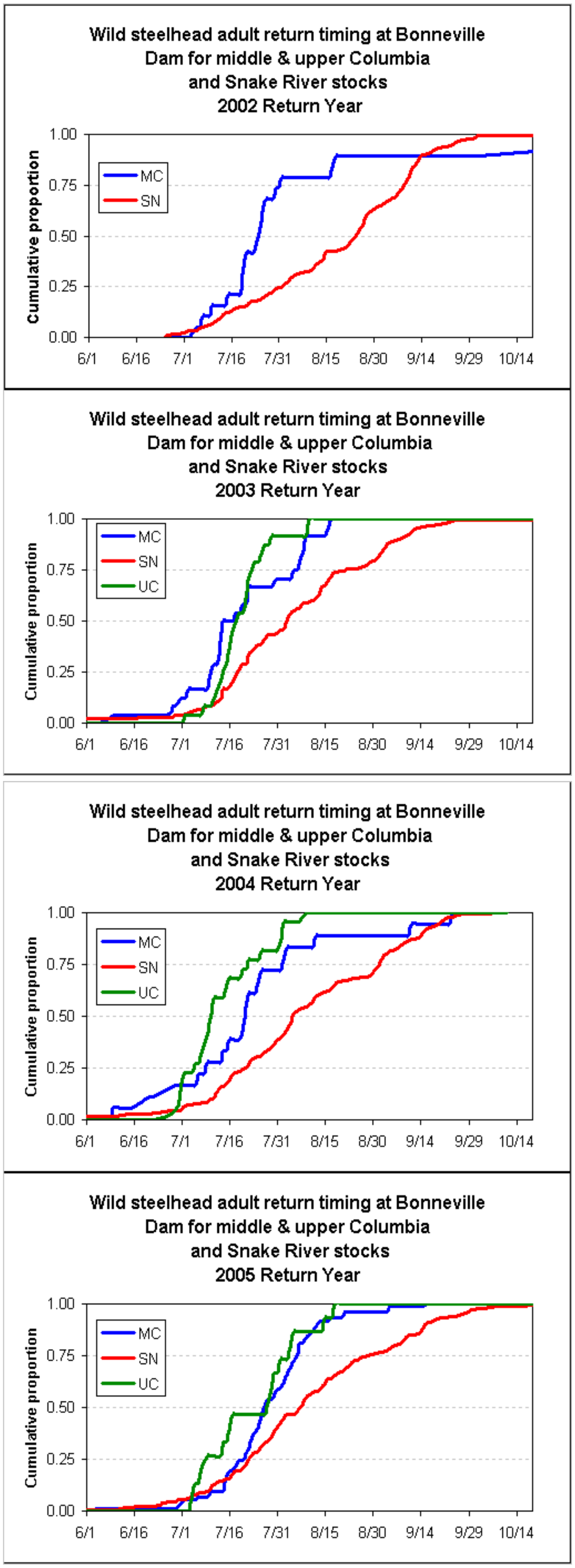

Figure A-14 Timing of PIT-tagged wild summer steelhead adults by basin of origin at Bonneville Dam for return years 2002-2005.

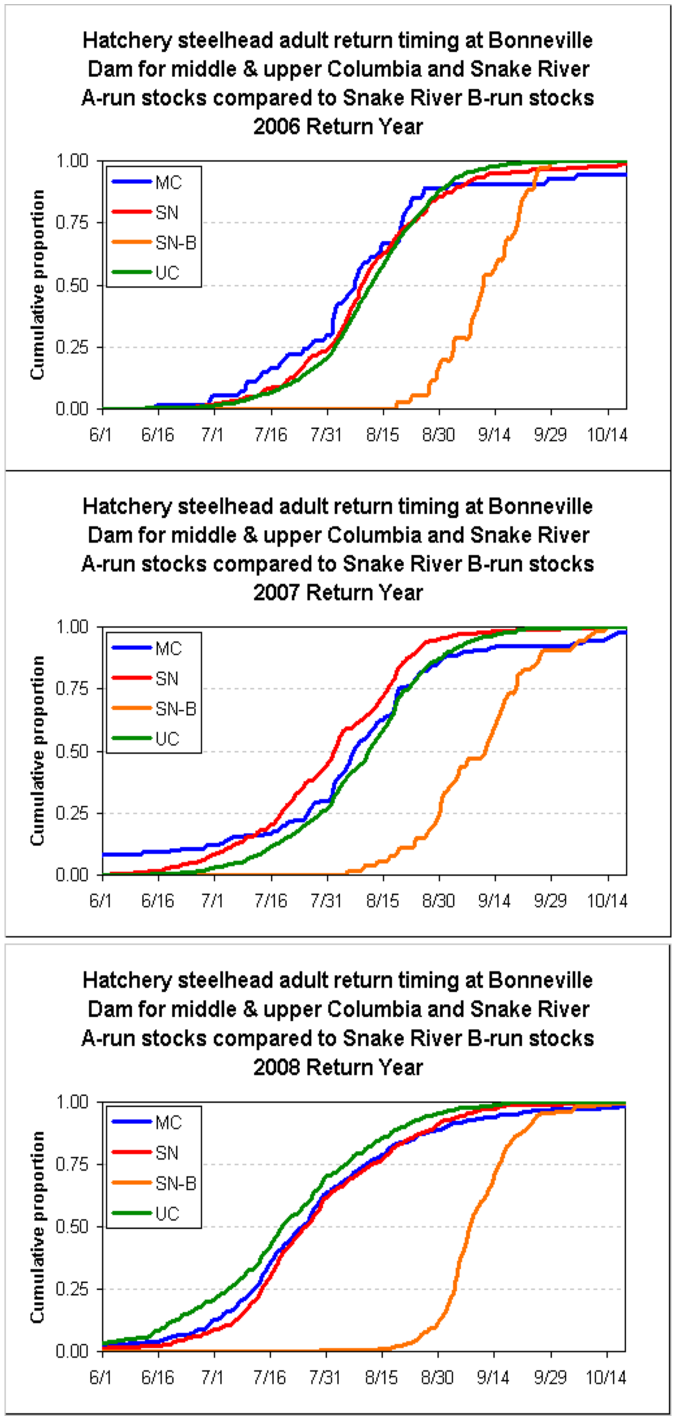

Figure A-15 Timing of PIT-tagged hatchery summer steelhead adults by basin of origin at Bonneville Dam for return years 2006-2008.

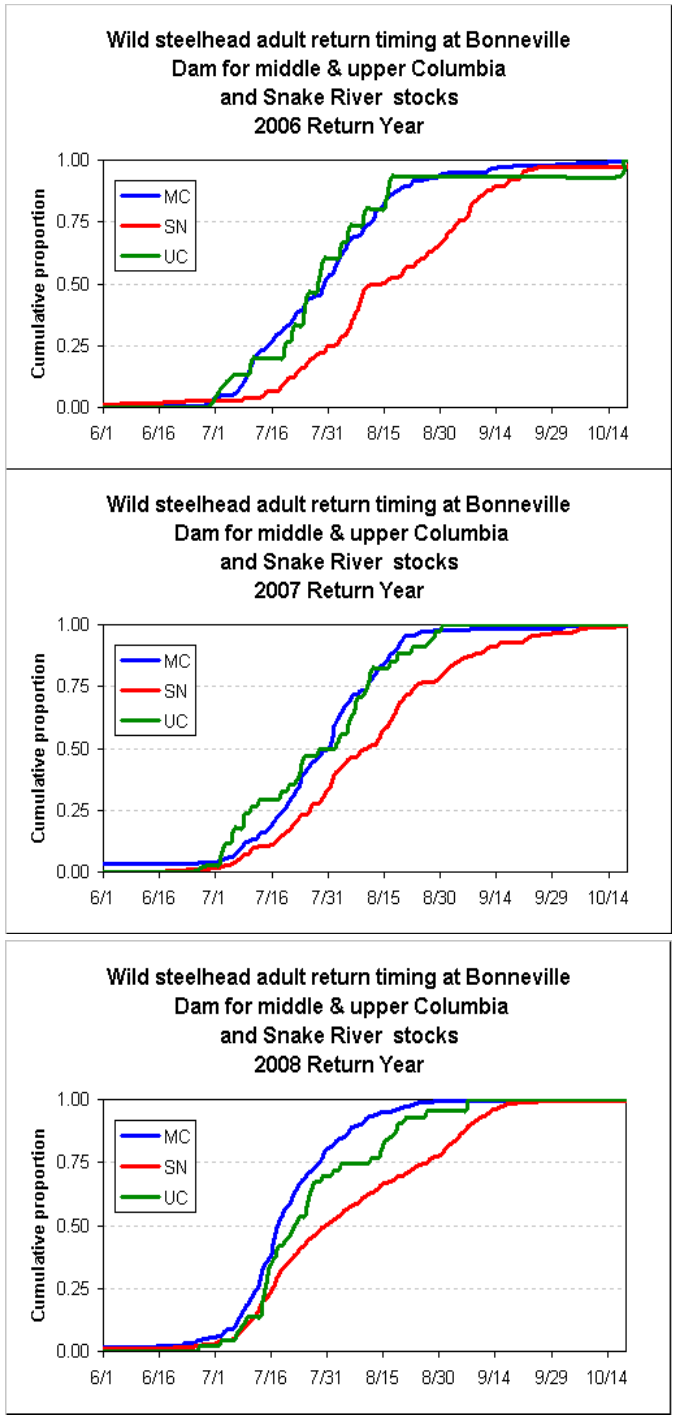

Figure A-16 Timing of PIT-tagged wild summer steelhead adults by basin of origin at Bonneville Dam for return years 2006-2008.

Appendix B

Supporting Tables of PIT-Tag Marking Data and Estimates of Survival and Major CSS Parameters

This appendix includes the time series of data by smolt migration year that are compiled annually by the CSS. These tables support analyses presented in Chapter 4. The information is organized by species (stream type Chinook salmon and steelhead) and origin (wild and hatchery) following the steps of the survival estimations and comparisons.

- Numbers, origins, and release sites of Lower Granite Dam of PIT-tagged juvenile fish used in the study are presented in Tables B-1 to B-5.

- Estimated size of each study category is presented: numbers of tagged smolts detected at Snake River collector dams and transported (T_0), not collected or transported at Snake River collector dams (C_0), or collected and returned to the river at Snake River collector dams (C_1); and counts of returning adults grouped by study category detected at Bonneville and Lower Granite dams are presented in Tables B-6 to B-13.

- Survival estimates from the CJS method of in-river migrating juvenile fish through specific reaches are presented in Table B-14 to B-21.

- Number of PIT-tagged smolts transported at each collector dam (plus estimated number if tagged fish had been transported in same proportion as the untagged population) and site-specific SAR estimates are presented in Tables B-22 to B-30.

Tables showing the age distribution of returning adult PIT-tagged Chinook and steelhead detected at Lower Granite Dam, and the two comparative transport and in-river SAR ratios (TIR and D) have been placed directly at the end of Chapter 4. The LGR-BON in-river reach survival rates (SR) are presented in Chapter 3 along with estimates for the partition from LGR-MCN and MCN-BON.

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 2007.

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	49,657	8,292	1,423	8,828	27,725	3,391
1995	74,639	17,605	1,948	12,330	40,609	2,148
1996	21,523	2,246	913	7,079	7,016	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	103,012	15,106	381	14,057	60,261	13,165
2004	99,743	17,214	541	12,104	56,153	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
Average % of total		**16.4%**	**1.7%**	**15.0%**	**54.4%**	**12.5%**

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

Table B-2 Hatchery summer Chinook PIT-tagged and released in Snake River basin specifically for CSS (long time series), 1997 to 2007.

Hatchery	Migr. Year	Hatchery Release	Fish # / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT Tag Proportion
McCall H (MCCA)	1997	238,647	17.1	128	52,652	0.2206
	1998	393,872	17.5	126	47,340	0.1202
	1999	1,143,083	23.9	117	47,985	0.0420
	2000	1,039,930	23.3	117	47,705	0.0459
	2001	1,076,846	19.4	129	55,124	0.0512
	2002	1,022,550	23.0	122	54,734	0.0535
	2003	1,053,660	21.1	121	74,317	0.0705
	2004	1,088,810	20.9	(none taken)	71,363	0.0655
	2005	1,047,530	20.9	121	71,725	0.0685
	2006	1,096,130	18.1	126	51,895	0.0473
	2007	1,087,170	19.1	122	51,726	0.0476
Imnaha AP (IMNA)	1997	50,911	17.0	122	13,378	0.2628
	1998	93,108	21.1	122	19,825	0.2129
	1999	184,725	18.5	117 [A]	19,939	0.1079
	2000	179,797	19.1	113 [A]	20,819	0.1158
	2001	123,014	16.0	121 [A]	20,922	0.1701
	2002	303,737	14.1	121 [A]	20,920	0.0689
	2003	268,426	16.3	123 [A]	20,904	0.0779
	2004	398,469	26.1	98 [A]	20,910	0.0525
	2005	435,186	24.5	105 [A]	20,917	0.0481
	2006	320,752	27.1	105 [A]	20,623	0.0643
	2007	432,530	21.6	107 [A]	20,885	0.0483

[A] Tagged in fall ~5 months before release; otherwise tagged in spring 1-2 months before release.

Table B-3 Hatchery spring Chinook PIT-tagged and released in Snake River basin specifically for CSS (long time series), 1997 to 2007.

Hatchery	Migr. Year	Hatchery Release	Fish # / lb	Median Length at Tagging (mm)	PIT Tags Released	PIT Tag Proportion
Rapid River H (RAPH)	1997	85,838	20.5	100A	40,451	0.4712
	1998	896,170	20.3	117	48,336	0.0539
	1999	2,847,283	17.9	120	47,812	0.0168
	2000	2,462,354	19.2	119	47,747	0.0194
	2001	736,601	18.8	118	55,085	0.0748
	2002	2,669,476	19.8	122	54,908	0.0206
	2003	2,330,557	18.8	119	54,763	0.0235
	2004	2,762,058	24.5	(none taken)	51,969	0.0188
	2005	2,761,430	19.1	124	51,975	0.0188
	2006	2,530,528	19.3	129	51,874	0.0205
	2007	2,498,246	20.0	117	51,761	0.0207
Dworshak H (DWOR)	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
Catherine Ck AP (CATH)	2001	136,833	19.7	117 [A]	20,915	0.1529
	2002	180,343	18.6	115 [A]	20,796	0.1153
	2003	105,292	12.8	123 [A]	20,628	0.1959
	2004	162,614	23.2	109 [A]	20,994	0.1291
	2005	189,580	25.1	106 [A]	20,839	0.1099
	2006	68,820	22.7	102 [A]	20,958	0.3045
	2007	71,268	26.9	102 [A]	20,817	0.2921

A Tagged in fall ~5 months before release; otherwise tagged in spring 1-2 months before release.

Table B-4 Number of PIT-tagged wild steelhead smolts from tributaries above Lower Granite Dam (plus Snake River trap) used in the CSS for migration years 1997 to 2006.

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	24,284	5,885	1,197	4,261	6,969	5,972
2004	25,156	7,642	1,922	2,977	7,102	5,513
2005	25,002	8,391	2,749 [B]	3,773	5,652	4,437
2006	16,579	8,301	4	1,950	4,090	2,234
Average % of total		**36.5%**	**6.2%**	**13.1%**	**26.4%**	**17.8%**

A Snake River trap at Lewiston, ID, collects fish originating in Grande Ronde, Salmon, and Imnaha rivers.
B Includes 1,400 PIT-tagged wild steelhead released in Asotin Creek, above Lewiston ID.

Table B-5 Number of PIT-tagged hatchery steelhead smolts from four tributaries above Lower Granite Dam (plus mainstem Snake River) used in the CSS for migration years 1997 to 2006.

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)	Snake River at HCD (Rkm 397)
1997	35,705	12,872	725	6,039	9,394	6,379	296
1998	30,913	8,451	4,209	4,904	8,457	4,604	288
1999	36,968	11,486	3,925	5,316	9,132	6,808	301
2000	32,000	8,488	3,290	5,348	8,173	6,436	265
2001	29,099	9,155	3,126	4,677	7,859	3,995	287
2002	26,573	7,819	4,722	3,888	7,011	2,839	294
2003	26,379	4,912	4,171	3,113	7,764	6,123	296
2004	19,879	3,400	4,841	2,263	4,072	5,098	205
2005	23,520	7,228	3,354	2,395	3,684	6,802	57
2006	16,068	4,545	2,146	4,397	3,208	1,667	105
Average % of total		**28.3%**	**12.4%**	**15.3%**	**24.8%**	**18.3%**	**0.9%**

A Snake River trap at Lewiston, ID, collects fish released in Grande Ronde, Salmon, and Imnaha rivers, and below Hells Canyon Dam.

Table B-6 Estimated number of PIT-tagged wild Chinook (aggregate of fish tagged in 10-month period between July 25 and May 20) arriving Lower Granite Dam in each of the three study categories from 1994 to 2007 (with 90% confidence intervals), with detected adults at Lower Granite (GRA) and Bonneville (BON) adult ladders.

Migr Year	Estimated smolt population at LGR* (with 90% CI)	Study category	Estimated smolt numbers in each study category (with 90% CI)		Detected adults (2-salt & older) GRA	BON
1994	15,260 (15,008 – 15,520)	T0	2,004	(1,922 – 2,084)	9	
		C0	1,801	(1,693 – 1,911)	5	
		C1	4,431	(4,275 – 4,618)	3	
1995	20,206 (19,950 – 20,457)	T0	2,283	(2,202 – 2,367)	8	
		C0	2,709	(2,602 – 2,812)	10	
		C1	14,206	(13,997 – 14,413)	36	
1996	7,868 (7,682 – 8,070)	T0	400	(365 – 434)	2	
		C0	1,917	(1,805 – 2,034)	5	
		C1	5,209	(5,057 – 5,366)	7	
1997	2,898 (2,784 – 3,024)	T0	230	(207 – 255)	4	
		C0	680	(614 – 757)	16	
		C1	1,936	(1,843 – 2,028)	18	
1998	17,363 (17,172 – 17,562)	T0	1,271	(1,214 – 1,330)	15	
		C0	3,081	(2,976 – 3,187)	42	
		C1	12,276	(12,111 – 12,444)	131	
1999	33,662 (33,343 – 33,988)	T0	1,768	(1,697 – 1,841)	43	
		C0	4,469	(4,339 – 4,595)	95	
		C1	26,140	(25,855 – 26,424)	495	
2000	25,053 (24,721– 25,397)	T0	839	(790 – 890)	12	21
		C0	6,494	(6,321 – 6,686)	155	184
		C1	16,833	(16,574 – 17,087)	392	456
2001	22,415 (22,234 – 22,595)	T0	547	(512 – 587)	7	10
		C0	231	(208 – 253)	1 [A]	1 [A]
		C1	20,307	(20,124 – 20,491)	29	32
2002	23,356 (22,995 – 23,697)	T0	3,886	(3,775 – 3,995)	31	41
		C0	6,218	(6,042 – 6,395)	76	86
		C1	12,687	(12,455 – 12,922)	125	137
2003	31,093 (30,705 – 31,472)	T0	8,713	(8,556 – 8,881)	30	29
		C0	8,919	(8,701 – 9,124)	29	33
		C1	12,744	(12,538 – 12,952)	22	22

Migr Year	Estimated smolt population at LGR* (with 90% CI)	Study category	Estimated smolt numbers in each study category (with 90% CI)		Detected adults (2-salt & older)	
2004	32,546 (32,297 – 32,815)	T0	12,887	(12,721 – 13,067)	68	88
		C0	2,264	(2,167 – 2,348)	11	15
		C1	16,561	(16,363 – 16,785)	37	44
2005	35,216 (34,945 – 35,489)	T0	15,910	(15,702 – 16,116)	38	48
		C0	1,358	(1,297 – 1,425)	1	1
		C1	17,066	(16,854 – 17,276)	19	27
2006 [B]	22,827 (22,530 – 23,133)	T0	9,794	(9,615 – 9,964)	75	87
		C0	3,496	(3,367 – 3,628)	34	44
		C1	8,772	(8,614 – 8,941)	45	57
2007 [B C]	22,979 (22,613 – 23,378)	T0	3,233	(3,136 – 3,327)	30	37
		C0	11,166	(10,894 – 11,457)	90	112
		C1	8,483	(8,310 – 8,660)	50	59

A One returning adult with no detections may have inadvertently been transported.
B Migr. year 2006 and 2007 data use combined groups TWS & BWS
C Incomplete with 2-salt adult returns through August 3, 2009.

Table B-7 Estimated number of PIT-tagged spring Chinook from Rapid River Hatchery arriving Lower Granite Dam in each of the three study categories from 1997 to 2007 (with 90% confidence intervals), with detected adults at Lower Granite (GRA) and Bonneville (BON) adult ladders.

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimate smolt numbers in each study category (with 90% CI)		Detected adults (2-salt & older)	
					GRA	BON
1997	15,765 (15,246 – 16,439)	T0	4,324	(4,224 – 4,424)	34	
		C0	4,176	(3,904 – 4,448)	19	
		C1	6,843	(6,515 – 7,187)	36	
1998	32,148 (31,801 – 32,473)	T0	12,876	(12,711 – 13,032)	257	
		C0	4,402	(4,260 – 4,537)	53	
		C1	13,597	(13,389 – 13,820)	91	
1999	35,895 (35,272 – 36,542)	T0	12,857	(12,666 – 13,050)	391	
		C0	7,040	(6,842 – 7,238)	167	
		C1	14,456	(14,157 – 14,773)	235	
2000	35,194 (34,652 – 35,769)	T0	16,587	(16,302 – 16,883)	349	492
		C0	11,046	(10,676 – 11,427)	176	201
		C1	5,248	(5,110 – 5,375)	70	90
2001	38,026 (37,822 – 38,211)	T0	19,090	(18,904 – 19,273)	207	265
		C0	966	(919 – 1,016)	2 [A]	2 [A]
		C1	15,989	(15,802 – 16,177)	8	12
2002	41,471 (40,785 – 42,099)	T0	11,589	(11,378 – 11,817)	117	132
		C0	13,625	(13,303 – 13,950)	91	106
		C1	14,854	(14,551 – 15,161)	94	104
2003	37,911 (37,310 – 38,512)	T0	13,353	(13,127 – 13,570)	33	52
		C0	16,953	(16,513 – 17,431)	39	41
		C1	7,100	(6,934 – 7,253)	11	11
2004	36,178 (35,972 – 36,404)	T0	19,519	(19,313 – 19,719)	70	88
		C0	3,493	(3,352 – 3,643)	8	10
		C1	12,813	(12,644 – 12,983)	15	15
2005	38,231 (38,033 – 38,426)	T0	20,190	(20,011 – 20,379)	55	69
		C0	1,836	(1,765 – 1,908)	1	2
		C1	15,524	(15,340 – 15,711)	19	21
2006 [B]	39,576 (39,074 – 40,071)	T0	18,262	(17,997 – 18,534)	105	147
		C0	8,113	(7,870 – 8,366)	34	55
		C1	10,594	(10,374 – 10,818)	35	47
2007 [B C]	38,454 (37,839 – 39,081)	T0	9,016	(8,857 – 9,184)	41	64
		C0	19,422	(18,951 – 19,918)	48	66
		C1	8,688	(8,502 – 8,877)	22	28

[A] Two returning adults with no detections may have inadvertently been transported (in-river SARs are based solely on Category C1 fish in 2001).
[B] Migr. year 2006 and 2007 data use combined groups TWS & BWS
[C] Incomplete with 2-salt adult returns through August 3, 2009.

Table B-8 Estimated number of PIT-tagged spring Chinook from Dworshak Hatchery arriving Lower Granite Dam in each of the three study categories from 1997 to 2007 (with 90% confidence intervals), with detected adults at Lower Granite (GRA) and Bonneville (BON) adult ladders.

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimate smolt numbers in each study category (with 90% CI)		Detected adults (2-salt & older)	
					GRA	BON
1997	8,175 (7,735 – 8,683)	T0	1,931	(1,866 – 2,000)	16	
		C0	2,529	(2,310 – 2,755)	13	
		C1	3,613	(3,370 – 3,884)	12	
1998	40,218 (39,660 – 40,742)	T0	14,728	(14,563 –14,915)	132	
		C0	11,151	(10,882 – 11,447)	139	
		C1	13,128	(12,875 – 13,387)	118	
1999	40,804 (39,771 – 41,948)	T0	9,787	(9,608 – 9,985)	115	
		C0	10,484	(10,181 – 10,820)	125	
		C1	19,083	(18,596 – 19,612)	181	
2000	39,412 (38,782 – 40,101)	T0	18,317	(17,987 – 18,660)	183	296
		C0	13,075	(12,612 – 13,529)	132	172
		C1	5,416	(5,280 – 5,568)	44	56
2001	41,251 (41,068 – 41,446)	T0	21,740	(21,555 – 21,934)	79	96
		C0	886	(839 – 938)	0	0
		C1	16,872	(16,672 – 17,062)	7	8
2002	45,233 (44,268 – 46,304)	T0	9,665	(9,431 – 9,902)	60	80
		C0	19,008	(18,512 – 19,582)	95	113
		C1	14,914	(14,538 – 15,354)	74	80
2003	38,612 (37,945 – 39,331)	T0	13,205	(12,966 – 13,455)	34	44
		C0	17,822	(17,323 – 18,302)	38	45
		C1	6,816	(6,650 – 6,978)	12	12
2004	45,505 (42,223 – 42,793)	T0	21,658	(21,437 – 21,866)	61	121
		C0	6,309	(6,123 – 6,492)	20	24
		C1	14,069	(13,891 – 14,253)	26	42
2005	43,042 (42,827 – 43,257)	T0	21,003	(20,811 – 21,199)	43	65
		C0	3,333	(3,225 – 3,443)	8	8
		C1	17,718	(17,528 – 17,918)	22	27
2006 [A]	43,534 (42,744 – 44,330)	T0	14,702	(14,382 – 15,040)	52	85
		C0	13,479	(13,093 – 13,877)	53	84
		C1	12,773	(12,457 – 13,052)	26	46
2007 [A B]	42,755 (41,947 – 43,583)	T0	2,343	(2,260 – 2,433)	16	27
		C0	28,813	(28,181 – 29,493)	90	123
		C1	10,380	(10,135 – 10,584)	33	46

[A] Migr. year 2006 and 2007 data use combined groups TWS & BWS
[B] Incomplete with 2-salt adult returns through August 3, 2009.

Table B-9 Estimated number of PIT-tagged spring Chinook from Catherine Creek Acclimation Pond arriving Lower Granite Dam in each of the three study categories from 2001 to 2007 (with 90% confidence intervals), with detected adults at Lower Granite (GRA) and Bonneville (BON) adult ladders.

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimate smolt numbers in each study category (with 90% CI)		Detected adults (2-salt & older)	
					GRA	BON
2001	10,885 (10,747 – 11,021)	T0	4,790	(4,683 – 4,899)	11	18
		C0	379	(345 – 414)	0	0
		C1	4,642	(4,540 – 4,738)	2	3
2002	8,435 (8,181 – 8,709)	T0	2,697	(2,600 – 2,797)	24	33
		C0	2,445	(2,312 – 2,590)	12	11
		C1	3,120	(2,992 – 3,258)	10	10
2003	7,202 (6,926 – 7,493)	T0	2,494	(2,390 – 2,593)	9	10
		C0	3,222	(3,026 – 3,437)	8	8
		C1	1,412	(1,346 – 1,486)	5	6

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimate smolt numbers in each study category (with 90% CI)		Detected adults (2-salt & older)	
2004	5,348 (5,225 – 5,469)	T0	2,877	(2,787 – 2,963)	11	14
		C0	507	(464 – 552)	1	0
		C1	1,875	(1,800 – 1,942)	6	7
2005	4,848 (4,745 – 4,954)	T0	2,495	(2,417 – 2,574)	11	14
		C0	276	(247 – 307)	0	0
		C1	1,971	(1,903 – 2,043)	4	4
2006 [A]	6,478 (6,263 – 6,729)	T0	2,918	(2,801 – 3,045)	12	23
		C0	1,626	(1,507 – 1,745)	15	19
		C1	1,799	(1,705 – 1,889)	8	14
2007 [A B]	7,093 (6,835 – 7,362)	T0	2,237	(2,147 – 2,324)	12	15
		C0	3,268	(3,075 – 3,463)	12	14
		C1	1,534	(1,460 – 1,607)	8	8

[A] Migr. year 2006 and 2007 data use combined groups TWS & BWS
[B] Incomplete with 2-salt adult returns through August 3, 2009.

Table B-10 Estimated number of PIT-tagged summer Chinook from McCall Hatchery arriving Lower Granite Dam in each of the three study categories from 1997 to 2007 (with 90% confidence intervals), with detected adults at Lower Granite (GRA) and Bonneville (BON) adult ladders.

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimate smolt numbers in each study category (with 90% CI)		Detected adults (2-salt & older) GRA	BON
1997	22,381 (21,588 – 23,224)	T0	6,013	(5,888 – 6,136)	91	
		C0	6,761	(6,398 – 7,132)	74	
		C1	9,272	(8,854 – 9,738)	102	
1998	27,812 (27,474 – 28,141)	T0	10,142	(9,988 – 10,286)	273	
		C0	3,849	(3,721 – 3,983)	53	
		C1	12,816	(12,578 – 13,060)	94	
1999	31,571 (30,816 – 32,358)	T0	10,515	(10,281 – 10,742)	377	
		C0	8,407	(8,122 – 8,675)	202	
		C1	11,391	(11,062 – 11,684)	231	
2000	31,825 (31,170 – 32,466)	T0	12,806	(12,552 – 13,083)	497	584
		C0	13,064	(12,558 – 13,601)	269	299
		C1	4,485	(4,349 – 4,624)	91	101
2001	36,784 (36,578 – 36,994)	T0	16,704	(16,511 – 16,882)	206	246
		C0	1,000	(946 – 1,052)	3 [A]	3 [A]
		C1	15,536	(15,351 – 15,728)	6	7
2002	32,599 (32,042 – 33,229)	T0	8,842	(8,666 – 9,027)	131	164
		C0	10,280	(9,987 – 10,578)	106	127
		C1	12,315	(12,029 – 12,631)	126	154
2003	43,144 (42,480 – 43,777)	T0	14,006	(13,776 – 14,243)	111	124
		C0	19,821	(19,350 – 20,293)	107	122
		C1	8,722	(8,549 – 8,881)	30	32
2004	40,150 (39,903 – 40,402)	T0	20,858	(20,651 – 21,071)	84	113
		C0	2,368	(2,275 – 2,460)	6	7
		C1	16,352	(16,180 – 16,526)	19	34
2005	43,229 (42,951 – 43,487)	T0	22,567	(22,359 – 22,784)	141	168
		C0	2,501	(2,415 – 2,590)	10	11
		C1	17,325	(17,132 – 17,522)	31	38
2006 [B]	32,854 (32,318 – 33,407)	T0	14,142	(13,874 – 14,412)	164	191
		C0	8,912	(8,621 – 9,226)	92	119
		C1	9,102	(8,900 – 9,320)	61	67
2007 [B C]	28,581 (28,022 – 29,158)	T0	5,267	(5,144 – 5,403)	77	92
		C0	17,588	(17,135 – 18,063)	123	152
		C1	5,637	(5,497 – 5,787)	28	34

[A] Three returning adults with no detections may have inadvertently been transported (in-river SARs based solely on Category C1 fish in 2001).
[B] Migr. year 2006 and 2007 data use combined groups TWS & BWS
[C] Incomplete with 2-salt adult returns through August 3, 2009.

Table B-11 Estimated number of PIT-tagged summer Chinook from Imnaha River Acclimation Pond arriving Lower Granite Dam in each of the three study categories from 1997 to 2007 (with 90% confidence intervals), with detected adults at Lower Granite (GRA) and Bonneville (BON) adult ladders.

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimated smolt numbers in each study category (with 90% CI)		Detected adults (2-salt & older) GRA	BON
1997	8,254 (7,814 – 8,740)	T0	2,147	(2.079 – 2,212)	25	
		C0	2,219	(2,032 – 2,433)	19	
		C1	3,785	(3,535 – 4,040)	26	
1998	13,577 (13,327 – 13,833)	T0	4,809	(4,709 – 4,910)	41	
		C0	1,995	(1,900 – 2,085)	11	
		C1	6,335	(6,194 – 6,483)	19	
1999	13,244 (12,829 – 13,687)	T0	4,827	(4,688 – 4,963)	130	
		C0	2,869	(2,733 – 3,008)	41	
		C1	5,084	(4,884 – 5,268)	62	
2000	14,267 (13,926 – 14,650)	T0	6,789	(6,597 – 6,991)	211	262
		C0	4,396	(4,159 – 4,672)	106	114
		C1	2,254	(2,166 – 2,353)	37	41
2001	15,650 (15,531 – 15,763)	T0	7,730	(7,609 – 7,855)	48	61
		C0	336	(336 – 396)	1 [A]	4 [A]
		C1	6,939	(6,819 – 7,055)	4	4
2002	13,962 (13,560 – 14,380)	T0	3,912	(3,777 – 4,041)	31	41
		C0	4,637	(4,429 – 4,853)	21	27
		C1	5,135	(4,952 – 5,333)	28	33
2003	14,948 (14,553 – 15,372)	T0	5,189	(5,039 – 5,338)	30	39
		C0	6,707	(6,426 – 7,024)	32	38
		C1	2,917	(2,818 – 3,012)	11	13
2004	12,867 (12,705 – 13,015)	T0	6,927	(6,802 – 7,052)	26	41
		C0	1,307	(1,228 – 1,384)	3	5
		C1	4,471	(4,367 – 4,580)	5	7
2005	11,172 (11,035 – 11,316)	T0	6,012	(5,898 – 6,134)	17	23
		C0	615	(570 – 665)	1	1
		C1	4,384	(4,280 – 4,478)	7	7
2006 [B]	13,095 (12,766 – 13,428)	T0	5,722	(5,559 – 5,893)	44	59
		C0	2,805	(2,664 – 2,954)	35	38
		C1	4,201	(4,067 – 4,348)	20	28
2007 [B C]	14,273 (13,940 – 14,679)	T0	2,182	(2,107 – 2,258)	21	25
		C0	7,811	(7,555 – 8,126)	48	61
		C1	4,249	(4,108 – 4,393)	20	27

[A] One returning adult with no detections may have inadvertently been transported (in-river SARs based solely on Category C1 fish in 2001).
[B] Migr. year 2006 and 2007 data use combined groups TWS & BWS
[C] Incomplete with 2-salt adult returns through August 3, 2009.

Table B-12 Estimated number of PIT-tagged wild steelhead (aggregate of tagged fish >130 mm released in 12-month period between July 1 and June 30) arriving Lower Granite Dam in each of the three study categories from 1997 to 2006 (with 90% confidence intervals), with detected adults at Lower Granite (GRA) adult ladders.

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimated smolt numbers in each study category (with 90% CI)		LGR detected returning adults
1997	3,830 (3,744 – 3,920)	T0	275	(248 – 301)	4
		C0	454	(415 – 492)	3
		C1	2,984	(2,905 – 3,066)	7
1998	7,109 (7,010 – 7,208)	T0	480	(443 – 518)	1
		C0	750	(700 – 800)	8
		C1	5,150	(5,053 – 5,242)	11
1999	8,820 (8,695 – 8,960)	T0	391	(358 – 424)	12
		C0	1,113	(1,052 – 1,178)	15
		C1	6,992	(6,878 – 7,114)	53
2000	13,609 (13,418 – 13,818)	T0	466	(426 – 505)	13
		C0	1,871	(1,780 – 1,961)	36
		C1	10,616	(10,461 – 10,773)	192

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimated smolt numbers in each study category (with 90% CI)		LGR detected returning adults
2001[A]	12,929 (12,810 – 13,066)	T0	201	(179 – 226)	5
		C0	103	(87 – 120)	3 [B]
		C1	11,892	(11,748– 12,014)	8
2002	13,378 (13,148 – 13,598)	T0	317	(289 – 346)	9
		C0	4,045	(3,908 – 4,197)	27
		C1	8,726	(8,552 – 8,891)	82
2003	12,926 (12,707 – 13,143)	T0	2,210	(2,123 – 2,295)	44
		C0	3,324	(3,194 – 3,458)	15
		C1	7,137	(6,980 – 7,285)	37
2004	13,263 (13,118 – 13,398)	T0	4,474	(4,369 – 4,566)	39
		C0	330	(284 – 374)	0
		C1	7,865	(7,730 – 7,991)	5
2005	15,621 (15,486 – 15,757)	T0	4,861	(4,757 – 4,967)	41
		C0	210	(188 – 233)	3
		C1	9,622	(9,486 – 9,756)	14
2006[C]	7,908 (7,771 – 8,058)	T0	3,424	(3,328 – 3,518)	46
		C0	585	(541 – 629)	8
		C1	3,610	(3,513 – 3,717)	23

[A] Estimates of number of smolts in study categories in 2001 are approximate due to potentially high holdover rate in lower Snake River affecting reach survival estimates and ultimately the smolt estimates in LGR-equivalents for each study category.
[B] Three returning adults with no detections may have inadvertently been transported or held-over to the following year (in-river SARs based solely on Category C1 fish in 2001).
[C] Migration year 2006 is incomplete until 3-salt returns (if any) occur after 7/1/2009 at GRA.

Table B-13 Estimated number of PIT-tagged hatchery steelhead (aggregate of tagged fish released in 3-month period between April 1 and June 30) arriving Lower Granite Dam in each of the three study categories from 1997 to 2005 (with 90% confidence intervals), with detected adults at Lower Granite (GRA) adult ladders.

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimated smolt numbers in each study category (with 90% CI)		LGR detected returning adults
1997	24,710 (24,477 – 24,933)	T0	1,729	(1,665 – 1,798)	9
		C0	3,390	(3,266 – 3,526)	8
		C1	19,095	(18,895 – 19,307)	32
1998	23,507 (23,325 – 23,685)	T0	1,365	(1,304 – 1,425)	7
		C0	2,926	(2,826 – 3,023)	26
		C1	17,958	(17,778 – 18,129)	40
1999	27,193 (26,959 – 27,426)	T0	1,336	(1,274 – 1,395)	12
		C0	3,952	(3,839 – 4,055)	41
		C1	20,975	(20,767 – 21,192)	124
2000	24,565 (24,280 – 24,847)	T0	668	(621 – 717)	14
		C0	4,408	(4,237 – 4,589)	42
		C1	18,804	(18,598 – 19,013)	197
2001[A]	20,877 (20,739 – 21,031)	T0	427	(389 – 464)	4
		C0	372	(334 – 414)	2 [B]
		C1	19,132	(18,985 – 19,294)	3
2002	20,681 (20,328 – 21,037)	T0	284	(256 – 313)	3
		C0	6,129	(5,917 – 6,338)	43
		C1	14,038	(13,764 – 14,322)	102
2003	21,400 (21,051 – 21,734)	T0	4,595	(4,472 – 4,715)	83
		C0	6,465	(6,247 – 6,687)	44
		C1	10,122	(9,912 – 10,309)	37
2004	17,082 (16,985 – 17,176)	T0	470	(432 – 508)	10
		C0	382	(351 – 417)	3
		C1	15,609	(15,504 – 15,712)	30

Migr. Year	Estimated smolt population at LGR (with 90% CI)	Study category	Estimated smolt numbers in each study category (with 90% CI)		LGR detected returning adults
2005	19,640 (19,527 – 19,750)	T0	887	(839 – 941)	18
		C0	349	(324 – 375)	2
		C1	17,530	(17,408 – 17,652)	41
2006 [C]	13,473 (13,328 – 13,610)	T0	800	(750 – 846)	17
		C0	1,546	(1,474 – 1,617)	22
		C1	10,754	(10,625 – 10,889)	132

[A] Estimates of number of smolts in study categories in 2001 are approximate due to potentially high holdover rate in lower Snake River affecting reach survival estimates and ultimately the smolt estimates in LGR-equivalents for each study category.
[B] Two returning adults with no detections may have inadvertently been transported or held-over to the following year so in-river SARs based solely on Category C1 fish in 2001
[C] Migration year 2005 is incomplete until 3-salt returns (if any) occur after 7/1/2009 at GRA.

Table B-14 In-river smolt survival rate estimates through hydrosystem for the PIT-tag aggregate of wild spring/summer Chinook migrating in 1994 to 2007.

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
1994	S1 (rel-lgr)	0.307	0.301	0.313
	S2 (lgr-lgs)	0.821	0.797	0.846
	S3 (lgs-lmn)	0.836	0.809	0.868
1995	S1 (rel-lgr)	0.271	0.267	0.275
	S2 (lgr-lgs)	0.895	0.879	0.911
	S3 (lgs-lmn)	0.951	0.924	0.978
	S4 (lmn-mcn)	0.764	0.657	0.917
1996	S1 (rel-lgr)	0.366	0.355	0.377
	S2 (lgr-lgs)	0.908	0.871	0.948
	S3 (lgs-lmn)	0.911	0.851	0.975
1997	S1 (rel-lgr)	0.296	0.283	0.314
	S2 (lgr-lgs)	0.922	0.859	0.990
	S3 (lgs-lmn)	0.931	0.822	1.057
1998	S1 (rel-lgr)	0.513	0.506	0.520
	S2 (lgr-lgs)	1.003	0.986	1.021
	S3 (lgs-lmn)	0.850	0.828	0.873
	S4 (lmn-mcn)	0.940	0.892	0.992
	S5 (mcn-jda)	0.854	0.760	0.967
1999	S1 (rel-lgr)	0.413	0.409	0.418
	S2 (lgr-lgs)	0.958	0.948	0.967
	S3 (lgs-lmn)	0.924	0.914	0.935
	S4 (lmn-mcn)	0.889	0.870	0.911
	S5 (mcn-jda)	0.889	0.852	0.926
	S6 (jda-bon)	0.845	0.736	1.002
2000	S1 (rel-lgr)	0.369	0.364	0.376
	S2 (lgr-lgs)	0.897	0.880	0.915
	S3 (lgs-lmn)	0.868	0.842	0.893
	S4 (lmn-mcn)	0.977	0.934	1.022
	S5 (mcn-jda)	0.734	0.674	0.804
	S6 (jda-bon)	0.866	0.708	1.097
2001	S1 (rel-lgr)	0.469	0.465	0.474
	S2 (lgr-lgs)	0.930	0.925	0.936
	S3 (lgs-lmn)	0.773	0.763	0.783
	S4 (lmn-mcn)	0.684	0.670	0.699
	S5 (mcn-jda)	0.714	0.668	0.770
	S6 (jda-bon)	0.662	0.548	0.817
2002	S1 (rel-lgr)	0.347	0.341	0.353
	S2 (lgr-lgs)	0.901	0.883	0.920
	S3 (lgs-lmn)	0.996	0.975	1.016
	S4 (lmn-mcn)	0.810	0.785	0.837
	S5 (mcn-jda)	0.873	0.826	0.927
	S6 (jda-bon)	0.967	0.780	1.268
2003	S1 (rel-lgr)	0.302	0.298	0.306
	S2 (lgr-lgs)	0.893	0.877	0.911
	S3 (lgs-lmn)	0.878	0.850	0.908
	S4 (lmn-mcn)	0.990	0.954	1.023
	S5 (mcn-jda)	0.798	0.754	0.841
	S6 (jda-bon)	0.962	0.822	1.159

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2004	S1 (rel-lgr)	0.326	0.324	0.330
	S2 (lgr-lgs)	0.970	0.961	0.980
	S3 (lgs-lmn)	0.830	0.810	0.850
	S4 (lmn-mcn)	0.878	0.838	0.921
	S5 (mcn-jda)	0.744	0.667	0.848
	S6 (jda-bon)	0.756	0.579	1.006
2005	S1 (rel-lgr)	0.317	0.314	0.320
	S2 (lgr-lgs)	0.905	0.898	0.913
	S3 (lgs-lmn)	0.890	0.874	0.907
	S4 (lmn-mcn)	0.895	0.861	0.932
	S5 (mcn-jda)	0.766	0.694	0.859
	S6 (jda-bon)	0.862	0.662	1.221
2006	S1 (rel-lgr)	0.431	0.424	0.438
	S2 (lgr-lgs)	0.937	0.920	0.953
	S3 (lgs-lmn)	0.932	0.908	0.955
	S4 (lmn-mcn)	0.879	0.842	0.921
	S5 (mcn-jda)	0.931	0.855	1.018
	S6 (jda-bon)	0.795	0.578	1.190
2007	S1 (rel-lgr)	0.438	0.430	0.446
	S2 (lgr-lgs)	0.932	0.907	0.960
	S3 (lgs-lmn)	0.952	0.912	0.997
	S4 (lmn-mcn)	0.881	0.845	0.920
	S5 (mcn-jda)	0.868	0.833	0.910

Table B-15 In-river smolt survival rate estimates from hatchery to LGR and through reaches in the hydrosystem for PIT-tagged Rapid River Hatchery spring Chinook migrating in 1997 to 2007.

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
1997	S1 (rel-lgr)	0.390	0.376	0.406
	S2 (lgr-lgs)	0.964	0.903	1.027
	S3 (lgs-lmn)	0.803	0.746	0.867
1998	S1 (rel-lgr)	0.665	0.658	0.672
	S2 (lgr-lgs)	1.005	0.986	1.024
	S3 (lgs-lmn)	0.847	0.826	0.869
	S4 (lmn-mcn)	0.982	0.924	1.045
	S5 (mcn-jda)	0.798	0.713	0.897
1999	S1 (rel-lgr)	0.751	0.738	0.765
	S2 (lgr-lgs)	0.923	0.901	0.943
	S3 (lgs-lmn)	0.957	0.937	0.977
	S4 (lmn-mcn)	0.906	0.875	0.939
	S5 (mcn-jda)	0.945	0.882	1.022
	S6 (jda-bon)	0.750	0.622	0.923
2000	S1 (rel-lgr)	0.737	0.724	0.752
	S2 (lgr-lgs)	0.846	0.813	0.882
	S3 (lgs-lmn)	1.127	1.016	1.255
	S4 (lmn-mcn)	0.823	0.721	0.937
	S5 (mcn-jda)	0.945	0.760	1.250
	S6 (jda-bon)	0.782	0.546	1.171
2001	S1 (rel-lgr)	0.690	0.686	0.694
	S2 (lgr-lgs)	0.958	0.951	0.965
	S3 (lgs-lmn)	0.856	0.843	0.867
	S4 (lmn-mcn)	0.698	0.683	0.715
	S5 (mcn-jda)	0.924	0.854	1.013
	S6 (jda-bon)	0.618	0.497	0.802
2002	S1 (rel-lgr)	0.755	0.741	0.769
	S2 (lgr-lgs)	0.947	0.923	0.972
	S3 (lgs-lmn)	0.981	0.959	1.004
	S4 (lmn-mcn)	0.841	0.819	0.863
	S5 (mcn-jda)	0.953	0.895	1.018
	S6 (jda-bon)	0.951	0.770	1.191
2003	S1 (rel-lgr)	0.692	0.679	0.705
	S2 (lgr-lgs)	0.916	0.883	0.952
	S3 (lgs-lmn)	0.875	0.808	0.945
	S4 (lmn-mcn)	0.964	0.890	1.045
	S5 (mcn-jda)	0.902	0.833	0.977
	S6 (jda-bon)	0.947	0.779	1.207

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2004	S1 (rel-lgr)	0.696	0.691	0.701
	S2 (lgr-lgs)	0.999	0.985	1.014
	S3 (lgs-lmn)	0.754	0.708	0.802
	S4 (lmn-mcn)	0.880	0.810	0.950
	S5 (mcn-jda)	0.766	0.659	0.893
	S6 (jda-bon)	0.696	0.477	1.113
2005	S1 (rel-lgr)	0.736	0.731	0.740
	S2 (lgr-lgs)	0.947	0.937	0.955
	S3 (lgs-lmn)	0.907	0.883	0.935
	S4 (lmn-mcn)	0.896	0.845	0.941
	S5 (mcn-jda)	0.887	0.779	1.021
	S6 (jda-bon)	0.784	0.583	1.106
2006	S1 (rel-lgr)	0.763	0.751	0.775
	S2 (lgr-lgs)	0.880	0.859	0.900
	S3 (lgs-lmn)	0.916	0.890	0.944
	S4 (lmn-mcn)	0.942	0.894	0.988
	S5 (mcn-jda)	0.842	0.775	0.928
2007	S1 (rel-lgr)	0.743	0.729	0.758
	S2 (lgr-lgs)	0.934	0.905	0.966
	S3 (lgs-lmn)	0.939	0.902	0.977
	S4 (lmn-mcn)	0.932	0.896	0.969
	S5 (mcn-jda)	0.982	0.939	1.026
	S6 (jda-bon)	0.786	0.687	0.925

Table B-16 In-river smolt survival rate estimates from hatchery to LGR and through reaches in the hydrosystem for PIT-tagged Dworshak Hatchery spring Chinook migrating in 1997 to 2007.

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
1997	S1 (rel-lgr)	0.581	0.547	0.613
	S2 (lgr-lgs)	1.047	0.959	1.148
	S3 (lgs-lmn)	0.810	0.725	0.908
1998	S1 (rel-lgr)	0.843	0.832	0.855
	S2 (lgr-lgs)	1.071	1.043	1.098
	S3 (lgs-lmn)	0.765	0.740	0.790
	S4 (lmn-mcn)	0.931	0.891	0.976
	S5 (mcn-jda)	0.782	0.696	0.891
1999	S1 (rel-lgr)	0.853	0.832	0.873
	S2 (lgr-lgs)	0.887	0.862	0.914
	S3 (lgs-lmn)	0.952	0.935	0.968
	S4 (lmn-mcn)	0.875	0.848	0.901
	S5 (mcn-jda)	0.899	0.849	0.959
	S6 (jda-bon)	0.816	0.684	1.010
2000	S1 (rel-lgr)	0.825	0.809	0.843
	S2 (lgr-lgs)	0.807	0.777	0.839
	S3 (lgs-lmn)	1.036	0.955	1.124
	S4 (lmn-mcn)	0.834	0.754	0.920
	S5 (mcn-jda)	0.944	0.804	1.145
	S6 (jda-bon)	0.730	0.543	1.007
2001	S1 (rel-lgr)	0.748	0.744	0.752
	S2 (lgr-lgs)	0.941	0.934	0.947
	S3 (lgs-lmn)	0.839	0.828	0.849
	S4 (lmn-mcn)	0.694	0.681	0.707
	S5 (mcn-jda)	0.693	0.654	0.739
	S6 (jda-bon)	0.636	0.510	0.839
2002	S1 (rel-lgr)	0.827	0.803	0.849
	S2 (lgr-lgs)	0.917	0.884	0.953
	S3 (lgs-lmn)	0.978	0.950	1.007
	S4 (lmn-mcn)	0.810	0.787	0.834
	S5 (mcn-jda)	0.931	0.877	0.995
	S6 (jda-bon)	0.910	0.758	1.086

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2003	S1 (rel-lgr)	0.706	0.692	0.721
	S2 (lgr-lgs)	0.905	0.875	0.937
	S3 (lgs-lmn)	0.897	0.855	0.946
	S4 (lmn-mcn)	0.983	0.931	1.031
	S5 (mcn-jda)	0.856	0.807	0.910
	S6 (jda-bon)	0.990	0.825	1.235
2004	S1 (rel-lgr)	0.823	0.817	0.830
	S2 (lgr-lgs)	0.977	0.964	0.991
	S3 (lgs-lmn)	0.969	0.911	1.024
	S4 (lmn-mcn)	0.779	0.726	0.839
	S5 (mcn-jda)	0.790	0.699	0.917
	S6 (jda-bon)	0.858	0.642	1.217
2005	S1 (rel-lgr)	0.831	0.826	0.836
	S2 (lgr-lgs)	0.927	0.917	0.936
	S3 (lgs-lmn)	0.893	0.870	0.918
	S4 (lmn-mcn)	0.967	0.920	1.012
	S5 (mcn-jda)	0.837	0.728	0.962
	S6 (jda-bon)	0.759	0.587	1.032
2006	S1 (rel-lgr)	0.839	0.820	0.857
	S2 (lgr-lgs)	0.835	0.812	0.860
	S3 (lgs-lmn)	0.925	0.899	0.952
	S4 (lmn-mcn)	0.874	0.836	0.919
	S5 (mcn-jda)	0.928	0.851	1.007
2007	S1 (rel-lgr)	0.828	0.810	0.847
	S2 (lgr-lgs)	0.923	0.891	0.953
	S3 (lgs-lmn)	0.938	0.906	0.972
	S4 (lmn-mcn)	0.947	0.914	0.978
	S5 (mcn-jda)	0.909	0.878	0.942
	S6 (jda-bon)	0.898	0.793	1.036

Table B-17 In-river smolt survival rate estimates from hatchery to LGR and through reaches in the hydrosystem for PIT-tagged Catherine Creek Acclimation Pond spring Chinook migrating in 2001 to 2007.

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2001	S1 (rel-lgr)	0.520	0.513	0.528
	S2 (lgr-lgs)	0.945	0.931	0.961
	S3 (lgs-lmn)	0.814	0.787	0.840
	S4 (lmn-mcn)	0.659	0.624	0.699
	S5 (mcn-jda)	0.768	0.654	0.901
	S6 (jda-bon)	0.639	0.419	1.101
2002	S1 (rel-lgr)	0.406	0.391	0.421
	S2 (lgr-lgs)	0.949	0.899	0.998
	S3 (lgs-lmn)	1.013	0.954	1.073
	S4 (lmn-mcn)	0.808	0.743	0.887
	S5 (mcn-jda)	0.928	0.779	1.125
	S6 (jda-bon)	0.896	0.562	1.726
2003	S1 (rel-lgr)	0.349	0.334	0.366
	S2 (lgr-lgs)	0.972	0.892	1.061
	S3 (lgs-lmn)	0.855	0.747	1.004
	S4 (lmn-mcn)	1.093	0.925	1.273
	S5 (mcn-jda)	0.764	0.643	0.919
2004	S1 (rel-lgr)	0.255	0.248	0.262
	S2 (lgr-lgs)	0.976	0.943	1.009
	S3 (lgs-lmn)	0.921	0.823	1.050
	S4 (lmn-mcn)	0.900	0.749	1.086
	S5 (mcn-jda)	0.704	0.503	1.036
	S6 (jda-bon)	0.579	0.273	2.172
2005	S1 (rel-lgr)	0.233	0.227	0.239
	S2 (lgr-lgs)	0.936	0.909	0.960
	S3 (lgs-lmn)	0.889	0.831	0.954
	S4 (lmn-mcn)	0.997	0.881	1.156
	S5 (mcn-jda)	0.728	0.525	1.090

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2006	S1 (rel-lgr)	0.309	0.296	0.323
	S2 (lgr-lgs)	0.904	0.851	0.965
	S3 (lgs-lmn)	0.934	0.855	1.028
	S4 (lmn-mcn)	0.937	0.811	1.096
	S5 (mcn-jda)	0.728	0.580	0.934
2007	S1 (rel-lgr)	0.341	0.326	0.357
	S2 (lgr-lgs)	0.930	0.862	0.998
	S3 (lgs-lmn)	1.007	0.914	1.130
	S4 (lmn-mcn)	0.885	0.794	0.976
	S5 (mcn-jda)	0.940	0.841	1.065
	S6 (jda-bon)	0.921	0.647	1.467

Table B-18 In-river smolt survival rate estimates from hatchery to LGR and through reaches in the hydrosystem for PIT-tagged McCall Hatchery summer Chinook in migration years 1997 to 2007.

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
1997	S1 (rel-lgr)	0.425	0.411	0.441
	S2 (lgr-lgs)	0.935	0.889	0.987
	S3 (lgs-lmn)	0.882	0.820	0.954
1998	S1 (rel-lgr)	0.588	0.580	0.595
	S2 (lgr-lgs)	0.991	0.971	1.012
	S3 (lgs-lmn)	0.843	0.820	0.867
	S4 (lmn-mcn)	0.942	0.884	1.007
	S5 (mcn-jda)	0.824	0.738	0.930
1999	S1 (rel-lgr)	0.658	0.642	0.675
	S2 (lgr-lgs)	0.908	0.880	0.939
	S3 (lgs-lmn)	0.936	0.908	0.961
	S4 (lmn-mcn)	0.913	0.872	0.957
	S5 (mcn-jda)	1.086	0.989	1.206
	S6 (jda-bon)	0.622	0.514	0.766
2000	S1 (rel-lgr)	0.667	0.650	0.685
	S2 (lgr-lgs)	0.867	0.813	0.932
	S3 (lgs-lmn)	0.917	0.807	1.036
	S4 (lmn-mcn)	1.034	0.911	1.181
	S5 (mcn-jda)	1.307	0.904	2.258
	S6 (jda-bon)	0.570	0.323	0.887
2001	S1 (rel-lgr)	0.667	0.663	0.672
	S2 (lgr-lgs)	0.928	0.920	0.937
	S3 (lgs-lmn)	0.771	0.756	0.786
	S4 (lmn-mcn)	0.647	0.628	0.666
	S5 (mcn-jda)	0.862	0.784	0.954
	S6 (jda-bon)	0.674	0.531	0.924
2002	S1 (rel-lgr)	0.596	0.583	0.609
	S2 (lgr-lgs)	0.964	0.936	0.992
	S3 (lgs-lmn)	0.990	0.964	1.016
	S4 (lmn-mcn)	0.837	0.809	0.869
	S5 (mcn-jda)	1.051	0.969	1.144
	S6 (jda-bon)	0.688	0.583	0.840
2003	S1 (rel-lgr)	0.581	0.570	0.591
	S2 (lgr-lgs)	0.921	0.893	0.951
	S3 (lgs-lmn)	0.884	0.844	0.932
	S4 (lmn-mcn)	1.014	0.962	1.068
	S5 (mcn-jda)	0.907	0.854	0.962
	S6 (jda-bon)	0.929	0.803	1.068
2004	S1 (rel-lgr)	0.563	0.559	0.567
	S2 (lgr-lgs)	0.938	0.927	0.949
	S3 (lgs-lmn)	0.993	0.938	1.055
	S4 (lmn-mcn)	0.754	0.698	0.814
	S5 (mcn-jda)	0.893	0.786	1.030
	S6 (jda-bon)	0.696	0.517	1.014

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2005	S1 (rel-lgr)	0.603	0.598	0.607
	S2 (lgr-lgs)	0.935	0.926	0.945
	S3 (lgs-lmn)	0.919	0.895	0.944
	S4 (lmn-mcn)	0.913	0.870	0.960
	S5 (mcn-jda)	0.864	0.756	1.011
	S6 (jda-bon)	0.782	0.612	1.042
2006	S1 (rel-lgr)	0.633	0.621	0.646
	S2 (lgr-lgs)	0.871	0.843	0.897
	S3 (lgs-lmn)	0.932	0.898	0.967
	S4 (lmn-mcn)	0.965	0.904	1.024
	S5 (mcn-jda)	0.862	0.769	0.963
2007	S1 (rel-lgr)	0.553	0.540	0.566
	S2 (lgr-lgs)	0.972	0.934	1.012
	S3 (lgs-lmn)	0.961	0.917	1.007
	S4 (lmn-mcn)	0.923	0.883	0.964
	S5 (mcn-jda)	1.016	0.973	1.064
	S6 (jda-bon)	0.939	0.813	1.111

Table B-19 In-river smolt survival rate estimates from hatchery to LGR and through reaches in the hydrosystem for PIT-tagged Imnaha Acclimation Pond summer Chinook in migration years 1997 to 2007.

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
1997	S1 (rel-lgr)	0.617	0.586	0.654
	S2 (lgr-lgs)	0.994	0.909	1.082
	S3 (lgs-lmn)	0.768	0.693	0.856
1998	S1 (rel-lgr)	0.685	0.673	0.697
	S2 (lgr-lgs)	0.978	0.951	1.006
	S3 (lgs-lmn)	0.843	0.812	0.872
	S4 (lmn-mcn)	0.956	0.894	1.035
	S5 (mcn-jda)	0.784	0.685	0.907
1999	S1 (rel-lgr)	0.664	0.645	0.686
	S2 (lgr-lgs)	0.921	0.885	0.957
	S3 (lgs-lmn)	0.954	0.920	0.989
	S4 (lmn-mcn)	0.876	0.825	0.931
	S5 (mcn-jda)	0.944	0.840	1.075
	S6 (jda-bon)	0.740	0.548	1.103
2000	S1 (rel-lgr)	0.685	0.665	0.707
	S2 (lgr-lgs)	0.822	0.774	0.877
	S3 (lgs-lmn)	1.008	0.869	1.201
	S4 (lmn-mcn)	0.885	0.717	1.081
	S5 (mcn-jda)	0.893	0.677	1.293
	S6 (jda-bon)	1.013	0.570	2.469
2001	S1 (rel-lgr)	0.748	0.742	0.755
	S2 (lgr-lgs)	0.958	0.950	0.968
	S3 (lgs-lmn)	0.892	0.877	0.908
	S4 (lmn-mcn)	0.751	0.729	0.776
	S5 (mcn-jda)	0.853	0.763	0.958
	S6 (jda-bon)	0.678	0.462	1.226
2002	S1 (rel-lgr)	0.667	0.645	0.691
	S2 (lgr-lgs)	0.951	0.910	0.994
	S3 (lgs-lmn)	0.947	0.911	0.984
	S4 (lmn-mcn)	0.858	0.817	0.904
	S5 (mcn-jda)	0.828	0.753	0.914
	S6 (jda-bon)	0.788	0.603	1.120
2003	S1 (rel-lgr)	0.715	0.694	0.739
	S2 (lgr-lgs)	0.901	0.853	0.953
	S3 (lgs-lmn)	0.905	0.813	1.014
	S4 (lmn-mcn)	0.914	0.816	1.029
	S5 (mcn-jda)	1.027	0.909	1.153

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2004	S1 (rel-lgr)	0.615	0.606	0.624
	S2 (lgr-lgs)	0.964	0.940	0.988
	S3 (lgs-lmn)	0.910	0.828	1.002
	S4 (lmn-mcn)	0.834	0.731	0.954
	S5 (mcn-jda)	0.878	0.686	1.153
	S6 (jda-bon)	0.576	0.315	1.429
2005	S1 (rel-lgr)	0.534	0.526	0.542
	S2 (lgr-lgs)	0.920	0.902	0.938
	S3 (lgs-lmn)	0.871	0.832	0.915
	S4 (lmn-mcn)	1.029	0.938	1.144
	S5 (mcn-jda)	0.822	0.665	1.051
2006	S1 (rel-lgr)	0.635	0.616	0.654
	S2 (lgr-lgs)	0.833	0.801	0.866
	S3 (lgs-lmn)	0.927	0.885	0.966
	S4 (lmn-mcn)	0.870	0.808	0.944
	S5 (mcn-jda)	0.877	0.763	1.025
2007	S1 (rel-lgr)	0.683	0.663	0.706
	S2 (lgr-lgs)	0.931	0.886	0.972
	S3 (lgs-lmn)	0.940	0.890	0.994
	S4 (lmn-mcn)	0.972	0.922	1.021
	S5 (mcn-jda)	0.949	0.887	1.015
	S6 (jda-bon)	0.851	0.670	1.166

Table B-20 In-river smolt survival rate estimates through reaches in the hydrosystem for the PIT-tag aggregate of wild summer steelhead in migration years 1997 to 2006.

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
1997	S1 (rel-lgr)	0.497	0.484	0.511
	S2 (lgr-lgs)	0.984	0.949	1.018
	S3 (lgs-lmn)	0.975	0.904	1.055
	S4 (lmn-mcn)	0.886	0.688	1.226
	S5 (mcn-jda)	0.721	0.380	2.054
1998	S1 (rel-lgr)	0.676	0.665	0.688
	S2 (lgr-lgs)	0.969	0.944	0.995
	S3 (lgs-lmn)	0.843	0.809	0.880
	S4 (lmn-mcn)	0.889	0.794	1.001
	S5 (mcn-jda)	0.868	0.746	1.019
1999	S1 (rel-lgr)	0.560	0.550	0.570
	S2 (lgr-lgs)	0.974	0.957	0.992
	S3 (lgs-lmn)	0.910	0.886	0.936
	S4 (lmn-mcn)	0.835	0.785	0.892
	S5 (mcn-jda)	1.040	0.944	1.161
	S6 (jda-bon)	0.580	0.466	0.738
2000	S1 (rel-lgr)	0.561	0.552	0.570
	S2 (lgr-lgs)	0.790	0.772	0.806
	S3 (lgs-lmn)	0.910	0.881	0.943
	S4 (lmn-mcn)	0.860	0.801	0.925
	S5 (mcn-jda)	0.659	0.588	0.728
2001	S1 (rel-lgr)	0.528	0.521	0.534
	S2 (lgr-lgs)	0.834	0.824	0.844
	S3 (lgs-lmn)	0.716	0.693	0.738
	S4 (lmn-mcn)	0.288	0.266	0.313
	S5 (mcn-jda)	0.230	0.188	0.279
	S6 (jda-bon)	0.958	0.629	1.800
2002	S1 (rel-lgr)	0.531	0.521	0.542
	S2 (lgr-lgs)	0.943	0.918	0.969
	S3 (lgs-lmn)	1.164	1.114	1.224
	S4 (lmn-mcn)	0.522	0.489	0.559
	S5 (mcn-jda)	0.960	0.841	1.105
	S6 (jda-bon)	0.939	0.697	1.377

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2003	S1 (rel-lgr)	0.538	0.527	0.550
	S2 (lgr-lgs)	0.908	0.879	0.937
	S3 (lgs-lmn)	0.914	0.867	0.967
	S4 (lmn-mcn)	0.729	0.669	0.791
	S5 (mcn-jda)	0.913	0.807	1.044
	S6 (jda-bon)	0.664	0.527	0.866
2004	S1 (rel-lgr)	0.527	0.520	0.534
	S2 (lgr-lgs)	0.955	0.940	0.968
	S3 (lgs-lmn)	0.752	0.704	0.805
	S4 (lmn-mcn)	0.603	0.496	0.756
2005	S1 (rel-lgr)	0.612	0.606	0.619
	S2 (lgr-lgs)	0.912	0.903	0.921
	S3 (lgs-lmn)	0.832	0.804	0.862
	S4 (lmn-mcn)	0.719	0.645	0.805
	S5 (mcn-jda)	0.650	0.511	0.869
2006	S1 (rel-lgr)	0.477	0.467	0.488
	S2 (lgr-lgs)	0.957	0.937	0.979
	S3 (lgs-lmn)	0.922	0.897	0.951
	S4 (lmn-mcn)	0.885	0.819	0.954
	S5 (mcn-jda)	0.843	0.732	0.976

Table B-21 In-river smolt survival rate estimates through reaches in the hydrosystem for the PIT-tag aggregate of hatchery summer steelhead in migration years 1997 to 2006.

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
1997	S1 (rel-lgr)	0.692	0.685	0.701
	S2 (lgr-lgs)	0.954	0.938	0.972
	S3 (lgs-lmn)	0.853	0.822	0.886
	S4 (lmn-mcn)	0.938	0.810	1.106
	S5 (mcn-jda)	0.656	0.428	1.116
1998	S1 (rel-lgr)	0.760	0.753	0.768
	S2 (lgr-lgs)	0.950	0.937	0.964
	S3 (lgs-lmn)	0.854	0.835	0.874
	S4 (lmn-mcn)	0.820	0.774	0.867
	S5 (mcn-jda)	1.058	0.968	1.151
	S6 (jda-bon)	0.915	0.626	1.627
1999	S1 (rel-lgr)	0736	0.728	0.743
	S2 (lgr-lgs)	0.966	0.954	0.977
	S3 (lgs-lmn)	0.895	0.879	0.910
	S4 (lmn-mcn)	0.801	0.769	0.835
	S5 (mcn-jda)	1.045	0.982	1.107
	S6 (jda-bon)	0.622	0.524	0.757
2000	S1 (rel-lgr)	0.768	0.758	0.778
	S2 (lgr-lgs)	0.693	0.672	0.714
	S3 (lgs-lmn)	0.812	0.776	0.852
	S4 (lmn-mcn)	0.803	0.731	0.884
	S5 (mcn-jda)	0.705	0.608	0.818
2001	S1 (rel-lgr)	0.717	0.712	0.724
	S2 (lgr-lgs)	0.693	0.681	0.705
	S3 (lgs-lmn)	0.678	0.651	0.708
	S4 (lmn-mcn)	0.284	0.262	0.311
	S5 (mcn-jda)	0.353	0.284	0.463
	S6 (jda-bon)	0.805	0.415	2.247
2002	S1 (rel-lgr)	0.778	0.762	0.794
	S2 (lgr-lgs)	0.908	0.881	0.934
	S3 (lgs-lmn)	0.970	0.936	1.007
	S4 (lmn-mcn)	0.570	0.531	0.620
	S5 (mcn-jda)	0.937	0.816	1.090
	S6 (jda-bon)	0.777	0.571	1.139
2003	S1 (rel-lgr)	0.811	0.796	0.827
	S2 (lgr-lgs)	0.949	0.920	0.977
	S3 (lgs-lmn)	0.935	0.893	0.977
	S4 (lmn-mcn)	0.709	0.655	0.768
	S5 (mcn-jda)	0.954	0.850	1.081
	S6 (jda-bon)	0.842	0.672	1.076

Migr Year	Reach of Survival	Survival Estimate	95% CI Lower Limit	95% CI Upper Limit
2004	S1 (rel-lgr)	0.859	0.854	0.865
	S2 (lgr-lgs)	0.871	0.861	0.880
	S3 (lgs-lmn)	0.892	0.850	0.940
	S4 (lmn-mcn)	0.541	0.459	0.644
2005	S1 (rel-lgr)	0.835	0.830	0.841
	S2 (lgr-lgs)	0.924	0.918	0.931
	S3 (lgs-lmn)	0.861	0.840	0.883
	S4 (lmn-mcn)	0.787	0.722	0.858
	S5 (mcn-jda)	0.739	0.610	0.912
2006	S1 (rel-lgr)	0.838	0.827	0.849
	S2 (lgr-lgs)	0.962	0.946	0.976
	S3 (lgs-lmn)	0.894	0.875	0.914
	S4 (lmn-mcn)	0.779	0.739	0.822
	S5 (mcn-jda)	1.037	0.935	1.150

Table B-22 Number of PIT-tagged wild Chinook actually transported from each dam and estimate (ti) of total PIT-tagged wild Chinook that would have been transported if all tagged fish were transported at same rate as the untagged run-at-large, 1994 to 2007.

Migr Year	Lower Granite Dam		Little Goose Dam		Lower Monumental Dam	
	Actual	t2	Actual	t3	Actual	t4
1994	1,051	6,851	387	2,094	330	1,308
1995	1,702	9,657	356	3,626	156	1,490
1996	268	2,269	85	1,749	32	927
1997	185	1,064	30	335	11	171
1998	820	7,669	359	4,002	79	1,632
1999	1,107	8,183	319	14,213	287	4,594
2000	327	7,095	244	6,603	187	2,095
2001	452	18,062	72	2,904	13	278
2002	1,640	4,813	1,856	6,505	167	3,705
2003	5,098	11,694	2,548	6,634	599	1,495
2004	8,951	20,367	2,812	6,552	834	1,849
2005	12,063	24,029	3,222	6,507	231	457
2006	4,023	5,376	4,169	6,088	1,155	2,484
2007	2,200	4,276	612	2,946	334	1,147
Overall average/dam		**58.2%**		**31.3%**		**10.5%**

Table B-23 Estimated dam-specific transportation SARs (%) of the PIT-tagged wild Chinook aggregate for migration years 1994 to 2007 (with 90% confidence intervals).

Migr Year	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
1994	0.67	(0.28 – 1.12)	7	0.52	(0.0 – 1.11)	2	NA		None
1995	0.41	(0.18 – 0.68)	7	0.28	(0.0 – 0.84)	1	NA		None
1996	0.37	(0.0 – 1.10)	1	1.18	(0.0 – 3.41)	1	NA		None
1997	1.08	(0.0 – 2.37)	2	6.67	(0.0 – 14.8)	2	NA		None
1998	1.34	(0.72 – 2.01)	11	0.84	(0.0 – 1.66)	3	1.27	(0.0 – 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	(0.0 – 2.38)	2
2001	1.33	(0.46 – 2.23)	6	1.39	(0.0 – 4.11)	1	NA		None
2002	0.61	(0.30 – 0.95)	10	1.08	(0.70 – 1.53)	20	0.60	(0.0 – 1.79)	1
2003	0.31	(0.19 – 0.45)	16	0.51	(0.28 – 0.75)	13	0.17	(0.0 – 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	(0.52 – 0.94)	29	0.70	(0.48 – 0.91)	29	1.47	(0.92 – 2.06)	17
2007 [A]	1.00	(0.68 – 1.38)	22	0.82	(0.31 – 1.46)	5	0.90	(0.28 – 1.85)	3

[A] **Migration year 2007 is incomplete until 3-salt returns at GRA.**

Table B-24 Number of PIT-tagged hatchery Chinook actually transported from each dam and estimate (ti) of total PIT-tagged hatchery Chinook that would have been transported if all PIT-tagged fish had been transported at same rate as the untagged run-at-large.

Migr Year	Hat. Code [A]	Lower Granite Dam Actual	t2	Little Goose Dam Actual	t3	Lower Monumental Actual	t4
1997	RAPH	4,135	5,365	132	1,618	38	949
	MCCA	5,851	7,428	105	2,241	31	1,153
	DWOR	1,864	2,351	52	970	15	517
	IMNA	2,074	2,603	45	954	12	487
1998	RAPH	11,279	15,274	1,359	7,578	197	3,100
	MCCA	8,988	12,178	896	6,970	157	3,073
	DWOR	11,096	14,350	3,574	9,326	225	3,887
	IMNA	4,036	5,621	606	3,749	97	1,354
1999	RAPH	7,385	9,488	4,724	12,750	290	3,818
	MCCA	4,730	6,374	4,986	10,584	203	3,515
	DWOR	4,930	6,346	3,798	14,602	484	5,304
	IMNA	2,160	2,785	2,293	5,129	114	1,428
2000	RAPH	10,367	14,386	4,181	6,123	1,213	1,625
	MCCA	8,496	11,734	2,821	4,086	776	1,279
	DWOR	9,805	13,399	4,911	7,206	2,030	2,539
	IMNA	3,862	5,447	1,812	2,705	530	713
2001	RAPH	15,385	28,122	2,846	5,874	582	1,076
	MCCA	13,093	27,575	2,643	5,119	500	892
	DWOR	16,567	28,345	4,091	8,490	639	1,177
	IMNA	5,734	10,629	1,604	3,380	246	483
	CATH	3,375	7,356	1,096	2,143	195	373
2002	RAPH	5,339	8,475	5,312	8,852	572	8,534
	MCCA	4,284	6,729	4,140	6,951	200	7,305
	DWOR	4,088	6,417	4,348	7,274	734	9,673
	IMNA	1,616	2,531	1,953	3,271	194	2,814
	CATH	1,464	2,286	1,112	1,826	50	1,586
2003	RAPH	8,391	12,925	3,887	6,115	574	874
	MCCA	8,334	13,604	4,242	7,094	866	1,391
	DWOR	7,031	10,747	4,345	6,926	1,113	1,695
	IMNA	3,094	4,764	1,557	2,547	299	464
	CATH	1,564	2,416	698	1,141	176	291
2004	RAPH	13,511	21,806	5,271	8,775	550	946
	MCCA	16,455	28,896	3,877	6,879	251	439
	DWOR	12,725	20,489	8,154	13,623	552	888
	IMNA	4,754	7,583	1,916	3,230	162	292
	CATH	2,078	3,292	700	1,181	73	188
2005	RAPH	15,736	24,756	3,990	6,876	205	538
	MCCA	17,268	27,350	4,510	7,685	411	780
	DWOR	14,606	23,686	5,447	9,503	431	1,010
	IMNA	4,452	6,831	1,361	2,130	65	220
	CATH	1,903	2,998	526	903	25	103
2006	RAPH	8,053	10,971	6,357	10,131	2,404	4,321
	MCCA	6,017	8,102	4,756	7,462	2,165	3,808
	DWOR	4,223	6,999	5,939	10,761	2,601	5,419
	IMNA	1,975	2,839	2,342	3,861	722	1,350
	CATH	1,186	1,583	1,129	1,727	408	704
2007 [B]	RAPH	6,111	7,839	1,493	3,931	1,147	2,703
	MCCA	3,544	4,605	878	2,219	766	1,904
	DWOR	1,452	4,411	432	3,774	366	2,351
	IMNA	1,694	2,514	257	1,549	186	964
	CATH	1,412	1,614	489	846	280	531
Overall average/ dam			**57.9%**		**30.8%**		**11.3%**

[A] **Abbreviations: RAPH = Rapid River H; MCCA = McCall H; DWOR = Dworshak NFH; IMNA = Imnaha AP; CATH = Catherine Ck AP.**

[B] **Migration year 2007 is incomplete until 3-salt returns at GRA.**

Table B-25 Estimated dam-specific transportation SAR percentages of PIT-tagged hatchery Spring Chinook that outmigrated in 1997 to 2007 (with 90% confidence intervals).

Migr_Yr & Hat.[A]	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
'97 raph	0.80	(0.58 – 1.02)	33	NA		None	2.63	(0.0 – 7.89)	1
'97 dwor	0.86	(0.54 – 1.23)	16	NA		None	NA		None
'98 raph	2.12	(1.89 – 2.35)	239	1.18	(0.75 – 1.72)	16	1.02	(0.0 – 2.29)	2
'98 dwor	0.99	(0.85 – 1.14)	110	0.62	(0.41 – 0.85)	22	NA		None
'99 raph	3.20	(2.89 – 3.52)	236	3.22	(2.79 – 3.64)	152	1.03	(0.31 – 2.13)	3
'99 dwor	1.26	(1.01 – 1.53)	62	1.29	(0.99 – 1.59)	49	0.83	(0.21 – 1.62)	4
'00 raph	2.34	(2.10 – 2.58)	243	1.89	(1.52 – 2.30)	79	2.23	(1.43 – 3.06)	27
'00 dwor	1.18	(1.01 – 1.37)	116	1.08	(0.83 – 1.32)	53	0.69	(0.40 – 1.03)	14
'01 raph	1.18	(1.04 – 1.33)	182	0.74	(0.49 – 1.00)	21	0.69	(0.17 – 1.29)	4
'01 dwor	0.36	(0.29 – 0.44)	60	0.44	(0.27 – 0.60)	18	0.16	(0.00 – 0.47)	1
'01 cath	0.33	(0.18 – 0.50)	11	NA		None	NA		None
'02 raph	1.14	(0.91 – 1.39)	61	0.94	(0.72 – 1.17)	50	1.05	(0.37 – 1.74)	6
'02 dwor	0.64	(0.44 – 0.83)	26	0.74	(0.54 – 0.96)	32	0.27	(0.0 – 0.60)	2
'02 cath	1.09	(0.66 – 1.53)	16	0.72	(0.29 – 1.18)	8	NA		None
'03 raph	0.32	(0.23 – 0.43)	27	0.13	(0.05 – 0.23)	5	0.17	(0.0 – 0.53)	1
'03 dwor	0.28	(0.18 – 0.39)	20	0.28	(0.16 –0.41)	12	0.18	(0.0 – 0.38)	2
'03 cath	0.32	(0.12 – 0.57)	5	0.57	(0.14 – 1.06)	4	NA		None
'04 raph	0.39	(0.31 – 0.48)	53	0.30	(0.17 – 0.42)	16	0.18	(0.00 – 0.54)	1
'04 dwor	0.17	(0.12 – 0.24)	22	0.45	(0.34 – 0.58)	37	0.36	(0.00 – 0.81)	2
'04 cath	0.29	(0.10 – 0.48)	6	0.57	(0.14 – 1.04)	4	1.37	(0.00 – 4.17)	1
'05 raph	0.26	(0.19 – 0.33)	41	0.35	(0.22 – 0.51)	14	NA		None
'05 dwor	0.21	(0.16 – 0.29)	32	0.20	(0.11 – 0.31)	11	NA		None
'05 cath	0.32	(0.11 – 0.53)	6	0.95	(0.36 – 1.72)	5	NA		None
'06 raph	0.66	(0.52 – 0.81)	53	0.55	(0.40 – 0.72)	35	0.71	(0.44 – 0.98)	17
'06 dwor	0.38	(0.22 – 0.55)	16	0.39	(0.27 – 0.52)	23	0.50	(0.28 – 0.74)	13
'06 cath	0.25	(0.00 – 0.51)	3	0.44	(0.17 – 0.79)	5	0.98	(0.24 – 0.18)	4
'07 raph [B]	0.59	(0.43 – 0.76)	36	0.20	(0.0 – 0.40)	3	0.17	(0.0 – 0.43)	2
'07 dwor [B]	0.69	(0.35 – 1.04)	10	0.69	(0.21 – 1.34)	3	0.52	(0.25 – 1.68)	3
'07 cath [B]	0.57	(0.28 – 0.90)	8	0.20	(0.0 – 0.61)	1	1.07	(0.33 – 2.25)	3

[A] Abbreviations: raph=Rapid River H; dwor=Dworshak NFH; cath=Catherine Ck AP.
[B] Migration year 2007 is incomplete until 3-salt returns at GRA.

Table B-26 Estimated dam-specific transportation SAR percentages of PIT-tagged hatchery Summer Chinook that outmigrated in 1997 to 2007 (with 90% confidence intervals).

Migr_Yr & Hat.A	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
'97 mcca	1.49	(1.21 – 1.76)	87	2.86	(0.85 – 5.83)	3	3.23	(0.0 – 9.52)	1
'97 imna	1.21	(0.84 – 1.66)	25	NA		None	NA		None
'98 mcca	2.93	(2.65 – 3.22)	263	1.00	(0.46 – 1.62)	9	0.64	(0.0 – 1.88)	1
'98 imna	0.92	(0.69 – 1.18)	37	0.66	(0.17 – 1.22)	4	NA		None
'99 mcca	4.36	(3.88 – 4.83)	206	3.23	(2.82 – 3.65)	161	4.93	(2.26 – 7.58)	10
'99 imna	3.43	(2.82 – 4.08)	74	2.31	(1.80 – 2.86)	53	2.63	(0.0 – 5.31)	3
'00 mcca	4.54	(4.18 –4.94)	386	3.26	(2.69 – 3.83)	92	2.45	(1.61 – 3.36)	19
'00 imna	3.99	(3.50 – 4.48)	154	2.48	(1.91 – 3.09)	45	2.26	(1.18 – 3.36)	12
'01 mcca	1.41	(1.23 – 1.58)	184	0.76	(0.49 – 1.05)	20	0.40	(0.00 – 0.91)	2
'01 imna	0.73	(0.56 – 0.92)	42	0.37	(0.13 – 0.64)	6	NA		None
'02 mcca	1.63	(1.31 – 1.95)	70	1.43	(1.14 – 1.74)	59	1.00	(0.0 – 2.21)	2
'02 imna	0.74	(0.38 – 1.12)	12	0.82	(0.51 – 1.19)	16	1.55	(0.00 – 2.97)	3
'03 mcca	0.82	(0.66 – 0.98)	68	0.85	(0.62 – 1.10)	36	0.81	(0.34 – 1.31)	7
'03 imna	0.58	(0.36 – 0.81)	18	0.64	(0.32 – 0.99)	10	0.67	(0.0 – 1.58)	2
'04 mcca	0.43	(0.35 – 0.51)	70	0.36	(0.21 – 0.53)	14	NA		None
'04 imna	0.34	(0.21 – 0.48)	16	0.42	(0.20 – 0.68)	8	1.23	(0.00 – 2.91)	2
'05 mcca	0.67	(0.59 – 0.77)	116	0.53	(0.36 – 0.72)	24	0.02	(0.00 – 0.07)	1
'05 imna	0.34	(0.20 – 0.48)	15	0.15	(0.0 – 0.36)	2	NA		None

Migr_Yr & Hat.A	SAR(TLGR) %	(CI%)	Adult #	SAR(TLGS) %	(CI%)	Adult #	SAR(TLMN) %	(CI%)	Adult #
'06 mcca	1.35	(1.11 – 1.59)	81	1.05	(0.84 – 1.33)	50	1.52	(1.11 – 1.95)	33
'06 imna	0.81	(0.51 – 1.19)	16	0.81	(0.52 – 1.13)	19	1.25	(0.59 – 1.94)	9
'07 mcca [B]	1.55	(1.22 – 1.89)	55	1.37	(0.77 – 2.06)	12	1.31	(0.66 – 2.02)	10
'07 imna [B]	1.18	(0.72 – 1.62)	20	0.39	(0.0 – 1.15)	1	NA		None

[A] **Abbreviations: mcca=McCall H; imna=Imnaha AP.**
[B] **Migration year 2007 is incomplete until 3-salt returns at GRA.**

Table B-27 Number of PIT-tagged wild steelhead actually transported from each dam and estimate (ti) of total PIT-tagged wild steelhead that would have been transported if all PIT- tagged fish had been transported at same rate as the untagged run-at-large.

Migr Year	Lower Granite Dam		Little Goose Dam		Lower Monumental Dam	
	Actual	t2	Actual	t3	Actual	t4
1997	214	2,112	33	344	26	184
1998	294	4,246	100	1,164	68	595
1999	223	2,910	90	3,134	67	1,129
2000	200	6,264	89	2,643	110	971
2001	162	11,126	23	833	7	139
2002	128	3,804	62	2,896	135	2,154
2003	1,215	4,705	655	2,958	227	991
2004	3,408	9,509	807	2,168	158	438
2005	3,519	10,116	1,133	3,040	76	173
2006	1,592	2,513	1,393	2,546	333	837
Overall average/dam		**66.1 %**		**25.1 %**		**8.8 %**

Table B-28 Estimated dam-specific transportation SAR percentages of PIT-tagged wild steelhead in the annual aggregate groups for 1997 to 2006 (with 90% confidence intervals).

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	(0.0 – 1.00)	1	NA		None	NA		None
1999	2.69	(0.98 – 4.65)	6	4.44	(1.12 – 8.43)	4	2.99	(0.0 – 7.04)	2
2000	3.50	(1.51 – 5.64)	7	3.37	(0.0 – 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	(0.0 – 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	(0.0 – 1.90)	1
2005	0.97	(0.71 – 1.25)	34	0.62	(0.27 – 1.01)	7	NA		None
2006 [A]	1.19	(0.75 – 1.67)	19	1.65	(1.12 – 2.27)	23	1.20	(0.30 – 2.29)	4

[A] **Migration year 2006 is incomplete until 3-salt returns (if any) occur at GRA after 7/1/2009.**

Table B-29 Number of PIT-tagged hatchery steelhead actually transported from each dam and estimate (ti) of total PIT-tagged hatchery steelhead that would have been transported if all PIT- tagged fish had been transported at same rate as the untagged run-at-large.

Migr Year	Lower Granite Dam		Little Goose Dam		Lower Monumental Dam	
	Actual	t2	Actual	t3	Actual	t4
1997	1,521	12,445	104	1,128	81	883
1998	795	13,080	358	4,264	157	2,127
1999	779	9,169	291	8,845	221	3,402
2000	399	14,023	73	2,091	92	1,472
2001	331	17,696	43	950	16	205
2002	124	4,951	64	4,101	79	4,278
2003	2,068	6,459	1,510	4,817	829	2,730
2004	353	12,430	87	2,828	13	259
2005	632	11,906	195	4,096	35	296
2006	303	4,295	360	4,173	105	1,441
Overall average/ dam		**66.2 %**		**23.2 %**		**10.6 %**

Table B-30 Estimated dam-specific transportation SAR percentages of PIT-tagged hatchery steelhead in the annual aggregate groups for 1997 to 2006 (with 90% confidence intervals).

Migr	SAR(TLGR)		Adult	SAR(TLGS)		Adult	SAR(TLMN)		Adult
Year	%	CI %	#	%	CI %	#	%	CI %	#
1997	0.59	(0.27 – 0.96)	9	NA		None	NA		None
1998	0.63	(0.24 – 1.13)	5	0.28	(0.0 – 0.84)	1	0.64	(0.0 – 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	(0.0 – 3.90)	1	1.09	(0.0 – 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	(0.0 – 2.29)	2	2.86	(0.0 – 8.82)	1
2006 [A]	1.65	(0.62 – 2.87)	5	2.78	(1.39 – 4.24)	10	1.90	(0.0 – 4.35)	2

[A] Migration year 2006 is incomplete until 3-salt returns (if any) occur at GRA after 7/1/2009.

Appendix C

Three-year CSS Study Plan
FY 2010-2012 F&W Program Project Solicitation

Project ID: 199602000

Title: Comparative Survival Rate Study (CSS) of Hatchery and Wild PIT tagged Chinook and Steelhead & Comparative Survival Rate Study Oversight Committee

A. Abstract

The Comparative Survival Rate Study (CSS) is a management-oriented, large scale monitoring study of spring/summer Chinook (Chinook hereafter unless specified otherwise) and steelhead. The foundational objective of the CSS is 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). Through utilization of PIT (Passive Integrated Transponder) tags, survival metrics such as SARs and juvenile survival rates within the hydrosystem, and important demographic responses such as migration rates, emigration timing, adult fallback rates, adult success rates and others can be estimated over the smolt-to-adult life cycle. The CSS was designed, through the use of PIT tagging efforts, to address several of the basin wide monitoring needs and to provide these demographic data and other responses for Snake River and Columbia River wild and hatchery salmon and steelhead populations. Monitoring survival rates in this way over the life-cycle can help identify where survival bottlenecks are occurring, which is critical input for informed management decisions (Good et al. 2007).

The CSS began as a PIT tag study to develop smolt-to-adult survival indices for Snake River Chinook and steelhead originating above Lower Granite Dam that were used to evaluate smolt migration mitigation measures and actions (such as flow augmentation, spill, and transportation) for the recovery of listed salmon stocks. The objective was and is to build a long-term database monitoring smolt-to-adult return rates and passage characteristics of specific wild and hatchery groups of Chinook and steelhead throughout the Columbia River Basin. 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 will make use of mark groups from other research to meet CSS requirements in order to reduce costs and handling of fish.

In addition to the present mark groups, in 2010 the CSS proposes to continue coordination efforts to effect cost savings and avoid redundancy as recommended by the ISAB/ISRP reviews (2007 and 2009). Collaborations in recent years include those with the marking programs of the Lower Snake River Compensation Plan (LSRCP), Idaho Power Company (IPC), and Smolt Monitoring Project (SMP). The CSS will 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.

The objective of developing smolt-to-adult survival indices was first recommended in the PATH (Plan for Analyzing and Testing Hypotheses) process that was carried out by the regional, state, federal and tribal salmon managers with the Northwest Power and Conservation Council (NPCC). The PATH recommendations address the question, "can transportation of fish to below Bonneville Dam compensate for the effect of the hydro system on juvenile survival rates of Chinook salmon during their downstream migration?" The NOAA Biological Opinions require a research, monitoring and evaluation program to provide information to continuously improve the survival characteristics of the FCRPS and to identify habitat needs. The NPCC Fish and Wildlife Program has established the need to collect annual salmon and steelhead migration characteristics including survival. The CSS was created to meet the needs stated in the PATH recommendations, the NOAA Biological Opinions and the NPCC Fish and Wildlife Program. The CSS is an observational study (Cochran 1983; Eberhardt and Thomas 1991; McDonald et al 2007) that measures the biological responses of population groups with different hydrosystem experiences. The two primary characteristics of observational studies as defined by Cochran (1983) are central to the CSS study design:

1. "The objective is to study the causal effects of certain agents, procedures, treatments or programs".;
2. "For one reason or another, the investigator cannot use controlled experimentation, that is the investigator cannot impose on a subject, or withhold from the subject, a procedure or treatment whose effects he desires to discover, or cannot assign subjects at random to different procedures".

The CSS specifically addresses the following: (1) estimate smolt-to-adult survival rate (SAR) for transported wild and hatchery Chinook and steelhead; (2) determine if SAR rates are significantly different from the interim SAR goal established by the NPCC; (3) evaluate SARs and other passage characteristics of Chinook and steelhead populations throughout the Columbia Basin; and (4) estimate transport/control ratio and in-river survival rates for wild and hatchery Chinook and steelhead concurrently over a number of years in order to span a range of environmental conditions.

The resulting CSS study data are designed to apply to a broad scope of management questions, including hydropower operations, hatchery evaluations and habitat evaluations. An interagency CSS Oversight Committee was established to participate in the study design, planning and analysis, and to oversee the conduct and analyses of this study. Analyses include comparing smolt-to-adult survival rates for wild and hatchery Snake River Chinook and steelhead that were transported with those that migrated in-river to below Bonneville Dam (BON). Estimates of smolt-to-adult survival rates will be made from Lower Granite Dam (LGR) back to Lower Granite Dam, from hatchery back to the hatchery, and between dams with available adult detectors [BON, McNary (MCN), Ice Harbor (IHR), and LGR]. These survival rates may be used in the evaluations of smolt mitigation measures such as flow augmentation, spill, and transportation for the recovery of listed salmon stocks.

In addition to the CSS study objectives described above, the proposed experimental design for hatchery steelhead will allow the region to meet three additional key LSRCP, FWS, and NOAA Fisheries objectives: (1) it will allow estimation of the total number of LSRCP hatchery steelhead returns to the Columbia River using PIT tags in conjunction with CWTs; (2) it will allow the evaluation of the success (SARs) to the LSRCP project area of various stocks from differing release locations; and (3) it will provide timing and survival data for both B and A run steelhead from Bonneville to McNary for use in evaluating fishing impacts, which is a critical element in managing the Zone 6 fishery under the ESA (previous analysis indicates little difference between survival of wild and hatchery B run steelhead through this area). These are very important aspects of the LSRCP's Federal ESA responsibilities and Tribal trust responsibilities. To meet the regional RME needs established through the Biological Opinions the CSS will pursue opportunities to coordinate and collaborate with existing tagging programs or propose additional tag groups in the Middle and Upper Columbia River region of the Basin to develop similar time series of demographic data, and smolt to adult survival for wild and hatchery populations in those areas. The CSS Oversight Committee and the FPC staff will review existing mark groups and develop proposed aggregate groups from existing marking and if necessary additional marks are required to develop smolt to adult return indices. Also, the CSS time series data and analysis will be available to the public through the Fish Passage Center web site.

B. Technical and/or scientific background

This project incorporates the long-term PIT tag marking and recovery of groups of wild and hatchery Chinook juveniles and steelhead. Hatchery Chinook groups are from Imnaha, Catherine Creek, McCall, Rapid River, Dworshak, and Carson facilities. Hatchery steelhead groups are from Dworshak, Clearwater, Magic Valley, Hagerman, Niagara Springs, and Irrigon hatcheries. Wild Chinook and steelhead are from tributary tagging programs in the John Day River and Snake River basin. These PIT tag groups will also be an important component of the regional Smolt Monitoring Program. The interagency CSS Oversight Committee will analyze recovery of tag data in returning adults. These analyses will result in smolt-to-adult survival rate estimates for Chinook and summer steelhead, comparisons between wild and hatchery stocks, and evaluate the transportation program as a mitigation option. These analyses will address key Action Items in the 2008 FCRPS Biological Opinion. In particular, Action Items 18-25, 30, 31, 52, 53, 54, and 55 are addressed through the CSS's estimation of SARs for transported and in-river migrating smolts, ratios of the transport SARs to the in-river SARs (T/I ratios), and differential delayed mortality (D) levels.

Although the project was developed through the regional PATH process, and is intended in part to address the question, "can transportation of fish to below Bonneville Dam compensate for the effect of the hydrosystem on juvenile survival rates of Snake River Chinook salmon during their downstream migration?", the study is designed to provide a long term consistent time series of smolt to adult return data on populations throughout the Columbia River Basin.

The CSS Oversight Committee developed the study design for the CSS. This multi-agency committee was established to assure that the study meets the needs of and is consistent with the management programs of the state, tribal and federal fish and wildlife agencies. The committee includes representatives of US Fish and Wildlife, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, and Columbia River Inter-Tribal Fish Commission. The CSS study design was previously reviewed by the Northwest Power and Conservation Council (NPCC) and Independent Scientific Advisory Board in 1997 and 1998 (ISAB 1997 & ISAB 1998) and approved in both reviews. The 2005 CSS annual report was reviewed in 2006 (ISAB 2006) and the CSS 10-year retrospective report was reviewed in 2007 (ISAB/ISRP 2007); both of these reports were approved as well.

C. Rationale and significance to regional programs

This study is intended to provide the basis for the Mainstem Monitoring and Evaluation (M&E) Program's analysis of long-term alternatives for recovery of depressed listed and unlisted stocks of Chinook and steelhead. The Region has committed to utilization of the Mainstem M&E Program in assessing alternative future recovery options. It will also provide downstream migration information for the regional Smolt Monitoring Program. This study will provide specific information, which will provide the basis for long-term restoration decisions in the region, specifically the role of the smolt transportation program in recovery. The CSS directly addresses the questions of transportation versus in-river migration found in the 2008 FCRPS Biological Opinion's Hydrosystem RME, specifically RPA's 52, 53, 54, and 55 which include, in-river survival, delayed mortality, transportation effectiveness, and overall SARs relative to recovery goals. The CSS will provide relevant SAR and other demographic data for use in the Biological Opinions Hatchery Strategies, specifically RPAs 63-64. The project reflects the reviews by the NPCC and ISAB & ISRP.

D. Relationships to other projects

In addition to the above purpose, additional PIT tag mark groups from other studies and projects will be included in this analysis where possible. The CSS long-term proposal is to maintain consistent and continuous mark groups throughout the Columbia River Basin. Every effort is made to avoid duplication of mark groups with other studies and gain the maximum efficiency from mark groups from other research studies. The actual mark proposals for CSS will be dependent on year-to-year coordination with other research entities. The CSS PIT tagging goals have been coordinated with those of Lower Snake River Compensation Plan (LSRCP). As part of our cost-saving coordination efforts, the CSS has coordinated with Scott Marshall, the LSRCP coordinator for USFWS, to fund the PIT tagging of 75,000 hatchery steelhead at various hatcheries including: Clearwater, Magic Valley, Hagerman, and Lyons Ferry hatcheries (all LSRCP facilities); Irrigon hatchery (IPC facility); and Dworshak National Fish Hatchery. This coordination is as part of the LSCRCP/FWS hatchery evaluation monitoring. The CSS PIT tagging provides a "return-to-river" group of tagged fish at each hatchery to complement the LSRCP/FWS production fish "monitor" mode releases. Additionally, the CSS provides a complement of monitor mode and return-to-river mode production steelhead from Niagara Springs Hatchery, an Idaho Power Company (IPC) facility, not covered under LSRCP/FWS efforts. Monitor mode PIT tagged fish are routed the same as untagged fish at each collector dam throughout the migration season (i.e., to raceways for transportation during the transport season), and provides the ability to directly estimate the overall SARs of hatchery releases. Return-to-river PIT tagged smolts are bypassed if collected at the dams throughout the season, and provide the ability to estimate reach survival rates between monitored dams in the hydrosystem and compare the SARs of transported versus bypassed smolts. PIT tagging of hatchery steelhead across facilities is approximately proportional to production release sizes.

E. Project history (for ongoing projects)

The project began in 1996 and has had extensive regional review. The study is a coordinated regional effort under the auspices of a regional oversight committee and is closely tied to the goals of the Mainstem Monitoring and Evaluation Program. Originally this study was conducted under two separate Bonneville Power Administration (BPA) project numbers #198712700 and #199602000. Based on the ISAB 1997 review and recommendations, the CSS is now consolidated into one project number #199602000. Thus far, 13 years of juvenile marking have been completed. Adult returns from migration years 1996 to 2006 have been analyzed in seven Project Status Reports completed in Oct 2000, Feb 2002, Nov 2003, Apr 2005, Dec 2005, Nov 2006, and Nov 2008. In response to NPCC request, and ISAB recommendations, a Ten Year CSS Retrospective Analyses Report was completed in Aug 2007 (Schaller et al. 2007). The Report included analysis of ten years of CSS data, to address questions identified in ISAB and ISRP reviews, including assessment of the effect of various migration routes, environmental conditions and migration timing on juvenile reach survival and smolt to adult return rates. In addition, the CSS convened a workshop in February 2004 on the effects of hydrosystem configuration and operation on salmon and steelhead survival (Marmorek et al. 2004).

F. Proposal biological objectives, work elements, and methods

The CSS is an important component of the Research, Monitoring and Evaluation (RM&E) and Data Management studies. This study will provide specific information that will provide the basis for long-term restoration decisions in the region, specifically the role of the smolt transportation program, flow augmentation, and spill for the recovery of listed salmon stocks. In addition to providing a time series of SAR data for PIT tagged wild and hatchery Chinook and steelhead, the coordinated experimental design for Snake River hatchery Chinook and steelhead would allow for evaluations to meet other objectives for the LSRCP, IPC, federal tribal trust, and ESA responsibilities (see section A. Abstract). The CSS is also proposing to coordinate with other PIT tagging in the Middle and Upper Columbia regions to establish a similar time series of SARs and demographic data for management and recovery decisions related to those stocks.

Work Element – Develop RM&E Methods and Designs

For this study, Snake River hatchery fish are sampled from regular hatchery production and implanted with a PIT (Passive Integrated Transponder) tag, which allows unique identification of each fish. The wild fish are sampled at tributary traps in the Snake River basin and also PIT tagged. Tagged fish will be assigned to transportation and bypass groups using the protocol developed by Nez Perce Tribe for sub-basin evaluations. With this protocol a fixed proportion of the tagged fish will be placed in a group to mimic the ongoing transportation of collected fish operation (i.e., monitor mode) and the remaining fish will be placed in a group to mimic a bypass of collected fish operation (i.e., return-to-river mode). The former PIT tagged group will completely mimic what happens to the untagged fish in the run-at-large, while the latter PIT tagged group will mimic what would happen if all collected fish were bypassed back to the river instead of transported. In addition, the latter group will provide the opportunity to estimate in-river survival rates with Cormack-Jolly-Seber capture-recapture method. Reach survival rates are necessary for expanding Little Goose and Lower Monumental PIT tag detection data to Lower Granite equivalents, thus accounting for the mortality rate from Lower Granite Dam to these two downstream dams. Reach survival rate estimates from Lower Granite to Bonneville Dam are used in the computation of differential delayed mortality estimates (D). The choice of this approach, instead of simply routing a proportion of fish collected at a dam to the raceways for transportation as had been done in the prior years through the 2005 outmigration, makes the estimation of overall SARs for the tagged fish much simpler. This is because the PIT tagged group that mimics the ongoing transportation operation will have the identical proportion of transported (collected fish) and in-river migrants (uncollected fish) as the untagged run-at-large.

Existing tagging programs in the Middle and Upper Columbia River provide a wealth of information for research, management and evaluation of these stocks. The CSS proposes to coordinate with these existing tagging efforts in the Middle and Upper Columbia and to analyze smolt survival and SARs from smolts at the first dam encountered to adults returning to Bonneville Dam through upstream passage. The assignment of fish to monitor mode or return-to-river-modes is not necessary for tag releases in cases where smolts are not transported. This would fall in line with ISAB/ISRP recommendations to cooperate with existing tagging programs (ISAB/ISRP 2007, ISAB/ISRP 2009).

One of the major recommendations from a recent review of the CSS by the ISAB and ISRP (2007 and 2009) was to “initiate a comprehensive study to determine why the PIT tagged Snake River wild spring/summer Chinook are producing lower SARs than the unmarked wild Chinook.” To this end, an analysis to determine the effects of daily detection probabilities at any applicable Snake River Dams on non-PIT tag SARs will be initiated.

Two recent COE-funded transportation evaluation projects for Snake River fall-run Chinook and Snake River sockeye have adopted the CSS approach of releasing PIT tagged fish above Lower Granite and assignment of tagged fish to monitor and return-to-river modes. The CSS will coordinate with these projects as necessary. Specifically, in 2010 the CSS Oversight Committee will review and evaluate the application of the CSS study design and analysis to PIT tagged juvenile fall Chinook and sockeye.

Work Element – Mark/Tag Animals

The CSS proposes to continue the PIT tagging of hatchery steelhead from the Snake River basin begun in 2009. The PIT tagging will be spread over the four drainages (Clearwater, Salmon, Imnaha, and Grande Ronde) proportional to the total hatchery steelhead production releases in each of these drainages. The goal is to obtain representative PIT tagging effort on hatchery steelhead across the four drainages (see Table 1).

Establishing PIT tagging quotas for Chinook and steelhead (Tables 1 and 2) requires levels of difference that are biologically meaningful for the smolt groups being compared. For hatchery Chinook in the Snake River basin, the tagging quotas are set to produce hatchery specific SAR estimates. For hatchery steelhead in the Snake River, the tagging quotas are set to produce an SAR reflective of the total hatchery steelhead releases above LGR. For wild Chinook and wild steelhead smolts PIT tagged in the Snake River basin and used in the CSS, the tagging efforts are established by each participating organization, and geared to targeting a high proportion of collected fish at the various tributary traps operated. Organizations routing a portion of their PIT tagged wild Chinook and steelhead to transportation include Idaho Department of Fish and Game (IDFG), Oregon Department of Fish and Wildlife (ODFW), Confederated Tribes of the Umatilla Reservation (CTUIR), and Shoshone-Bannock Tribes, and Nez Perce Tribe (NPT). The CSS provides a portion of the PIT tags for wild Chinook used by IDFG at their tributary traps and by ODFW at their lower Grande Ronde River trap (Tables C-1 and C-2). The CSS does not need to provide additional PIT tags for wild steelhead except at the Clearwater River Trap, since most on-going studies do not require any more tags then currently being used under their existing contracts.

Table C-1. Number of Snake River hatchery steelhead (see tributary allocations on next page), hatchery Chinook, and additional wild Chinook and wild steelhead to be PIT tagged through CSS contract in 2009.

Organi-zation	Budget Contacts	Tagging Site	Species and rearing type	PIT tag number
IDFG	P. Hassemer	Magic Valley H	H-Stld	11,406
		Hagerman NFH	H-Stld	8,139
	E. Buettner	Clearwater H	H-Stld	6,455
		Niagara Springs H	H-Stld	24,000
		Rapid R H	H-Ch	32,000[A]
		McCall H	H-Ch	52,000
		Salmon R trap	W-Ch	5,000[B]
		Snake R trap	W-Ch	2,000[B]
		Clearwater R trap	W- Ch	3,200
		Clearwater R trap	W-Stld	1,400
		Other tributary traps	W-Ch	14,500[C]
		Clearwater H	H-Ch	12,400
		Pahsimeroi H	H-Ch	3,800
		Sawtooth H	H-Ch	3,800
ODFW	R. Carmichael and B. Jonasson	Irrigon H	H-Stld	14,000
		Lookingglass H		
		• Imnaha R	H-Ch	21,000[D]
		• Catherine Ck	H-Ch	21,000[D]
		Grande Ronde R trap	W-Ch	1,400[B]
USFWS	D. Wills	Dworshak NFH	H-Stld	9,000
	H. Burge	Dworshak NFH	H-Ch	52,000
WDFW	J. Bumgarner	Lyon Ferry H. – Cottonwood AP	H-Stld	2,000

[A] Additional 20,000 PIT tags provided by Idaho Power Company to create the normal 52,000 PIT tag release from Rapid River Hatchery

[B] Additional smolts to be PIT tagged above the current SMP tagging quotas.

[C] Cost for PIT tags only to complement on-going PIT tagging efforts in Idaho.

[D] Fish PIT tagged in the fall of the contract year for the next year's migration.

Table C-2. Summary of Snake River PIT tagged groups that will be pre-assigned in 2009 as part of the CSS. Chinook and steelhead stocks are shown in bold and normal text respectively.

	Marking Agency	Total tagged	CSS tags	Tagging Site	Release Site	Stock	In-river percentage	SbyC Agency	LSCRP Cooperative Site	SMP Cooperative Site	Idaho Power Cooperative Site	New CSS Site my2009
1	IDFG	52k*	32k	Rapid River H.	Rapid River	**HCH(sp)**	30%	FPC			√	
2	IDFG	52k	52k	McCall H.	Knox Bridge	**HCH(su)**	30%	FPC				
3	IDFG	45k->75k	14.5k□	Fall & Spring Marking+	Same as tag	**WCH**/WST	30%	FPC				
4	IDFG	30.4k(SMP)	7k□	Snake & Salmon Traps	Same as tag	**WCH**/WST	30%	FPC		√		
5	IDFG	5.2k	5.2k	Clearwater Trap	Same as tag	**WCH**/WST	30%	FPC				
6	IDFG	37.5k	11.4k	Magic Valley H.	E.F. Salmon, Slate Creek, Squaw creek/pond, Little Salmon	63%HST(A); 37%HST(B)	30%	FPC				
7	IDFG	26.8	8.1k	Hagerman H.	MS. Salmon, Pahsimeroi, Yankee Fork, Valley Creek, Little Salmon	41%HST(A); 59%HST(B)	30%	FPC				
8	IDFG	21k	6.5k	Clearwater H.	SF Clwr, Lolo Creek	100%HST(B)	30%	FPC				
9	IDFG	25.2k	24k	Niagara Springs H.	Hell's Canyon, Little Salmon, Pahsimeroi	100%HST(A)	30%	FPC				√
10	IDFG	68.9k	12.4k	Clearwater H.	Upper Lochsa, Clear Cr, Lower Selway, SF Clearwater	**HCH(sp)**	25%	IDFG	√			√
11	IDFG	18.8k	3.8k	Pahsimeroi H.	Onsite, upper Salmon	**HCH(su)**	28%	IDFG	√			√
12	IDFG	18.8k	3.8k	Sawtooth H.	Onsite, upper Salmon	**HCH(sp)**	28%	IDFG	√			√
13	ODFW	21k	21k	Lookingglass H.	Imnaha AP	**HCH(su)**	30%	FPC				
14	ODFW	21k	21k	Lookingglass H.	Catherine AP	**HCH(sp)**	30%	FPC				
15	ODFW	10.4k(SMP)	1.4k	Grand Ronde Trap	Same as tag	**WCH**	30%	FPC		√		
16	ODFW	3.2k -> ?	0	Fall & Spring Marking°	Same as tag	**WCH**/WST	50%	FPC				
17	ODFW	44.7k	14k	Irrigon H.	Grande Ronde, Imnaha	100% HST(A)	30%	ODFW	√			√
18	USFWS	52k	52k	Dworshak H.	North Fork Clearwater	**HCH(sp)**	30%	FPC				
19	USFWS	~28.9k	9k	Dworshak H.	Clearwater MS, Clearwater SF, Clear Creek	100%HST(B)	30%	FPC				
20	WDFW	6k	2k	Lyon's Ferry H.	Cottonwood AP	100%HST(A)	33%	WDFW	√			√
21	CTUIR	1k -> ?	0	Fall & Spring Marking∆	Same as tag	**WCH**/WST	50%	FPC				
22	Shoban	~ 0.8k	0	upper Salmon R.	Same as tag	**WCH**	30%	FPC				
23	Nez Perce	~10k-12k	0	Imnaha Trap (Fall & Spring marking)	Same as tag	**WCH**/WST	~16%	Nez Perce				

* Idaho Power provided 20,000 of this total
□ The CSS provides tags for WCH at these sites but not for WST
\+ Marking at: American R, Crooked R. Trap, Red R. Trap, Crooked Fork C. Trap, Colt Kill Creek, Marsh Creek Trap, Pahsimeroi R. Trap, Sawtooth Trap, Big Creek Middle Fork, Knox Bridge, Secesh River Trap, Lemhi R. Weir, Lemhi R., Hayden Creek, Fish Trap, Rapid R. Trap
o Marking at: Catherine Creek, Lostine R., Minam R.
∆ Marking at: Lookingglass C., West Fork Yankee Fork Salmon R., East Fork Salmon R.

Although the CSS does not provide PIT tags for the tagging efforts below Lower Granite Dam (*i.e.* Middle and Upper Columbia River regions) it may use the PIT tags from the tagging efforts in these sections of the Columbia River for comparisons with the CSS PIT tag groups from the Snake River (see Table C-3).

Table C-3 Middle and Upper Columbia River PIT tag marking for 2009. Tags were not pre-assigned as part of CSS but available for other analyses. The CSS *does not* provide tags for these studies.

Marking Agency	Total tagged	Facility/River (Wild)	Release Site	Stock	Tagging Purpose
USFWS	20k	Warm Springs NFH	Warm Springs River	Spring Chinook	HRT Rec./Hatchery Evaluation
USFWS	15k	Leavenworth NFH	Icicle Creek	Spring Chinook	Smolt Monitoring Program
USFWS	3k	Winthrop NFH	Methow River	Spring Chinook	Hatchery Evaluation
USFWS	15k	Carson NFH	Wind River	Spring Chinook	HRT Rec./Hatchery Evaluation
USFWS	15k	Little White Salmon NFH	Little White Salmon River	Spring Chinook	HRT Rec./Hatchery Evaluation
USFWS	40k	Little White Salmon NFH	White River (Wenatchee R.)	White River Spr. Chinook	ESA Recovery Program
USFWS	??? *	Warm Springs R. (Wild)	Warm Springs River	W. Spr. R. Spr. Chin. (Wild)	Wild Stock Evaluation
USFWS		**Total Spring Chinook = 108k**			
USFWS	5k	Winthrop NFH	Methow River	Steelhead	Hatchery Evaluation
USFWS	1.5k	Dworshak NFH	North F. Clearwater River	Steelhead	Smolt Monitoring Program
USFWS		**Total Steelhead = 6.5k**			
USFWS	6k	Wells SH	Columbia River @ Wells	Summer Chinook	Smolt Monitoring Program
USFWS		**Total Summer Chinook = 6K**			
USFWS	15k	Spring Creek NFH	Columbia River @ Spr. Ck.	Tule Fall Chinook	HRT Rec./Hatchery Evaluation
USFWS	25k	Little White Salmon NFH	Little White Salmon River	URB Fall Chinook	HRT Rec./Hatchery Evaluation
USFWS	3k	Priest Rapids SH	Columbia River @ P. Rapids	URB Fall Chinook	Smolt Monitoring Program
USFWS	??? *	Deschutes River (Wild)	Deschutes River	URB Fall Chinook	Wild Stock Evaluation
USFWS		**Total Fall Chinook = 43k**			
Yakama Nation	40k	Cle Elum Hatchery	Yakima R. @ 3 Accl. Ponds	Upper Yakima Spring Chinook	Supplementation
ODFW	~4.8k	John Day River (Wild)	John Day River	Wild Spring Chinook	Smolt to Adult survival
ODFW	3k	Umatilla River (Wild)	Umatilla River	Wild Summer Steelhead	Supplementation
ODFW	4k	John Day River (Wild)	John Day River	Wild Summer Steelhead	Smolt to Adult survival
ODFW	~1.5k	Deschutes River (Wild)	Trout Creek	Wild Summer Steelhead	Habitat Evaluation
	10k	Chiwawa[1]	Chiwawa ponds	Hatchery Spring Chinook	SAR/residualism/timing/distribution
	30k	Dryden Dam/ Tumwater Dam[1]	Dryden Dam/ Tumwater Dam	Chinook (wild?)	SAR/residualism/timing/distribution
	10k	Chiwawa River smolt trap[1]	Chiwawa River smolt trap	Wild Steelhead & Chinook	Life history, smolt to smolt and smolt to adult Survival
	2k	Lower Monitor River smolt trap[1]	Lower Monitor River smolt trap	Wild Steelhead & Chinook	Life history, smolt to smolt and smolt to adult Survival
	8k	Tucannon R. [2]	Touchet R. direct	Wild Steelhead	SAR
	8k	Touchet R. [2]	Touchet R. direct	Wild Steelhead	Wild SAR
	2.5k	Tucannon R. smolt trap[2]	Tucannon R. smolt trap	Wild Steelhead	Wild SAR

Marking Agency	Total tagged	Facility/River (Wild)	Release Site	Stock	Tagging Purpose
WDFW	4k	Asotin Creek smolt Monitoring[2]	Asotin Creek smolt Monitoring	Wild Steelhead	Smolt behavior / SAR
	3.3 k	Prosser Dam[3]	Prosser Dam[3]	Hatchery and wild Chinook	Smolt-smolt survival
	3.6 k	Roza Dam[3]	Roza Dam	Hatchery and wild Chinook	Smolt-smolt survival
	1450	Roza Dam[3]	Roza Dam	Wild steehead	Smolt-smolt survival
	1 k	Teanaway River[3]	Teanaway River[3]	Wild Steelhead	Proportion of steelhead in population
	300-600	Methow River smolt trap[4]	Methow River smolt trap[4]	Wild spring Chinook	SAR, migration timing, straying
	300-500	Methow River smolt trap[4]	Methow River smolt trap[4]	Wild summer steelhead	SAR, migration timing, straying
	500	Methow River[4]	Methow River[4]	Wild summer steelhead	SAR, migration timing, straying
	1000-2500	Twisp River trap[4]	Twisp River trap[4]	Wild spring Chinook	SAR, migration timing, straying
	500-800	Twisp River trap[4]	Twisp River trap[4]	Wild summer steelhead	SAR, migration timing, straying
	500	Twisp River[4]	Twisp River[4]	Wild summer steelhead	SAR, migration timing, straying
	500	Chewuch River[4]	Chewuch River[4]	Wild summer steelhead	SAR, migration timing, straying

* **At this point, these groups are potential marked groups for 2009 so totals are not known.**

1 **Wenatchee River Basin**

2 **Lower Snake River Basin**

3 **Yakima River Basin**

4 **Methow River Basin**

Work Element – Collect/Generate/Validate Field and Lab Data

The state and federal fishery organizations conducting the PIT tagging at the hatcheries and at tributary traps for the CSS will be responsible for the proper collection of smolts for PIT tagging and the validation of the tagging data in the field before submission to PTAGIS.

Work Element – Submit/Acquire Data

The state and federal fishery organizations conducting the PIT tagging at the hatcheries and at tributary traps for the CSS will submit the completed PIT tag files to PTAGIS using the approved data entry program. Once on the PTAGIS database, the PIT tagged fish will be available to all interested researchers. The FPC staff will download the PIT tag data onto their own database for subsequent running through their bootstrap program to generate the SARs, ratios of SARs, and D parameters desired.

Work Element – Install Fish Monitoring Facility/Equipment

Fish are PIT tagged solely for the CSS at only a single trap, the Clearwater River trap operated by Idaho Dept. of Fish and Game (IDFG). At all other traps where some fish are PIT tagged specifically for the CSS, the main operation and tagging efforts are conducted for other research programs. This includes three Smolt Monitoring Programs traps -- located on the Salmon River and mainstem Snake River (IDFG operated), and the lower Grande Ronde River trap operated by Oregon Dept. of Fish and Wildlife (ODFW). The 14,500 PIT tags provided to IDFG for use at various tributary trap sites (see table 2) are supplemental tags that augment the ongoing tagging efforts at these sites. The costs for installation and operation of the traps and tagging equipment at each of these sites, except the Clearwater River trap, are covered under the other research programs. The cost for installation and operation of the Clearwater River trap is covered directly in the CSS contract.

Work Element – Create/Manage/Maintain Database

The existing database, bootstrap program, and the new simulation program created in earlier years of the ongoing CSS program will be managed and maintained at the FPC Office in Portland by computer programmers involved in the original creation of these computer programs.

Work Element – Disseminate Raw/Summary Data and Results

All computer runs with the bootstrap program used in analyses will be archived for later use by interested parties. The summary data results will be presented in the annual status reports. CSS data and results are available to the region of the Fish Passage Center web site at www.fpc.org.

Work Element – Analyze/Interpret Data

Objectives and tasks:

1. Develop a long-term index of transport survival rate (smolt-to-adult) to in-river survival rate (smolt-to-adult) for Snake River hatchery and wild Chinook and steelhead smolts.
    a. Compute annual ratio of transport survival rate to in-river survival rate.
    b. Test if the annual ratio of transport survival rate to in-river survival rate (measured at LGR w/associated confidence interval) is significantly greater than 1.0.

2. For Snake River basin hatchery Chinook and steelhead, develop a long-term index of survival rates from release of smolts at hatcheries to return of adults to hatcheries.
    a. Partition survival rates
        i. from hatchery (smolts) to LGR (smolts)
        ii. from LGR (smolts) back to LGR (adults), and
        iii. from LGR (adults) to the hatchery (adults).
    b. Compute and compare the annual SARs back to the hatcheries for fish transported or migrating in-river as smolts through the hydro system.
    c. Evaluate any differential between PIT tagged SARs and non-PIT tagged SARs.

3. Compute overall smolt-to-adult survival rates and timing information for populations throughout the Columbia Basin.
    a. Compute annual survival rates from Lower Granite Dam as smolts to Lower Granite Dam as returning adults using PIT tags for wild and hatchery Chinook and steelhead releases above LGR that were pre-assigned to monitor mode.
    b. Compute annual survival rates from first dam encountered as smolts to Bonneville Dam as returning adults using PIT tags for available populations in the middle and upper Columbia River basin.
    c. Compute arrival timing and travel timing for Columbia Basin populations.

4. Coordinate with other PIT tagging in the Middle and Upper Columbia regions to establish a time series of SARs and demographic data for management and recovery decisions related to those stocks.

5. Continue the time series of SARs for use in the regional long-term RME evaluations; evaluate feasibility of additional stocks including Snake River sockeye and fall Chinook.

Methods to address the objectives:

Overall SARs for wild and hatchery Chinook and steelhead (Objectives 2, 3, & 4)

The Snake River monitor mode groups will reflect the ongoing transportation operations for the untagged run-at-large and will provide direct measures of SARs from release as smolts to LGR as adult. These estimates will be made at the individual hatchery level for Chinook and steelhead (where possible). With the estimate of survival from release site to LGR tailrace obtained from total release (combination of pre-assigned monitor mode and return-to-river mode groups of smolts), we will generate $SAR_{LGR\text{-}toLGR}$ for each Chinook hatchery in the study and for the wild Chinook, wild steelhead, and hatchery steelhead aggregate groups.

For tagging efforts in the Middle and Upper Columbia, analyze smolt survival and SARs from smolts at the first dam encountered to adults returning to Bonneville Dam through upstream passage. The assignment of fish to monitor mode or return-to-river-modes is not necessary for tag releases in cases where smolts are not transported.

CSS transport and in-river study categories (Objectives 1 – 4)

One major objective of the CSS was to compute and compare overall SARs for smolts collected and transported from Snake River dams through the hydro system versus those uncollected smolts that migrated in-river through the hydro system. The Snake River collector dams include LGR, Little Goose Dam (LGS), and Lower Monumental Dam (LMN). From the total release (combination of pre-assigned monitor mode and return-to-river mode groups of smolts), we will be extracting detected smolts at LGR, LGS, and LMN that are transported and those that are bypassed to create the study groups T_0 and C_1 as used in all years. Additionally, a group T_1 will be created which utilized all transported fish including those with detections at upstream dams. Likewise, the fish undetected at the three Snake River collector dams will form the C_0 in-river group. The bypassed fish (i.e., C_1 group) provides information on the possible effects on subsequent survival by passing through the Snake River dams in bypass systems at the facilities. The approach to estimating the numbers of smolts in each category is provided in detail in Bouwes *et al*. 2002 and Berggren *et al.* 2003.

Smolt in-river survival estimation (Objectives 1 – 4)

The CJS (Cormack 1964; Jolly 1965; and Seber 1965) methodology is used to estimate the seasonal in-river survival rates and total population number of PIT tagged Snake River smolts at LGR. Estimates of seasonal in-river survival are necessary for both computing smolt numbers per study group in LGR equivalents and in computing the LGR-to-BON in-river survival rate, termed S_R, used in computing *D*. The CJS methodology will also be used for Middle and Upper Columbia River PIT tagged smolts to estimate smolt numbers at the uppermost dam and first dam-to-BON survival rate.

Calculation of ratios of key SARs (Objectives 1, 3 & 4)

To evaluate a given year's overall management operations, including spill and transportation, to what may have occurred without transportation, we will compare the calculated $SAR_{LGR\text{-}to\text{-}LGR}$ for the monitor mode pre-assigned group with the calculated $SAR_{LGR\text{-}to\text{-}LGR}$ for the return-to-river pre-assigned group. To evaluate the relative SARs for fish that were transported to fish that migrated in-river we calculate T/I = $SAR(T_0)$ / $SAR(C_0)$. In addition, we make a comparison between the C_0 and C_1 groups, estimating a C_1/C_0 ratio = $SAR(C_1)$ / $SAR(C_0)$.

Estimating *D* (Objectives 1 & 4)

D is the ratio of post-BON survival rate ($SAR_{BON\text{-}LGR}$) of transported fish to in-river fish. Thus,

$$D = \{SAR_{LGR\text{-}LGR}(T_0) / SAR_{LGR\text{-}LGR}(C_0)\} * (S_R / V_T)$$

where S_R is the estimated in-river survival from LGR tailrace to BON tailrace (typically around 50% for Chinook and 35% for steelhead) and V_T incorporates the in-river survival components to LGS and LMN and an assumed direct transportation survival of 98% once the fish are in the barge. The parameter *D* would equal 1 if there was no differential mortality occurring between transported and in-river migrating smolts once they are both below BON and eventually entering the ocean. Since *D* has averaged around 0.7 for hatchery and wild Chinook in the last 10 years (Berggren *et. al.* 2008) there is evidence that the post-BON delayed mortality of in-river fish is lower than that of transported fish.

Calculation of confidence intervals for smolt numbers, SARs, ratios of SARs, and *D* (Objectives 1 – 4)

Confidence intervals for all in-river survival components, SARs, ratios of SARs and *D* estimates used in CSS analyses are computed using a bootstrap resampling (Efron and Tibshirani 1993) program developed by FPC staff. All parameters of interest are computed within each iteration of the bootstrap program. Typically 1000 iterations are run from which averages, variances, and 80, 90 and 95% confidence intervals are computed for each parameter.

Comparisons of key parameters between transported and in-river migrating smolts (Objective 1)

Under the null hypothesis that $SAR(T_0) = SAR(C_0)$, we check for significant differences between the SARs of fish in study groups T_0 and C_0 by looking for non-overlapping 90% confidence intervals and for T/I ratios where the 90% confidence intervals do not include the value 1. Likewise, when the 90% confidence interval of D does not include 1, there is a significant difference in the relative post-BON survival rate between transported and in-river migrants.

G. Facilities and equipment

PIT tag detection facilities for detection of migrating smolts at LGR, LGS, LMN, MCN, JDA, and BON and PIT tag separation-by-code capabilities at LGR, LGS, LMN, and MCN are required. The separation-by-code capabilities allow researchers to specify which PIT tagged smolts to route to the raceways at the four collector dams during the transportation season for the CSS. The PTAGIS data system is required. Juvenile PIT tag detection facilities are in place at Rapid River Hatchery to monitor the volitional release of juvenile salmon at that hatchery. PIT tag detection equipment is required for the detection of returning adults in the ladders at BON, MCN, IHR, and LGR, plus at key hatchery sites. The Fish Passage Center would maintain key databases and software to implement CSS analyses.

Appendix D

Comments on CSS report by Shoshone-Bannock Tribes

The Shoshone-Bannock Tribes

Fisheries, sockeye research 208.239.4568 Memorandum

DATE: 8 October 2009

TO: Michele Dehart

FROM: Doug Taki

SUBJECT: Snake River sockeye salmon smolt survivals

I have not heard who is going to evaluate survivals from the Snake River sockeye salmon smolts that received PIT tags this year. As this will be the first time that a sufficient sample size of smolts has been tagged for a valid analysis, I would suggest that the CSS program would be the appropriate venue to do this analysis and that they will be able to include sockeye salmon in future reports. I will encourage the action agencies to continue this tagging effort so survivals under different snowpack and system operations conditions can be evaluated. Hopefully, in future years we will be able to tag enough w/n smolts to be included in the analysis.

Since it may be too late for the CSS to do an analysis for the 2009 migration I am requesting that the FPC do a survival study not only for the hatchery reared smolts that were released, but for w/n fish that were tagged at Pettit, Alturas, and Redfish lakes during the spring of 2009. Due to the small sample size the w/n analysis may not be possible.

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November 17, 2009

Doug Taki
Shoshone-Bannock Tribes of Fort Hall
Fisheries Division
29 Shoshone Dr. / P.O. Box 306
Fort Hall, ID 83203

Dear Mr. Taki:

The CSS oversight committee members of Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, and US Fish and Wildlife Service, agree with your suggestion that the CSS program is an appropriate venue for the analyses of PIT-tagged Snake River sockeye salmon. As this year's annual report is slated to be completed on November 30, 2009, there is not enough time to include any work in this regard in the current report. The CSS Oversight Committee has agreed to include analyses of Snake River sockeye salmon smolts in the 2010 report and to expand on this in later reports as adults return. We will begin our preliminary analyses towards these results after the completion of the 2009 report.

Sincerely

Michele Dehart
Project leader, Comparative Survival Study