Adult Upper Columbia River and Snake River Spring Chinook Salmon and Steelhead Survival through the Federal Columbia River Power System Hydroelectric Projects

Final Phase I Report

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Acronyms and Definitions

BON	Bonneville Dam
CWT	Coded-wire tag
DPS	Distinct Population Segment
ESU	Evolutionary Significant Unit
LGR	Lower Granite Dam
MCN	McNary Dam
PIT	Passive Integrated Transponder (tag)
PTAGIS	PIT Tag Information System
PRD	Priest Rapids Dam
SR	Snake River
Straying	Where a fish spawns in a non-natal stream.
TAC	Technical Advisory Committee (for US *v* OR process)
Wandering	When a fish ascends or spends time in a non-natal stream, but continues its migration after some period of time. Wander rates apply more to steelhead than spring Chinook because of the time of year they enter freshwater (assumes one of the reasons for wandering is for thermal refuge).
UCR	Upper Columbia River

1. Introduction

During development of the Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp; NMFS 2008), new data were presented that suggested that upper Columbia River (UCR) adult spring Chinook salmon and steelhead were surviving[1] at substantially lower rates through the lower Columbia River than Snake River (SR) stocks and what had been previously estimated.

Previously, assumptions had been made that adult survival through the lower Columbia River FCRPS system was approximately between 85-90% for both UCR and SR spring Chinook salmon and steelhead. However, recent investigation for the FCRPS BiOp suggested that survival of UCR spring Chinook salmon averaged below 85% and less than 75% in most years for steelhead. For SR stocks, the numbers averaged higher, especially for steelhead.

Although the BiOp does not contain confidence intervals for the PIT-tag based estimates, subsequent analysis (Paulsen, unpublished) suggested that the survival differences were in fact significantly different in most years.

Further investigation is needed to determine the cause of these differences in the estimates of mortality. Reasonable and Prudent Alternative (RPA) 52 from the FCRPS Biological Opinion in part requires the Action Agencies to:

> *Cooperate with NOAA Fisheries, US v Oregon parties, Confederated Tribes of the Colville Reservation, and other co-managers to 1) review relevant information and identify factors (migration timing, spatial distribution, etc.) that might explain the differential conversion rates(BON to MCN) observed for UCR steelhead and spring Chinook salmon compared to SR steelhead and spring/summer Chinook salmon (see RPA Table 7 and SCA - Adult Survival Estimates Appendix); 2) develop a monitoring plan to determine the most likely cause of these differential losses (considering the potential use of flat plate PIT tag detectors in tributaries or fishery areas, additional adult detectors at The Dalles and John Day fishways, etc. to provide improved estimates of harvest or stray rates for improved conversion rate estimates in the future); and 3) implement the monitoring plan.*

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[1] It is important to define the use of the term survival in the context of this document. The survival estimates discussed within this document should be considered *minimal* estimates. In most cases (but not all - see below), they have been adjusted to account for estimated harvest and straying rates of adults, but otherwise capture all other sources of mortality manifested within the identified reaches. These include effects resulting from the existence and operation of the FCRPS, unknown mortality from other potential sources (e.g., unreported or delayed mortality caused by fisheries, marine mammal predator attacks, etc.), and unknown "natural" mortality (i.e., mortality in the migratory corridor that would have occurred with no human influence).

The exception to the above rule is when we use statistical models to relate upstream survival to Chinook salmon and steelhead population characteristics (e.g., hatchery or wild, ESU, or size at age), environmental factors (e.g., flow, water temperature), and other potential covariates. Because important properties of harvest and stray rate estimates are unknown (variance, degree to which harvest rates vary between stocks and within seasons), for modeling purposes we will employ simple Cormack-Jolly-Seber survival rate estimates (e.g., the number of PIT tagged adults detected at McNary divided by the number of fish detected at Bonneville) with none of the adjustments described above.

The "effect zone" (the segment of the hydroelectric system where fish encounter the mortality agents under study) for consideration in this study plan is the FCRPS between Bonneville Dam and McNary Dam (specifically, between the exits of the adult fish ladders of Bonneville and McNary dams).

1.1 Phased Approach

This document reports the initial results of the first phase of this investigation. Under the first phase, existing information is reviewed and analyzed to determine if the survival reduction (and differences) can be explained. If the conclusion of this first phase is that there is not enough information, then a detailed study plan (Phase II) will be developed that will outline an approach to collect empirical information that will explain the survival discrepancies.

2. Goal and objectives

The goal of the first phase of this investigation is the desired outcome, while the objectives are measureable and will inform whether the goal is being achieved. The goal for this phase of the investigation is:

> *Using existing and on-going information, summarize Upper Columbia River and Snake River spring Chinook salmon and steelhead survival rates between FCRPS dams and understand why survival rates of UCR spring Chinook salmon and steelhead between FCRPS dams is lower than SR species and the 98% per hydroproject survival assumed in policy forums.*

The objectives and hypotheses and associated tasks for the first phase are outlined in Table 1:

Table 1. Objectives, hypotheses, and tasks for the initial investigation of survival for UCR spring Chinook salmon and steelhead through the lower Columbia River FCRPS.

Objective	Hypotheses	Tasks
Determine the survival differences between UCR and SR spring Chinook salmon and steelhead.	*H_O1- Survival through the effect zone for UCR spring Chinook salmon and steelhead equals SR spring/summer Chinook salmon and steelhead.*	1. Gather, review and summarize (conduct statistical analysis) past and ongoing PIT tag and other tagging data for UCR and SR stocks to evaluate survival through the *effect zone*, 2. Gather, review and summarize past radio-tag studies that provide stock specific evaluation of survival through the *effect zone*.
Determine reasons for differential survival between UCR and SR spring Chinook salmon and steelhead	*H_O1-Migration rates (either km or miles/day) and timing for UCR spring Chinook salmon and steelhead are the same as SR spring/summer Chinook salmon and steelhead through the effect zone.*	1. Determine run timing of UCR and SR spring Chinook and steelhead through the *effect zone* (using PIT tag detections). 2. Determine overlap of UCR spring Chinook with SR spring/summer Chinook through the *effect zone*. 3. Determine overlap of UCR steelhead with SR steelhead through the *effect zone*.

Objective	Hypotheses	Tasks
		4. Determine "A" and "B" SR steelhead run timing through the *effect zone.* 5. Review and summarize migration rate and timing of UCR and Snake River stocks through the *effect zone* via previous radio-tag and PIT tag evaluation to determine migration rate and 25, 50, 75 and 100 percent cumulative passage dates.
	H_O2- Spatial distribution within the FCRPS "effect zone" of UCR spring Chinook salmon and steelhead is the same as SR spring/summer Chinook salmon and steelhead (A-run)	1. Gather appropriate reports and data that will assist in determining spatial distribution of UCR and SR stocks migrating through the *effect zone*. This information may be gleaned from: a. Radio and/or acoustic telemetry, b. Passage at dams (which ladder they were detected on if PIT detectors are installed). c. Investigate ladder usage and harvest effort compared to passage (especially in BON pool).
	H_O3- Harvest rate of UCR spring Chinook salmon and steelhead equals SR spring/summer Chinook salmon and steelhead through the effect zone	1. Gather appropriate reports and data for harvest of UCR and SR stocks through the *effect zone*. 2. Review and summarize treaty and non-treaty harvest rate estimates of UCR and Snake River stocks through the *effect zone*, 3. Determine level of precision or monitoring effort associated with harvest rate estimates, 4. Determine level of harvest effort for spring summer and fall fisheries during 25, 50, 75 and 100 percent passage dates for UCR and Snake River stocks through the *effect zone*, 5. Determine level of harvest effort in areas of "wandering" (see Ho6).
	H_O4-Fallback rates of UCR spring Chinook salmon and steelhead equals SR spring/summer Chinook salmon and steelhead (A-run)	1. Gather appropriate reports and data to summarize fall back rates of UCR and SR stocks (see DART - minimal fall back from PITs) 2. Determine if there is PIT passage information during years of no radio tag studies. 3. Review and summarize radio-tag and/or acoustic tag data to assess fallback and re-ascent rates for UCR

Objective	Hypotheses	Tasks
		and SR stocks through the *effect zone*,
	H_O5- Ladder use (passage) through the effect zone for UCR spring Chinook salmon and steelhead equals SR spring/summer Chinook salmon and steelhead	1. Assess PIT tag and radio-tag data to determine spatial and temporal use of ladders during passage at BON, TDA, JDA and MCN
	H_O6- Wander rates of UCR spring Chinook salmon and steelhead through the effect zone equals SR spring/summer Chinook salmon and steelhead	1. Gather, review and summarize appropriate reports and data to determine "wander rates" of UCR and SR stocks (see Keefer et al. 2010).
	H_O7- Stray rates of UCR spring Chinook salmon and steelhead through the effect zone equals SR spring/summer Chinook salmon and steelhead	1. Gather, review and summarize appropriate reports and data to determine stray rates of UCR and SR stocks.
	H_O8-Survival through the effect zone for UCR spring Chinook jack salmon equals SR spring/summer Chinook jack salmon	1. Determine run timing of UCR spring Chinook and SR spring/summer Chinook jacks through the *effect zone* (using PIT tag detections). 2. Determine overlap (spatial and temporal) of UCR spring Chinook with SR spring/summer Chinook jacks through the *effect zone*. 3. Review and summarize migration rate and timing of UCR and Snake River Chinook jacks through the *effect zone* via previous radio-tag and PIT tag evaluation to determine migration rate and 25,50,75 and 100 percent cumulative passage dates.
	H_O9- Abiotic factors affect survival through the effect zone differently for UCR spring Chinook salmon and steelhead than SR spring/summer Chinook salmon and steelhead	1. Determine if flow, temperature, splii level, or gas concentrations effects survival of UCR and SR spring (summer) Chinook salmon and steelhead differently

3. Results

Each objective below will be evaluated separately, with specific methods and results identified.

3.1 Objective 1: Determine the survival differences between UCR and SR spring Chinook salmon and steelhead.

3.1.1 H_O1- Survival through the effect zone for UCR spring Chinook salmon and steelhead equals SR spring/summer Chinook salmon and steelhead.

3.1.1.1. Data

The data used are similar to those employed in the 2008 BiOp, but with a few important differences. First, Chinook salmon of 1-ocean age (jacks) were excluded from the BiOp but are included here. Second, because environmental conditions (flow, spill, etc.) and their effect, if any on survival, were of interest only for fish that passed BON on days when these data are available. This consideration reduces the sample size by about 1%. The BiOp used tagger-assigned migration year to determine each fish's age at return (i. e. ocean age = year at BON - migration year); the year of downstream detection where available, instead of the tagger-assigned year was used. "Unknown" run and origin (hatchery vs. wild) fish were excluded. Data through October 2010 are included, with the caveat that upstream passage may be incomplete for 2010, especially for steelhead. Finally, the BiOp included both "raw" survival and survival adjusted for estimated straying and harvest, while the current analysis includes only unadjusted survival - ***no attempt is made to account for harvest or straying***, since we simply do not know whether these rates vary by ESU.

Appendix A displays simple univariate statistics - N, the number of fish at BON, the number of fish with missing values (for the total at MCN), proportions of hatchery and wild origin, proportions of barged and in-river migrants and ocean age breakdowns, and statistics for flow, spill, etc. encountered at BON. Note that the Snake Chinook salmon ESU includes both spring and summer-run populations. These data, or subsets thereof, will be used in the survival and travel time regression models described below.

3.1.1.2. Methods

Since survival can be modeled as a binomial process (fish either survive to MCN or they don't) we used logistic regression models to describe survival as a function of ocean life stage (1-ocean or 2+ ocean years), rearing type (hatchery or wild), year at BON (2002-2010, as dummy or classification variables), ESU (Snake or UC), and, for some models, flow, spill, dissolved gas, turbidity, and water temperature at BON. Chinook and steelhead were modeled separately. The purpose of these models was to investigate whether survival differed among Snake and UC ESU's, after accounting for the factors noted. Survival of one-ocean fish (jacks, for the Chinook salmon ESU's) was modeled similarly, but for obvious reasons we did not include ocean life stage.

Estimates of adult survival are based on PIT tagged fish known to have migrated in-river as juveniles (no transported smolts) that are detected at BON (adult survivors detected again at MCN) as returning adults. This method has several advantages over previous methods (i.e., radiotelemetry or dam counts):

- It relies upon automatic detection of PIT tagged adults and so does not require additional handling or surgery which could affect adult migration behavior (as necessary in radiotelemetry studies);
- It produces survival estimates for individual ESU's/DPS's using known-origin fish as surrogates for the ESU population at large;
- The calculations are simple and straightforward; and
- The PIT tag database is readily available – ensuring transparency and reproducible results.

Specifically, the methodology for estimating adult system survival includes the following steps:

1. Determine the number of PIT tagged adult salmon and steelhead detected at BON that represents the ESU/DPS in question. This is accomplished by selecting adult detections from the PTAGIS database that meet the following requirements:

    a. are of known origin, i.e., are from the ESA-listed stock or a valid surrogate stock (e.g., hatchery fish),
    b. migrated in-river as juveniles, and
    c. returned as adults (not jacks). For example, to represent UCR spring Chinook salmon, select all appropriate age 2+ spring Chinook salmon tagged upstream of Rock Island Dam detected at BON Dam to represent UCR spring Chinook salmon.

2. Determine the number of PIT tagged adult salmon and steelhead (of those identified in step 1) that were re-detected at MCN. Note that this method assumes detection rates near 100% at MCN (see Results).

3. Calculate an unadjusted survival rate: $\mathbf{S = N_U / N_B}$
   where S = survival rate,
   N_U = number of fish re-detected at or above the upstream targeted dam (MCN or LGR), and
   N_B = number of fish initially detected at BON Dam.

Because important properties of harvest and stray rate estimates are unknown (variance, degree to which harvest rates vary between stocks and within seasons), we present simple Cormack-Jolly-Seber survival rate estimates (e.g., the number of PIT tagged adults detected at McNary divided by the number of fish detected at Bonneville).

3.1.1.3. Results

Detection rates at MCN appear to be over 99%. We determined this by comparing detections at MCN to adult detections at LGR and Upper Columbia projects, and found that all but less than 1% was detected at MCN.

Survival from BON to MCN is displayed in the Figures 1 and 2 and Table 2. Upper Columbia survival rates are lower every year for both steelhead and Chinook salmon (preliminary estimates for 2010). Bootstrapping[2] the data suggests that this pattern is unlikely to occur by chance: the 90th percentile of the ratio of UCR/SR survival is usually less than one (Table 2).

[2] Bootstrapping is the practice of estimating properties of an estimator (such as its variance) by measuring those properties when sampling from an approximating distribution.

Table 2. Results of survival estimates based on in-river migrant yearling Chinook and steelhead, hatchery and naturally produced combined, for all age classes.

	Steelhead					**Chinook**				
	UCR		**SR**			**UCR**		**SR**		
Year	**Surv.**	**n @ BON**	**Surv.**	**n @ BON**	**UCR/SR**	**Surv.**	**n @ BON**	**Surv.**	**n @ BON**	**UCR/SR**
2002	0.810	295	0.791	746	1.020	0.783	83	0.826	1,165	0.948
2003	0.780	50	0.818	439	0.954	0.795	44	0.838	840	0.949
2004	0.718	3,156	0.819	437	0.877	0.766	394	0.845	1,650	0.907
2005	0.681	4,912	0.817	208	0.833	0.668	202	0.888	394	0.752
2006	0.721	5,720	0.828	128	0.871	0.647	346	0.793	246	0.817
2007	0.724	1,000	0.831	431	0.872	0.723	112	0.811	132	0.892
2008	0.758	538	0.789	615	0.962	0.752	210	0.737	1,091	1.020
2009	0.730	1,171	0.793	2,724	0.921	0.773	119	0.792	1,219	0.976
2010[a]	0.765	825	0.703	2,286	1.090	0.828	443	0.793	2,087	1.050
Avg.	**0.743**	**1,963**	**0.799**	**890**	**0.933**	**0.748**	**217**	**0.814**	**980**	**0.923**

[a] 2010 information incomplete

In addition, Appendix B provides additional information concerning the analysis of maximum likelihood estimates, including the descriptions of the variables, values for dummy variables (more on this below), degrees of freedom, point estimates, standard errors, chi-squares, probability of obtaining a larger chi square by chance, and the exponentiated value of the point estimate.

For dummy variables (all except the water quality metrics), the estimated parameter is the difference between the value of the dummy displayed and the value excluded from the table. For example, for Chinook salmon 1-ocean fish had significantly higher survival from BON to MCN than their 2+ ocean cousins (see Hypothesis 8 below in Section 3.2.8.2). Similarly, hatchery-origin fish had lower survival than wild fish; fish moving upstream in 2002 had lower survival than those in 2010; SR Chinook salmon had higher survival than UCR Chinook salmon; and fish outmigrating in-river (non-transported fish) had higher apparent survival than transported fish.

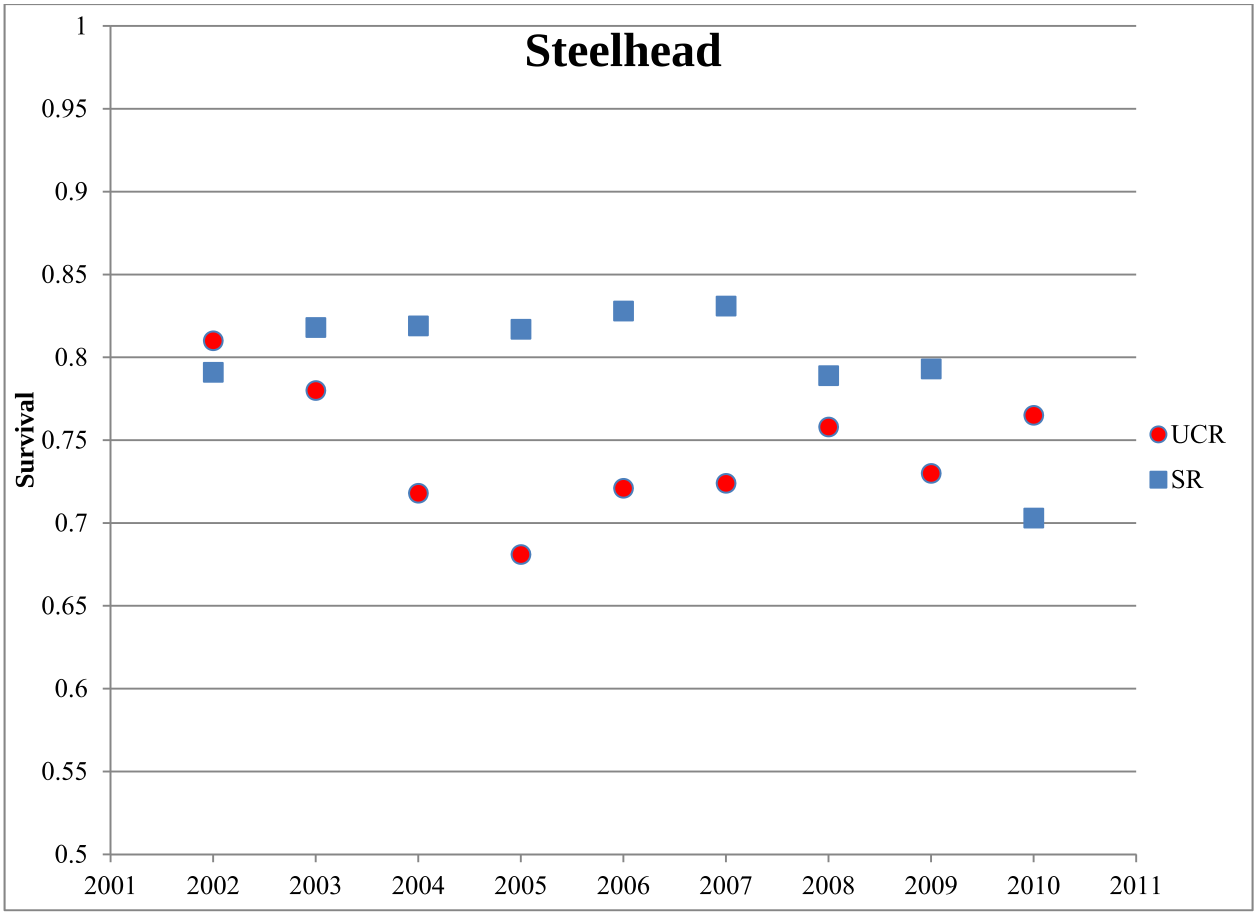

Figure 1. Minimal survival estimates (not adjusted for harvest or straying) of upper Columbia River steelhead and Snake River steelhead based on PIT tag detections between Bonneville and McNary dams, 2002-2010.

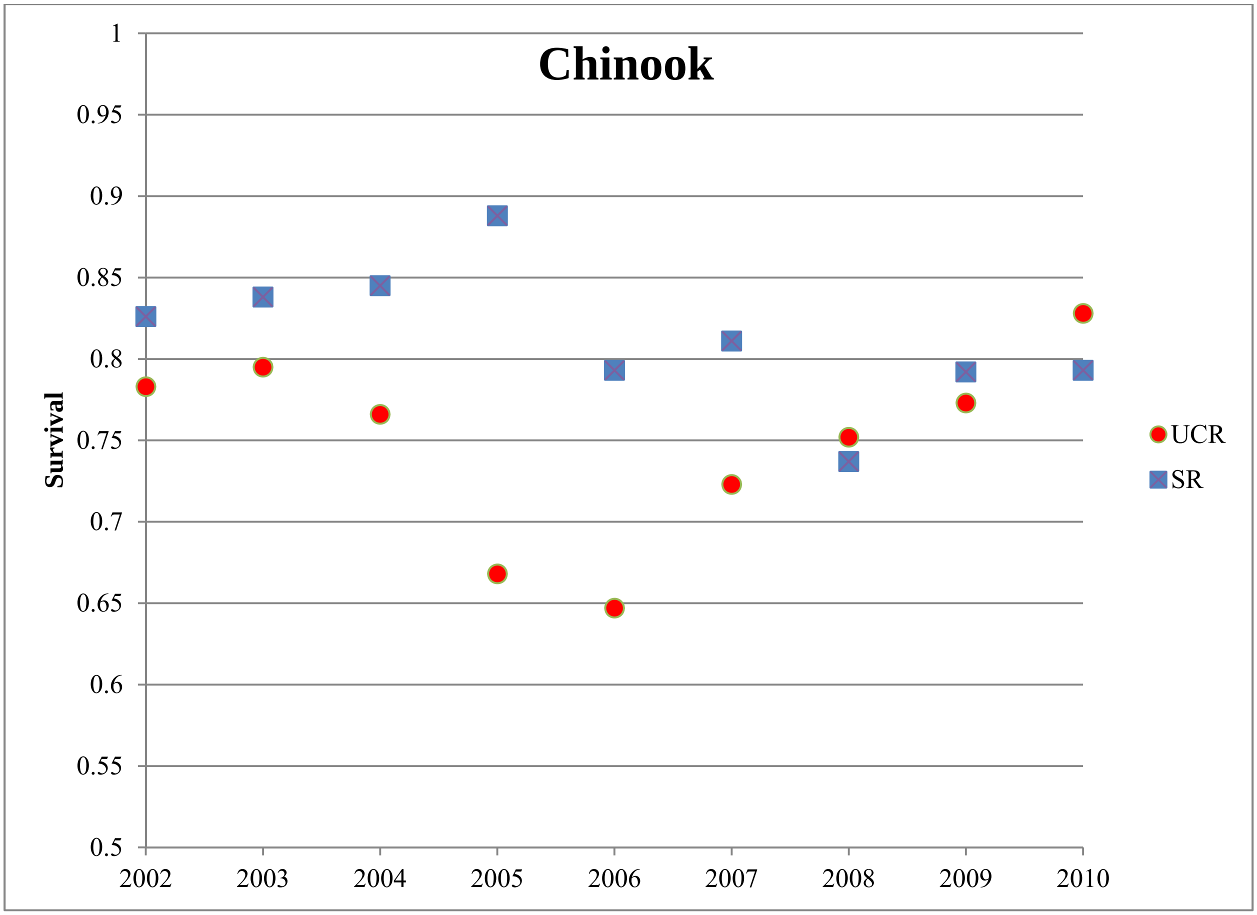

Figure 2. Minimal survival estimates (not adjusted for harvest or straying) of upper Columbia River spring Chinook salmon and Snake River spring/summer Chinook salmon based on PIT tag detections between Bonneville and McNary dams, 2002-2010.

For Chinook salmon (Appendix B1) we see from the exponentiated value that Snake Chinook salmon survive to MCN at a rate about 32% (from the 1.321 value, right-most column in Appendix B1) higher than UCR Chinook salmon. For steelhead, Snake fish survive at about a 17% higher rate, after accounting for life stage, rearing, year effects, etc. (Appendix B2).

Conclusion: Reject the null hypothesis. Survival differences between UCR and SR cannot be explained by chance alone.

3.2 Objective 2. Determine reasons for differential survival between UCR and SR spring Chinook salmon and steelhead.

3.2.1 $H_0$1-Migration rates (either km or miles/day) and timing for UCR spring Chinook salmon and steelhead are the same as SR spring/summer Chinook salmon and steelhead through the effect zone.

3.2.1.1. Data

For description of data see section 3.1.1.1 above.

3.2.1.2. Methods

Travel time was modeled using ordinary least squares (OLS) regression, using similar variables to those in the survival models, but without the river environmental variables. Here, we were interested in whether or not travel time differed among ESU's, speculating that UCR fish, which often had lower survival rates, might take longer to traverse the BON to MCN reach, and so be more exposed to harvest and other factors that might lead to increased mortality. We note the obvious point that travel time can only be estimated for fish surviving or traversing the BON-MCN reach and successfully ascending the MCN ladders.

Finally, we compiled annual data on the 5th, 25th, 50th, 75th, and 95th percentiles of Julian dates (1-366) of passage at BON. We thought that we might find a consistent difference in temporal distributions of upstream passage, which, if present, might lead to UCR fish being more vulnerable to harvest or other causes of mortality. Given the results of this exercise, we decided not to analyze the arrival date information more formally.

3.2.1.3. Results

Appendix C displays the OLS regression results for travel time in days for Chinook salmon and steelhead. As can be seen from Appendix C1, Snake Chinook salmon travel time is not significantly different from that of UCR Chinook salmon. However, the steelhead travel time results (Appendix C2) do demonstrate a significant difference between ESU's, but opposite of what would be expected given the differential survival between the SR and UCR stocks. That is, SR steelhead take about 10 additional days to travel from BON to MCN than do UCR steelhead. Generally speaking, an increased travel time is typically associated with an increased likelihood of mortality associated with harvest, etc.

Conclusion: Do not reject the null hypothesis for Chinook salmon, but reject it for steelhead.

3.2.2 H_O2- Spatial distribution within the FCRPS "effect zone" of UCR spring Chinook salmon and steelhead is the same as SR spring/summer Chinook salmon and steelhead (A-run)

We were unable to find information that could "test" this hypothesis. However, Keefer et al. (2005) note that Snake River fish tended to wander or stray into Oregon streams while UCR fish tended to wander or stray into Washington streams.

3.2.3 H_O3- Harvest rate of UCR spring Chinook salmon and steelhead equals SR spring/summer Chinook salmon and steelhead through the effect zone

3.2.3.1. Methods

In 2008, the *US v. Oregon* Technical Advisory Committee (TAC) provided a biological assessment of incidental impacts to salmon species listed under ESA for Columbia River fisheries (TAC 2008). Much of the information discussed below was obtained from the biological assessment, other TAC reports (e.g., Joint Staff Reports), and sport catch card information available from the states of Oregon and Washington. Typically, harvest data is presented as catch statistics that describe the number, location, rates, and season of harvest for salmon and steelhead. The precision of estimates or effort associated with harvest rates is seldom reported. Consequently, much of the information presented is on catch and harvest rates.

Spring Chinook salmon returning to the Columbia River are comprised of lower river (downstream from BON) and upriver (upstream from BON) components. Spring Chinook salmon entering the lower Columbia River during mid-February to mid-March are predominantly larger fish destined for lower river tributaries. Upriver spring Chinook salmon returning to areas upstream of BON begin to enter the Columbia River in substantial numbers after mid-March and generally reach peak abundance at BON in late April to early May. Historically, all Chinook salmon passing BON from March through May were counted as upriver spring Chinook salmon. Since 2005, the upriver spring Chinook salmon run size has included Snake River summer Chinook salmon due to similarities in run timing among the stocks.

The upriver spring run is comprised of stocks from several ESUs and three geographically separate production areas:

1. **Upper Columbia** the Columbia River system upstream of the Yakima River,
2. **Snake River system**, and
3. **Mid-Columbia** includes the Columbia River tributaries between Bonneville Dam and the Yakima River, excluding the Snake River system.

Harvest of spring Chinook or spring/summer Chinook salmon reported in the *effect zone* and its tributaries may include Chinook salmon from these three geographic areas.

The Columbia River summer steelhead run includes populations from lower- and upper river tributaries. Summer steelhead enter freshwater year-round with the majority of the run entering from June through October. The lower river component of the run tends to be earlier-timed than the upriver stocks, with abundance peaking during May and June. Skamania stock hatchery summer steelhead are widely planted in the lower Columbia tributaries. Skamania stock hatchery fish are also released annually in some tributaries upstream of BON.

The upriver steelhead run has been historically separated into A and B index groups depending on whether they passed Bonneville Dam before and after August 25 (TAC 2008). Group A steelhead include early-returning Skamania stock. Group A steelhead also include non-Skamania stock destined to return to tributaries throughout the Columbia and Snake basins. Group B steelhead return to the Clearwater and Salmon rivers in Idaho and are generally larger and later timed than Group A steelhead. NMFS has divided the upriver wild summer steelhead run into three DPSs:

1. **Middle Columbia DPS** which includes steelhead destined for Columbia River tributaries from upstream of the Wind and Hood rivers upstream to and including the Yakima River,
2. **Upper Columbia DPS** which includes steelhead destined for Columbia River tributaries upstream of the Yakima River, and
3. **Snake River DPS** which includes steelhead returning to the Snake River basin.

Currently, there is no reliable method available to segregate the steelhead run at BON into individual DPS's. Steelhead catch reported in the *effect zone* and its tributaries may include steelhead from all three distinct populations plus Skamania stock.

Non-Indian Recreational Fisheries

Recreational fisheries for salmon and steelhead occur in the Columbia River between BON to MCN (Zone 6) and in tributary streams of Oregon and Washington entering the Columbia River within this zone. The states of Washington and Oregon set regulations concerning sport fisheries in the mainstem Columbia River. Non-externally marked (no adipose fin clip) spring Chinook salmon and wild steelhead release is required in all recreational fisheries.

In recent years spring Chinook salmon fisheries have occurred in areas above BON upstream to MCN or as far upstream as PRD (TAC 2008). These fisheries occur if upriver run size forecasts allow for surplus harvest of hatchery fish and ESA impact limits won't be exceeded. A mark-selective fishery for spring Chinook salmon has occurred annually since 2001. Effort, reported as the number of anglers reported for each year, ranged from 1,000 to over 15,000 between 2001 and 2007 (Table 3). We were unable to locate catch per unit effort information.

Table 3. Effort and season of the spring Chinook recreational fisheries observed upstream of Bonneville Dam (from TAC 2008).

Year	Anglers	Season	General Area
1999	---	No Season	None
2000	---	No Season	None
2001	1,000	May 3-8	The Dalles - McNary
2002	7,996	March 16 – May 15	The Dalles - McNary
2003	15,100	March 15 – May 16 (4 days/week)	Bonneville - McNary
2004	7,600	March 16 – May 6	Bonneville - McNary
2005	2,707	March 16 – April 21	Bonneville - McNary
		June 4 – 15	Bonneville – Highway 395 Bridge
2006	4,211	March 1 – April 30	Bonneville - McNary
		June 6 – 15	Bonneville – Highway 395 Bridge
2007	3,734	March 16 – May 3	Bonneville - McNary
		June 6 – 15	

Total sport harvest for spring Chinook salmon and summer steelhead in tributaries and mainstem Columbia River are estimated through catch card reporting. The sport fishery upstream of BON is not monitored with the intensive creel program that is in place in the lower river, but is done as time and budgets allow. In Washington, sport harvest information is available from 1995-2003[3] (WDFW website; http://wdfw.wa.gov/fishing/harvest/). Sport harvest estimates for salmon and steelhead are made using catch record cards in Washington State. The number of fish harvested from sample cards is expanded to account for the un-sampled cards[4] and unreturned cards. A bias adjustment factor is applied in some areas and for some species to account for successful anglers returning cards at a higher rate than unsuccessful anglers.

In Oregon, sport harvest information is available from 1995-2009 (ODFW website; http://www.dfw.state.or.us/resources/fishing/sportcatch.asp). Additional historical data is also available summarizing total catch by waterbody from 1978-1994. All catch estimates from salmon-steelhead tag returns have been corrected for non-response bias, using the method described by Hicks and Calvin (1964).

In both states, information is summarized by monthly catch within segments of the Columbia River and its tributaries. We used available data from 2000-2003 from both states to summarize sport harvest and catch locations in the *effect zone.* These years were reported because WA only had catch estimated completed up to 2003.

Recreational steelhead catch in Washington tributaries and mainstem Columbia River is differentiated as marked and unmarked summer-run steelhead. Oregon reports total catch. Unmarked and marked catch for Washington was combined for each month because the unmarked catch is generally small ranging from 0.26% to 1.49% of the total catch reported for a location.

In Washington, catch summaries for Chinook salmon are not differentiated by race (spring, summer, and fall), while in Oregon, they are. Therefore, Washington catch data from January through June was used to distinguish harvest of spring Chinook salmon from later arriving summer and fall Chinook salmon. January through June 15 is the annual counting period used for spring Chinook at BON. It is likely that catch reported in Washington for July and August may contain additional spring Chinook salmon harvest. This is particularly true for harvest that may occur in the tributaries of the lower river.

Hatchery Spring Chinook Salmon (CWT returns)

We examined Chinook salmon CWT[5] returns from tributaries as a means to compare sport catch card harvest locations to CWT returns. Due to low numbers of CWT steelhead from many hatchery programs, it is not possible to determine if summer steelhead are represented in the tributary fisheries.

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[3] We note that because Washington State is so far behind in summarizing catch information, it limits our ability to evaluate the full data set for comparison between PIT tag information and catch information.

[4] We are unclear of the meaning of "un-sampled cards."

[5] For an overview of how the CWT recaptures are expanded and other information regarding the CWT program, see Nandor et al. (2009).

We examined whether Chinook salmon from the UCR and SR moved into non-natal streams in the *effect zone* where they could potentially be caught in tributary fisheries. Also, fish that move into non-natal streams can also be collected for hatchery broodstock.

We used CWT returns from hatchery Chinook salmon released from the two regions. For the UCR, we examined CWT's from four hatcheries located in the Wenatchee and Methow River basins. The hatcheries include the Chiwawa and Methow hatcheries as well as the Leavenworth and Winthrop National Fish Hatcheries (NFH). From the SR region, there were eight hatcheries within the Clearwater, Salmon, Grande Ronde, and Imnaha river systems. We examined brood year returns from 2000-2004. We stopped at 2004, because that was the last year that a brood cycle was complete for. We separated harvest and hatchery recoveries into three areas: downstream from, within, and upstream from the *effect zone*.

We also examined CWT returns from hatcheries as another source of information on migration behavior (straying, timing, etc.). Hatcheries routinely collect fish for broodstock, and in some instances, collect fish destined for other river basins. These fish cannot readily be distinguished during typical broodstock collection efforts. Similar to tributary harvest, hatchery broodstock collections may help to describe migration behavior within the *effect zone*.

Tribal Commercial, Ceremonial and Subsistence Fisheries

Tribal commercial and ceremonial and subsistence (C&S) fisheries occur above BON to MCN (Zone 6) and in tributaries throughout the Columbia River Basin. Set gillnets are the primary gear used in the Tribal commercial fishery. Other gear types used in commercial fisheries include drift gillnets, hoop nets, dip nets, and hook and line gear. Ceremonial fishing typically uses set or drift gillnets, but may include other gear. Subsistence fisheries typically use hoop nets, dip nets, and hook and line gear, but may use gillnets in Zone 6 and occasionally use spears or gaffs in tributaries. All Zone 6 adult Chinook salmon harvested from the period January 1 to June 15 annually are considered spring Chinook salmon. Spring Chinook salmon can be caught in the winter and spring fishing seasons while summer steelhead may be caught throughout the year.

The TAC reports harvest rates for wild spring Chinook based on run reconstruction analysis.

Monitoring and evaluation strategies and actions for fishery management including implementation and performance standards.

To determine whether the fishery programs are meeting their goals, robust monitoring and evaluation is needed. In addition, critical uncertainty research can increase the managers' understanding of how fishery programs may be affecting natural populations. Information obtained from RM&E can also assist managers in making informed decisions concerning fishery programs, allowing for adaptive management.

In this section, we highlight the current RM&E activities that are taking place within the ***effect zone***.

The following information was provided by S. Ellis (CRITFC), C. Le Fleur (WDFW), and E. Patino (NMFS), personal communication.

Non-Indian Fishery Monitoring and Evaluation above Bonneville Dam

Fisheries above Bonneville Dam are monitored in many of the same ways as below Bonneville Dam, where all recreational and commercial mainstem fisheries (and most major tributary fisheries) are sampled to estimate total catch. Biological data, including mark information, scale samples, length (and weight for commercial samples) of fish, injuries from marine mammals, and presence of a CWT are collected. The tribal commercial fishery is sampled in the same way as commercial fisheries in the lower river. The sport fishery upstream of Bonneville Dam is not monitored with the intensive creel program that is in place in the lower river, but is done as time and budgets allow. The sport fishery in this area is on a much smaller scale than below Bonneville Dam. Sport catch information is obtained primarily from catch record cards.

Treaty Fishery Monitoring and Evaluation

Harvest monitoring varies by fishery and season. There are three main types of salmon/steelhead fisheries; ceremonial/subsistence permit gillnet, platform/hook and line, and commercial gillnet. Platform/hook and line fisheries can occur simultaneously with commercial gillnet fisheries and can be commercial or non-commercial. Additionally, the tribes have commercial sturgeon gillnet and setline fisheries and commercial shad fisheries using trap and hoopnet gear.

Ceremonial and Subsistence Permit Fisheries

Tribal ceremonial and subsistence permit fisheries occur primarily in the spring management period targeting spring Chinook salmon. They may at the discretion of the tribes occur at other times of the year. Each tribe manages their C&S permit fisheries separately. Target harvest numbers are set to be within the overall harvest rate limits for the applicable species in that management period. Permits are issued to specific tribal fishing crews for set periods of time generally in specific locations. Gear restrictions can be part of the permit. Incidental harvest of non-target fish are retained. Some tribes monitor fisheries directly and collect some biological data (CWT, etc.). Other tribes require permit holders to report total catches. Because upriver spring Chinook are managed as a composite stock in Zone 6, complete CWT sampling is not necessary for stock composition calculations. Harvest rates are presumed to be equal on any ESU.

Tribal Fishery Monitors

The Yakama Nation currently employs four fishery monitors. Number of monitors is dependent on available funding. They work full time throughout most of the year. They monitor all four tribes' fisheries (except ceremonial permit fisheries). Nez Perce tribe has had funding to assist in Zone 6 monitoring in some years and will continue this as long as funding is available. Total monitoring effort limited by budget constraints so monitors focus on total catch estimates over any biological sampling and collect limited stock composition data.

Tribal Fishery Monitoring Tasks for Platform/Hook and Line Fisheries

Monitors are assigned to the three main geographic areas where platform fishing occurs (Cascade Locks, Lone Pine – below The Dalles Dam, and below the John Day Dam). Monitors count active gears (active platform sites and or active hook and line gear). Monitors observe active platforms for a set number of hours per shift. Monitors note numbers and species of fish observed and also note any non-observed catch reported by fishers.

Catch Estimation for Platform/Hook and Line Fisheries

Several assumptions are made to estimate the catch from platform/hook and line fisheries; 1) Platforms are fishing a certain numbers of hours and days in each season, 2) Catch is not even between daytime and nighttime fishing, and 3) 10% of the catch occurs outside the three main platform areas. There is a goal of monitoring 20% of the time that platforms are fishing. Platform monitoring rates decline during commercial gillnet fisheries because during these periods, platform effort is assumed to decline. Monitoring data are expanded for total active gears. They are also expanded for assumed daytime and nighttime hours fished. Catch estimates are made independently for Cascade Locks, Lone Pine and below John Day dam. Catches are expanded for assumed 10% harvest in un-monitored areas. During commercial gillnet periods; platform/hook and line catch is incorporated into a single weekly harvest estimate.

Net Count Methods

Arial flights are used to determine commercial gillnet fishing effort in Zone 6. This is a similar process to the flights used to estimate sport effort in the lower river. Flights occur once during each weekly commercial gillnet opening. Flights are set to approximately the middle of the opening and begin from about 6:00 to 7:00 AM. Flights always go the same direction. Flights go upstream along the Oregon shore and downstream along the Washington Shore. Almost all gillnetting is done with set net gear. Normally it is deployed along the shore or fairly near the shore outside the main shipping channel. The cork line of the nets is usually easy to see under most weather and light conditions. Nets are counted separately in specific geographic sections of each pool. If two counters are used, counts are averaged. This has been a standard method used for many years. Most gillnet fishermen have registered sites and have exclusive use of these sites. Because of this, many fishers who are regularly active in the fishery deploy their gear in the same locations during each fishery opening. This makes counting nets easier, because much of the gear is in the same general location for each opening.

Assumptions for Net Counts:

- Net counts are an index of fishing effort.
- Counting in the middle of the fishery observes most nets.
- Nets are equally visible during any weather or wind condition.
- Nets are not being put in or removed during counts.
- Using average counts (if two observers are used) assumes that it is equally likely to over-count as undercount.

Commercial Gillnet Catch Sampling

Monitors sample catch at landing points (often in-lieu fishing sites). Data are collected on number of fish per net, number of nets sampled, numbers of times per day nets are checked and number of nets each sampled crew are fishing. Any drift nets sampled are accounted for separately. Summer and fall season steelhead are measured $<$ or $\geq$ 78 cm and presence/absence of an adipose fin-clip. Data are matched with net flight data and catch estimates are made for each pool separately. Monitoring data are expanded based on the net counts and the total length of the fishery. CWT data are used in the fall season to make final stock composition estimates. In some years Bonneville sampling data have been used to adjust steelhead wild fish estimates in fall season. Commercial fish ticket data are not directly used except to double check total catch estimates

Biological Sampling
Tribal monitors do not do biological sampling. However, state samplers sample tribal catch for CWT, scales, and other data at commercial buying stations (often now at In-Lieu fishing sites-fishing sites provided to tribal members by the U.S. Army Corps of Engineers to compensate for traditional fishing areas flooded by the reservoirs). CWT analysis is the same as described in the non-Indian fishery section.

3.2.3.2. Results

Chinook Salmon Recreational Harvest
Table 4 presents the estimated total catch summaries based on expanded catch card data from 2000-2003 for spring Chinook salmon from Oregon and Washington. The majority (>80%) of the harvest occurred in April (33%) and May (54%) for the years examined (Table 4). In Oregon and Washington most sport harvest within the *effect zone* for spring Chinook salmon occurred in tributaries[6]. The Deschutes River in Oregon and Wind River in Washington made up more than 70 percent of the reported sport harvest (Figure 3). The Umatilla (OR) and Little White Salmon (WA) rivers were also a fairly large percentage of the reported catch. Combined, tributaries made up 94% of the sport harvest (Figure 3).

Table 4. Expanded sport catch card reported for the spring Chinook in the mainstem Columbia River and tributaries from Bonneville to McNary dams, 2000-2003.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Washington Catch Card Reporting										
Big White Salmon River	0	6	0	692	278	100				1076
Klickitat River	0	0	2	329	711	763				1805
Little White Salmon & Drano Lake	0	0	147	7355	3729	432				11663
Wind River	0	0	257	11690	26650	6501				45098
Columbia River	0	0	77	2184	882	67				3210
Oregon Catch Card Reporting										
Deschutes River	0	0	0	3535	9907	1199	19	0	0	14660
Hood River	0	0	0	69	201	167	24	1	0	462
Umatilla River	0	0	0	572	2573	57	4	20	4	3230
John Day River	3	3	0	44	18	30	12	0	0	110
Columbia River	15	15	63	657	427	210				1387
Total	**18**	**24**	**546**	**27127**	**45376**	**9526**	**59**	**21**	**4**	**82701**
Percent	**0.0**	**0.0**	**0.7**	**32.8**	**54.9**	**11.5**	**0.1**	**0.0**	**0.0**	

[6] It should be noted that some fish that are caught in the Columbia River in the immediate vicinity of the tributary mouth are recorded as caught within the tributary.

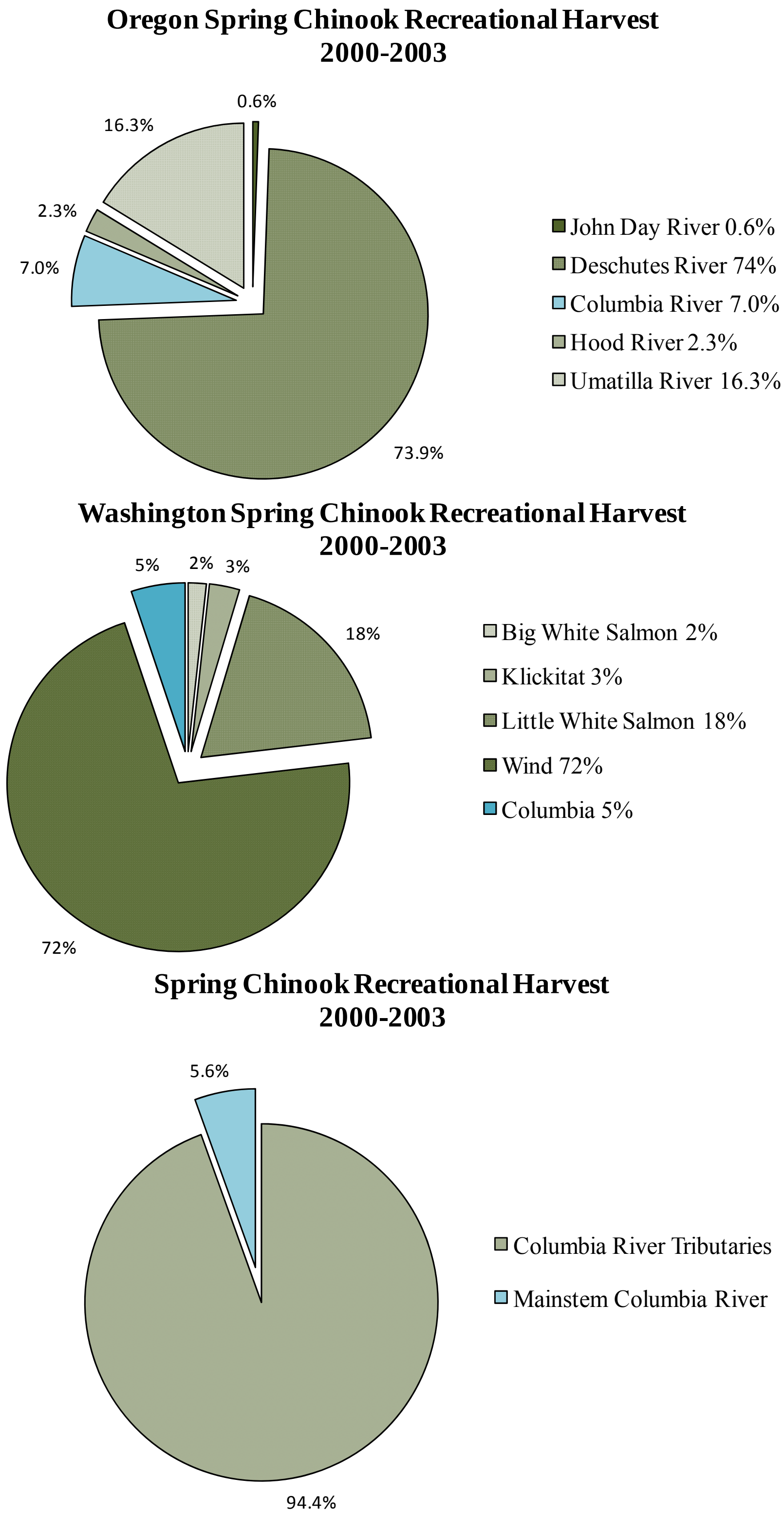
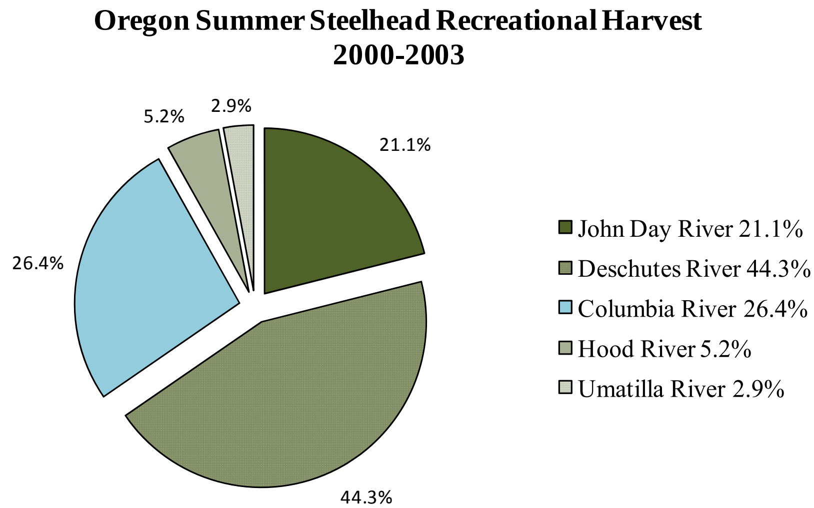


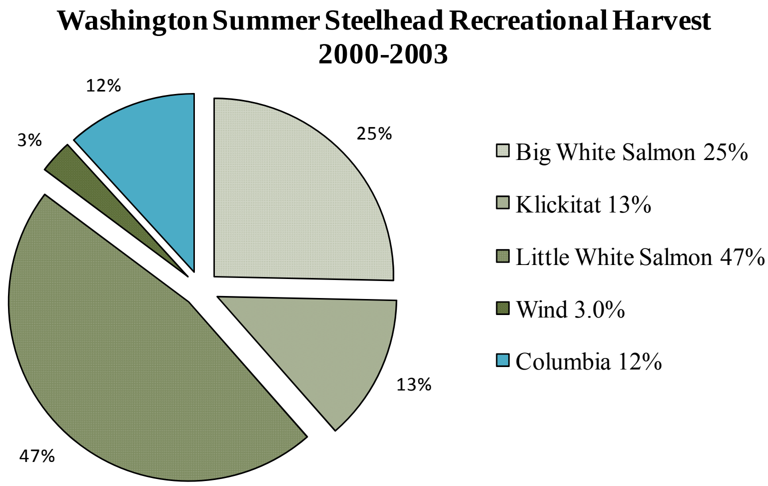
Figure 3. Pie charts representing the percent of spring Chinook harvested in sport fisheries in Oregon and Washington with combined harvest for the Columbia River and tributaries.

Steelhead Recreational Harvest- Table 5 presents the estimated total catch summaries based on expanded catch card data from 2000-2003 for summer steelhead from Oregon and Washington. Nearly half of the catch occurred in August (33%) and September (20%) for the years examined (Table 5). In Oregon and Washington most sport catch within the *effect zone* for summer steelhead occurred in tributaries (see footnote 3). The Deschutes River (44%) in Oregon and Little White Salmon River (47%) in Washington made up nearly half of the reported sport harvest for each state (Figure 4). The John Day (OR) and Big White Salmon (WA) rivers were also a fairly large percentage of the reported catch. Combined, tributaries made up 81% of the sport catch (Figure 4).

Table 5. Expanded sport catch card reported for steelhead in the mainstem Columbia River and tributaries from Bonneville to McNary dams, 2000-2003.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Washington Catch Card Reporting													
Big White Salmon River	0	0	14	19	436	1311	2703	9547	4022	237	0	0	18289
Klickitat River	0	0	0	0	44	1439	1993	2734	1859	1484	0	0	9553
Little White Salmon & Drano	18	22	19	54	41	156	3653	20430	8760	449	37	55	33694
Wind River	33	0	17	6	36	27	51	878	404	308	280	144	2184
Columbia River	894	445	255	31	40	94	443	1556	931	1024	1431	1320	8464
Oregon Catch Card Reporting													
Deschutes River	404	0	0	112	165	122	1997	5947	7987	6404	2723	2084	27945
Hood River	47	51	158	547	532	764	234	73	127	162	320	276	3291
Umatilla River	285	280	217	12	21	3	10	4	44	308	331	336	1851
John Day River	1389	717	158	23	22	19	15	29	218	2405	5142	3149	13286
Columbia River	895	599	999	320	54	133	1414	4119	2135	2010	2065	1902	16645
Total	**3965**	**2114**	**1837**	**1124**	**1391**	**4068**	**12513**	**45317**	**26487**	**14791**	**12329**	**9266**	**135202**
Percent	**2.9**	**1.6**	**1.4**	**0.8**	**1.0**	**3.0**	**9.3**	**33.5**	**19.6**	**10.9**	**9.1**	**6.9**	





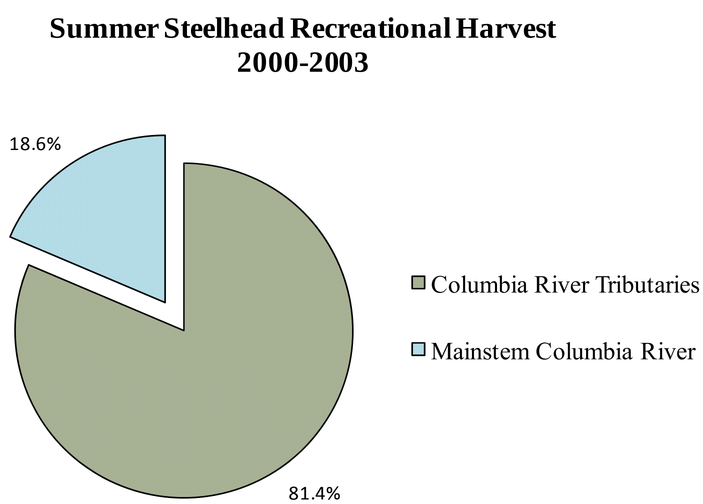


Figure 4. Pie charts representing the percent of summer steelhead harvested in sport fisheries in Oregon and Washington with combined harvest for the Columbia River and tributaries.

Tribal Commercial, Ceremonial and Subsistence Fisheries

Wild harvest rate estimates reported by the TAC (2010) are nearly identical for Chinook salmon from the two regions (Table 6). Non-Tribal harvest rates from 2000-2008 have varied from 1.7% to 2.1% while Treaty Indian harvest has varied from 6.2% to 13.9%. Harvest rates presented for wild Chinook salmon from both regions appear to be nearly equal in both non-Indian and Tribal fisheries (Table 6). Similarities is estimated harvest rate of UCR and SR within Tribal and non-Indian fisheries is a function of estimated total catch by fishery type and estimated populations of the two stocks within the fishery area (i.e. run reconstruction) and not specifically associated with known stock specific recoveries in the fisheries. It is unknown whether or not UCR and SR stocks are truly harvested at similar rates.

Table 6. Harvest rate as a percent of the run reported for Upper Columbia River wild spring Chinook and Snake River wild spring/summer Chinook.

Year	Wild Run Size	Non-Indian Catch[a]		Treaty Indian Catch[b]		Fisheries Total	
		No.	% of Run	No.	% of Run	No.	% of Run
Upper Columbia							
2000	2,937	6	0.2	179	6.1	185	6.3
2001	10,016	151	1.5	1,316	13.1	1,467	14.6
2002	5,683	106	1.9	617	10.9	723	12.7
2003	2,548	39	1.5	201	7.9	240	9.4
2004	3,072	65	2.1	267	8.7	332	10.8
2005	2,479	41	1.7	155	6.3	196	7.9
2006	2,371	32	1.3	156	6.6	188	7.9
2007	876	11	1.3	66	7.5	77	8.8
2008	1,961	41	2.1	272	13.9	313	16.0
Snake River							
2000	12,893	25	0.2	786	6.1	811	6.3
2001	60,437	900	1.5	7,941	13.1	8,841	14.6
2002	48,053	862	1.8	5,219	10.9	6,081	12.7
2003	52,179	813	1.6	4,102	7.9	4,915	9.4
2004	32,138	684	2.1	2,778	8.6	3,462	10.8
2005	15,341	261	1.7	956	6.2	1,217	7.9
2006	16,730	235	1.4	1,100	6.6	1,335	8.0
2007	10,642	132	1.2	800	7.5	932	8.8
2008	23,604	492	2.1	3,278	13.9	3,769	16.0

[a] Includes incidental mortalities in mainstem recreational and commercial fisheries.
[b] Since 1982 C&S catch includes gill net, dip net and hook and line. Includes harvest below BON from C&S fishery.

Estimated steelhead harvest rates reported for the winter, spring, summer, and fall are presented in Table 7. Steelhead harvest in the winter season is comprised of a mix of hatchery and wild winter and summer steelhead as well as possibly kelts. Steelhead in Zone 6 during the winter season may be from any DPS. There are no reliable methods to determine stock specific or DPS specific impacts during the winter period. In the spring portion of the winter/spring management period, the tribes harvest a small numbers of steelhead in ceremonial fisheries with harvest rates below 0.2%. Steelhead harvest in the summer season is comprised of a mix of both hatchery and wild summer steelhead from both the Skamania and A and B-Index groups. Steelhead in Zone 6 during the summer season may be from any DPS. Harvest rates have varied from 0.5% to 3.9%. Steelhead harvest is generally the highest in the Fall Season with Tribal steelhead harvest divided into wild and hatchery and A and B-Index groups, but there currently is no reliable method to determine DPS specific impact rates for steelhead.

Detailed information on Tribal catch per unit effort (number of nets, locations, fishing time) was not readily available. Detailed summaries of this type of information would be useful in describing the fishery and perhaps comparisons to CWT returns and passage indices of summer steelhead and spring Chinook salmon.

Table 7. Steelhead harvest (hatchery and wild) and percent wild harvest in the mainstem Columbia River Zone 6 Treaty Indian commercial and subsistence fisheries (TAC 2008). The seasons are: Winter season (Feb 1- Mar 21); Spring (Mar 22-May 31 or June 15 after 2005); Summer (June 1- July 31 or June 16-July 31 after 2004); Fall (Aug 1- Dec 31).

Year	Winter[1]	Spring[2]	Summer[3]	Fall
2001	230 (3.4%)	617 (0.1%)	8,220 (2.1%)	29,190
2002	78 (0.3%)	411 (0.1%)	4,967 (2.1%)	13,480
2003	788 (5.8%)	385 (0.1%)	4,455 (2.8%)	21,000
2004	70 (0.8%)	400 (0.1%)	5,514 (3.9%)	14,575
2005	17 (0.8%)	155 (0.1%)	3,552 (2.3%)	13,689
2006	139 (1.8%)	422 (0.2%)	1,345 (0.8%)	21,129
2007	558 (2.3%)	323 (0.1%)	1,039 (0.5%)	19,456
1. Wild harvest rate based on unmarked count of winter season steelhead at Bonneville Dam				
2. Harvest rate is based on the Bonneville count of wild Skamania run and wild A index steelhead				
3. Harvest rate based on total wild A run size (Skamania and A index).				

Hatchery Spring Chinook Salmon (CWT returns)

Table 8 displays the estimated number of Chinook salmon (based on CWT recoveries and expansions) from each region harvested in tributaries downstream, within, and upstream of the *effect zone*. There are few UCR or SR Chinook salmon harvested within *effect zone* tributaries. For brood years 2000-2004, there was only one UCR hatchery spring Chinook salmon harvested within tributaries of the *effect zone*. In comparison, there were thirty hatchery Chinook salmon from the SR harvested in *effect zone* tributaries. Most (23 fish) of the SR Chinook salmon harvested originated from a single hatchery. Similar to catch card information, the Deschutes River in Oregon and Wind River in Washington is where most of the Chinook salmon from the UCR and SR regions were harvested. For UCR spring Chinook salmon, more fish were harvested in tributaries (Willamette and Kalama rivers) downstream from BON. We found no CWT returns for SR spring/summer Chinook salmon downstream from BON.

Table 8. Coded wire tag (CWT) returns for brood years 2000-2004 from tributary harvest locations downstream, within, and upstream from the Effect Zone (BON-MCN).

Hatcheries	Tributary Harvest						Total
	Downstream		Effect Zone (BON-MCN)		Upstream		
	Harvest	Location(s)	Harvest	Location(s)	Harvest	Location(s)	
Upper Columbia River Region							
Chiwawa Hatchery	6	Kalama	0	None	11	Icicle Creek	17
Methow Hatchery	3	Willamette	0	None	0	None	3
Leavenworth NFH	8	Kalama	0	None	388	Icicle Creek	396
Winthrop NFH	0	None	1	Deschutes	0	None	1
Total	**17**		**1**		**399**		**417**
Snake River Region							
Clearwater River Hatchery	0	None	4	Wind	0	None	4
Dworshak National Fish Hatchery	0	None	0	None	0	None	0
Kooskia National Fish Hatchery	0	None	0	None	0	None	0
Lookingglass Hatchery	0	None	2	Deschutes	0	None	2
Rapid River Fish Hatchery	0	None	1	Deschutes	0	None	1
Sawtooth Fish Hatchery	0	None	0	None	0	None	0
McCall Fish Hatchery	0	None	23	Deschutes, Wind	0	None	23
Pahsimeroi River Fish Hatchery	0	None	0	None	0	None	0
Total	**0**		**30**		**0**		**30**

Similar numbers of UCR spring Chinook salmon and SR spring/summer Chinook salmon were collected by hatcheries within the *effect zone*. Table 9 displays the estimated number of Chinook salmon from each region collected by hatcheries downstream, within, and upstream of the *effect zone*. Over the four brood years examined there were 18 spring Chinook salmon from the UCR collected by hatcheries within the *effect zone*. Upper Columbia River hatchery spring Chinook salmon were recovered in hatcheries on the Deschutes (14 fish) and Little White Salmon (4 fish) rivers. For the same brood years, there were 16 spring/summer Chinook salmon collected from the SR region. Snake River spring/summer Chinook salmon were recovered in the same hatcheries on the Deschutes (12 fish) and Little White Salmon (4 fish) rivers.

Migration behavior for hatchery Chinook salmon, suggested by CWT returns from tributary fisheries and hatchery collections, appears to be similar for both regions. Hatchery Chinook salmon from both regions within the *effect zone* are present in the same tributary fisheries and hatchery collections.

Table 9. Expanded coded wire tag (CWT) returns for brood years 2000-2004 from hatchery recoveries located downstream, within, and upstream from the Effect Zone (BON-MCN).

Hatchery	Hatchery Recoveries			Total
	Downstream	Effect Zone (BON-MCN)	Upstream	
	Hatchery Recoveries	Hatchery Recoveries	Hatchery Recoveries	
Upper Columbia Region (spring Chinook)				
Chiwawa Hatchery	5	0	535	540
Methow Hatchery	0	0	1268	1268
Entiat NFH	0	2	894	896
Leavenworth NFH	2	12	3550	3564
Winthrop NFH	4	4	1829	1837
Total	**11**	**18**	**8076**	**8105**
Snake River Region (spring/summer Chinook)				
Clearwater Hatchery	0	4	116	120
Dworshak NFH	0	0	744	744
Kooskia NFH	0	0	316	316
Lookingglass Hatchery	6	7	16	29
Rapid River Fish Hatchery	0	0	0	0
Sawtooth Fish Hatchery	0	0	1	1
McCall Fish Hatchery	0	4	9	13
Pahsimeroi Fish Hatchery	4	1	1	6
	10	**16**	**1203**	**1229**

Conclusion

Based on the information available, we cannot reject the null hypothesis. Currently, there is no reliable method available to segregate the steelhead run at BON into individual DPS's, unless the fish are differentially marked with PIT or coded-wire tags.

There is also little evidence based on CWT returns that tributary harvest within the *effect zone* is biased toward UCR Chinook salmon. The relatively small number of fish harvested in tributary sport fisheries and collected by hatcheries is not likely to explain the observed difference in survival through the *effect zone*.

However, additional information is needed before we can definitively state conclusions regarding the influence of harvest in explaining the survival differences between UCR and SR fish.

The additional information needed includes:

- More DPS/ESU specific rates of harvest by all tribal and non-tribal fishers,
- Additional information from C&S fisheries in regards to specific ESU/DPS,
- PIT tag detection for all fisheries,
- Increased level of effort (survey) for some fisheries,

- Increased level of CWT marking for UCR steelhead,
- CWT tag detections of adipose clipped, non-adipose clipped steelhead and spring Chinook with Treaty and non-Treaty fisheries,
- Development of similar methods for harvest surveys for Treaty and non-Treaty fisheries, including Catch per Unit Effort (CPUE) and total estimated harvest effort by fishery type (recreational, commercial and ceremonial/subsistence) and harvest method (hook and line, gillnet, hoop net and dip net), and standardized methods of CWT and PIT tag evaluations of fish harvested (i.e. because not all UCR steelhead and spring Chinook are adipose clipped to indicate CWT, scan all fish encountered in fisheries for presence of CWT and or PIT tag).
- Increase the level of creel monitoring effort for Treaty and non-Treaty fisheries in Zone 6

3.2.4 $H_0$4-Fallback rates of UCR spring Chinook salmon and steelhead equals SR spring/summer Chinook salmon and steelhead (A-run)

3.2.4.1. Methods

Between 1996 and 2003, the University of Idaho (UI) and other collaborators performed radio telemetry studies of Chinook salmon and steelhead. Between 2000 and 2003, they used known stock fish that were PIT tagged as juveniles. While dozens of reports were looked at, the following summaries pertain to fallback and re-ascension.

Fallback percentage was defined as the number of unique fish that fell back at the dam, divided by the number of unique fish that were known to have passed the dam. Fallback rate was defined as the number of fallback events (this included multiple fallbacks by individual fish) at the dam divided by the number of unique fish known to have passed the dam. Re-ascension proportion was defined as the proportion of unique fish that fell back, and ultimately re-ascended a given dam and were detected upstream (Boggs et al. 2005).

Boggs et al. (2005) appears to be the best source of known-stock fallback information for the lower Columbia FCRPS dams. Boggs et al. (2005) grouped spring and summer Chinook salmon together into the "Mid-Columbia" designation. They separated the Yakima River fish, so our assumption is that most of the fish within this group (for Chinook salmon) were from areas upstream of the Yakima River, and hence, what we now call UCR. Steelhead were divided into only two groups; SR and mid-Columbia, however, it is likely that most fish were hatchery-origin, and thus from the UCR in the years that these studies took place (the report does not specify stocks, and there are no hatchery programs in the Yakima River basin for steelhead). ***In the following discussion, we have changed Boggs et al. (2005) use of the term "mid-Columbia" and use UCR to ensure consistency and avoid confusion, but it is important to note the qualifications mentioned above***.

3.2.4.2. Results

Boggs et al. (2005) summarize fallback behavior as follows:

The percentage of upriver-migrating salmon and steelhead that fall back at lower Columbia and Snake River dams varies widely depending on the run, species and project involved and river conditions when fish are migrating. In terms of salmon and steelhead fallback behavior, each dam on the Columbia and Snake rivers is unique; physically as a structure, operationally as a combination of river inflow, dam spill and turbine discharges at any given time, and geographically in its location relative to the natal spawning tributaries and hatcheries to which fish are returning. These factors and the timing, size and composition of anadromous fish runs appear to influence fallback behavior at dams. For example, a large return run to the Umatilla or John Day rivers could result in high fallback percentages at McNary Dam—the project just upstream from those tributaries—through increased overshoot fallback.

Spring/summer Chinook salmon

In general, between 2000-2003, spring/summer Chinook salmon from the SR and UCR fallback over lower Columbia River FCRPS hydroprojects at similar rates unless the SR fish had been transported (Figure 5). Fallback rates ranged between 0 to slightly over 5% for UCR fish, and between 0 to over 15% for SR (non-transported; Figure 5, Table 9). In general, it appears that SR fish fall back at higher rates than UCR fish, although in most years, not substantially so, except in 2000.

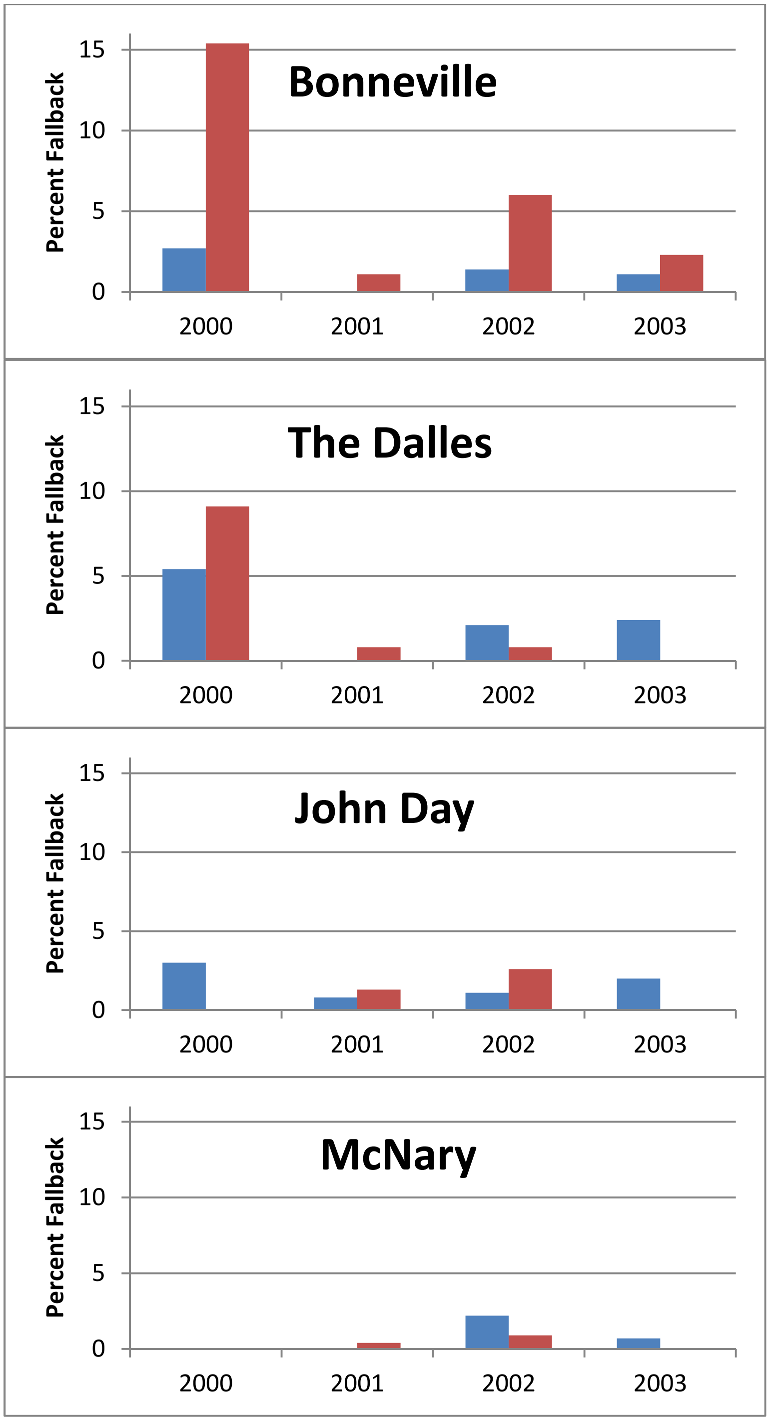


Figure 5. Fallback rates of spring/summer Chinook salmon from the Snake River (non-transported; red) and the UCR (blue) between 2000-2003 from Boggs et al. (2005).

Steelhead

Steelhead fallback rates were generally much lower than Chinook salmon (Figures 5, 6; Table 10).

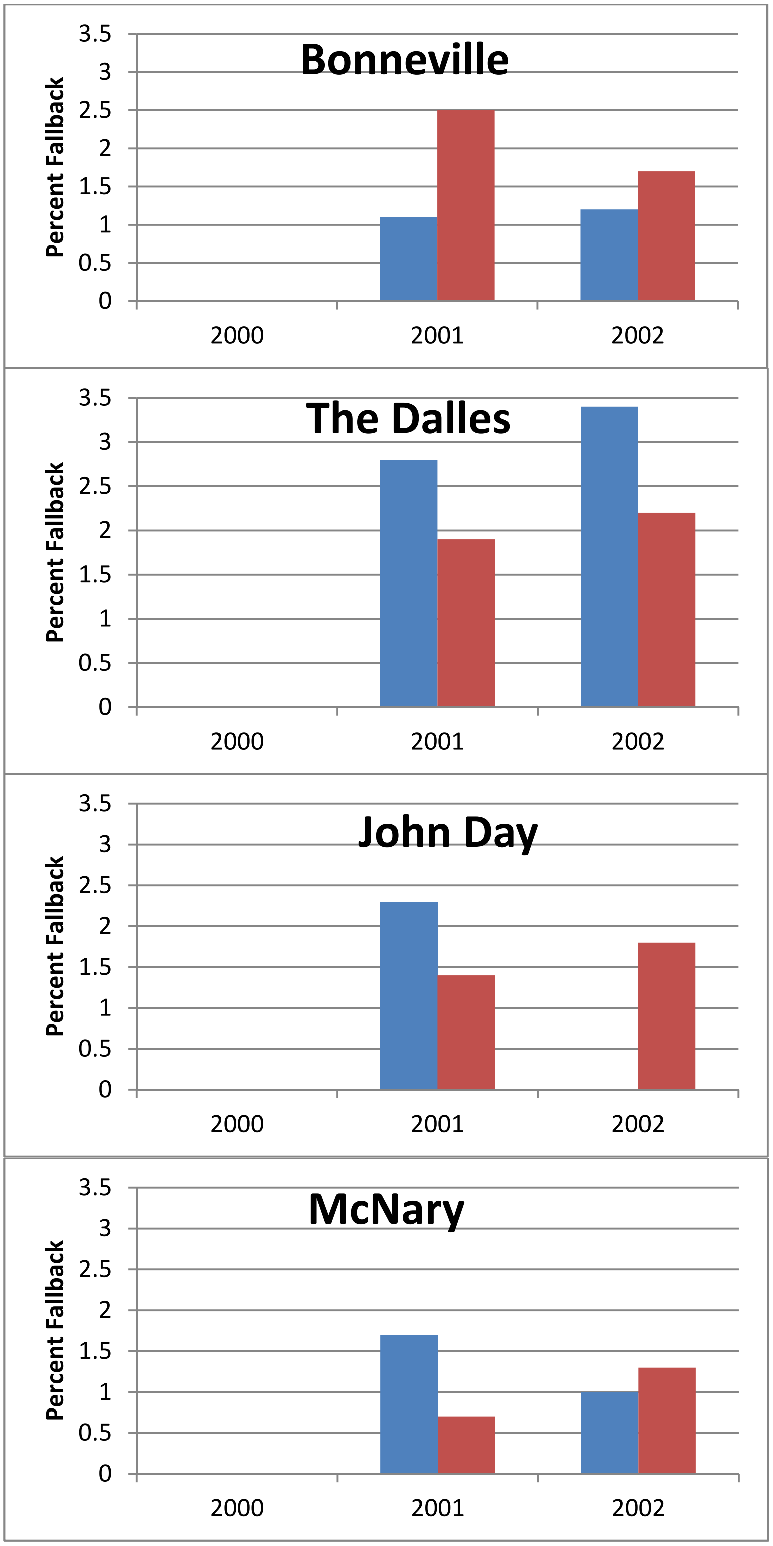


Figure 5. Fallback rates of steelhead from the Snake River (non-transported; red) and the mid-Columbia (blue) between 2000-2002 (no data from UCR fish for 2003) from Boggs et al. (2005).

Table 10. Annual percentages of spring/summer Chinook salmon and steelhead that fell back at lower Columbia River dams (based on Tables 7 and 8 of Boggs et al. 2005).

Species (known-stock region)	Year	Fallback percentage (n)			
		Bonneville	**The Dalles**	**John Day**	**McNary**
Chinook (UCR)	2000	2.7 (37)	5.4 (37)	3.0 (33)	0 (33)
	2001	0 (96)	0 (127)	0.8 (127)	0 (127)
	2002	1.4 (73)	2.1 (94)	1.1 (92)	2.2 (90)
	2003	1.1 (180)	2.4 (169)	2.0 (152)	0.7 (143)
	Total *n*	**386**	**427**	**404**	**393**
Chinook (SR; non-transported)	2000	15.4 (13)	9.1 (11)	0 (11)	0 (11)
	2001	1.1 (182)	0.8 (236)	1.3 (236)	0.4 (236)
	2002	6.0 (116)	0.8 (119)	2.6 (115)	0.9 (112)
	2003	2.3 (44)	0 (43)	0 (38)	0 (38)
	Total *n*	**355**	**409**	**400**	**397**
Steelhead (UCR)	2000	0 (2)	0 (1)	0 (1)	0 (1)
	2001	1.1 (183)	2.8 (284)	2.3 (257)	1.7 (235)
	2002	1.2 (82)	3.4 (117)	0 (107)	1.0 (104)
	2003	-	-	-	-
	Total *n*	**267**	**402**	**365**	**340**
Steelhead (SR; non-transported)	2000	0 (6)	0 (7)	0 (7)	0 (7)
	2001	2.5 (120)	1.9 (154)	1.4 (144)	0.7 (142)
	2002	1.7 (180)	2.2 (179)	1.8 (164)	1.3 (157)
	2003	0 (33)	0 (30)	0 (29)	0 (28)
	Total *n*	**339**	**370**	**344**	**334**

Discussion

Boggs et al. (2005) concluded that fallback at the Columbia River FCRPS dams varies widely depending on species and race of fish, configuration of the dam, and river conditions (primarily flow and spill conditions).

Spring/summer Chinook salmon migrate upriver during times when flows and spill are peaking, and therefore had higher percentages of fallback than steelhead, although most of the Chinook salmon used were later-running “summer” fish, which may have reduced the overall fall back rates of the earlier running “spring” Chinook salmon.

Boggs et al. (2005) concluded that mean daily river flow was positively correlated with river discharge for spring-summer Chinook salmon. This particular topic will be addressed in hypothesis 9 below.

Conclusion

We were unable to reject or not reject the null hypothesis with the available information. Based on the information available, it appears that SR spring/summer Chinook salmon fall back at lower Columbia River FCRPS hydroprojects at higher proportions than UCR spring/summer Chinook salmon. For steelhead, it appears that UCR fish fell back at slightly higher rates than SR fish. Boggs et al. (2005) performed Chi-square tests and found significant differences among fish from the various regions, but do not report enough detail to determine the differences between UCR and SR fish. However, not counting transported fish (which had much higher fall back rates than any other group), the differences were not very large, regardless of the Chi square test results.

3.2.5 $H_0$5- Ladder use (passage) through the effect zone for UCR spring Chinook salmon and steelhead equals SR spring/summer Chinook salmon and steelhead

We were unable to find information that could "test" this hypothesis. Additional information that would have been needed would be ESU/DPS specific information per ladder. Unfortunately, PIT tag information is reported for a whole project and not broken down by ladder.

3.2.6 $H_0$6- Wander rates of UCR spring Chinook salmon and steelhead through the effect zone equals SR spring/summer Chinook salmon and steelhead

We define wander rates as: *when a fish ascends or spends time in a non-natal stream, but continues its migration after some period of time*. Wander rates apply more to steelhead than spring Chinook salmon because of the time of year they enter freshwater (assumes the main reason for wandering is for thermal refuge).

Researchers have seen for years that radio-tagged adult salmonids use various streams entering the lower Columbia River to rest and seek thermal refuge (High 2002, High et al. 2006, Keefer et al. 2009). Keefer et al. (2009) tried to determine how this behavior may affect the final fate of various known populations, and is the focus of the discussion below.

3.2.6.1 Methods

Keefer et al. (2009) radio tagged steelhead at Bonneville Dam between 2001-2003 to assess four objectives:

1. Identify main stem water temperatures associated with thermoregulatory responses in migrating steelhead.

2. Assess among-population differences in thermal refugia use, including residency times and percentages of each population recorded in refugia sites.

3. Test for associations between refugia use and fish fate (i.e., main stem harvest, unknown main stem mortality, non-natal tributary harvest/mortality, and successful return to spawning tributaries).

4. Examine potential delayed effects of refugia use on fish fate in upstream river reaches.

The last two objectives were addressed using a subsample of the known-origin fish (steelhead that were PIT tagged as juveniles). This was a prerequisite for differentiating harvest of thermoregulating fish from harvest of returning local stocks. They tested two hypotheses for the four objectives:

(1) the degree and duration of behavioral thermoregulation differ among Columbia River steelhead populations as a function of stock-specific migration timing and migration corridor temperatures, and

(2) mortality risks associated with thermoregulation vary among populations, with greater risk for populations with proportionately greater refugia use and longer refugia residency times.

3.2.6.2 Results

Use of thermal refugia
Keefer et al (2009) found that steelhead use of thermal refuge increased rapidly after mainstem Columbia River water temperatures reached approximately 19 °C. The median travel time rose substantially when mainstem Columbia River temperatures rose above 21 °C (Table 11).

Table 11. Migration rates of all radio-tagged steelhead between Bonneville and The Dalles dams in relationship to mainstem temperature for all study years (1996-2003; from Keefer et al. (2009)).

Mainstem temperature (°C)	Median travel time (days)	Sample size	Percent recorded in cool-water tributaries
< 19	3	689	10
19-21	6	1,802	49
> 21	25	731	71

For the reach from BON to JDD, median passage time were five times longer for fish recorded using cool-water tributaries (32 days, n = 1,662) than for fish not using cool-water tributaries (6 days, n = 1,046) for all years combined.

For known stocks, Keefer et al (2009) found the same general trend of use of thermal refuge during mainstem temperatures above 19 °C, but the duration of use of thermal refuge was related to when the stock specific fish entered passed Bonneville Dam. Not surprisingly, they found that earlier and later migrating (prior to and after mainstem temperatures above 19 °C) steelhead stocks had the shortest migration rates (Figure 6).

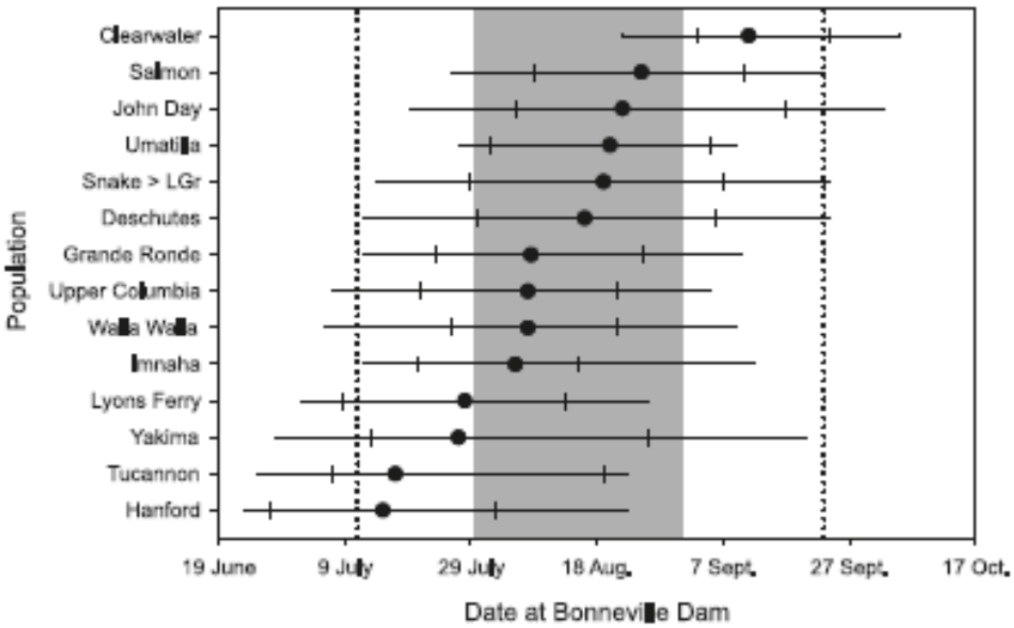


Figure 6. Migration timing distributions (median, quartiles, and 10th and 90th percentiles) at Bonneville Dam for steelhead that successfully returned to tributaries or hatcheries pooled across study years. Populations were identified by final fish locations. The vertical dotted lines show mean first and last dates that Columbia River water temperature was 19 °C; the shaded area shows dates with mean temperature ≥21 °C (Figure 6 copied from Keefer et al (2009)).

Fate of fish

Keefer et al (2009) found that fate patterns were mixed for individual populations, primarily due, at least in part, to among-stock difference in migration and demographic timing that may affect harvest rates (Table 12). Keefer et al (2009) also found that for the predominantly (96%) hatchery-origin UCR group, steelhead last recorded in refugia were larger (75.0 cm) than fish harvested in the main stem (72.2 cm), fish that homed (70.6 cm), and fish with unknown fate (70.0 cm) (ANOVA: $F = 5.18$, df = 464, $P = 0.002$). Mean migration timing at Bonneville Dam was latest for UCR fish harvested in the main stem (13 August) and progressively earlier for fish that homed (7 August), that were last recorded in refugia (6 August), and with unknown fate (3 August) ($F = 2.52$, df = 464, $P = 0.057$).

Also from Keefer et al. (2009): Sample sizes were limiting for several of the Snake River known-origin groups. However, with all Snake River wild fish combined, main stem harvested fish were largest (74.4 cm) followed by fish that homed (72.3 cm), fish with unknown fate (69.7 cm), and fish last recorded in refugia (68.7 cm) ($F = 3.57$, df =613, $P = 0.014$). Both Snake River wild and hatchery steelhead last recorded in refugia migrated earlier (8–14 days on average) than fish in other fate classes; these timing differences were not statistically significant ($P > 0.26$).

Snake River steelhead fates did differ (c2 = 13.1, df = 3, $P = 0.004$) for wild versus hatchery fish. With all Snake River groups combined, wild fish were twice as likely to have unknown fate (12.9%, $n = 614$) as hatchery fish (6.3%, $n = 206$). Further, more wild (10.8%) than hatchery fish

(8.3%) were reported harvested in main stem fisheries, more hatchery (9.7%) than wild fish (4.7%) were last recorded in refugia sites, and more hatchery (75.7%) than wild fish (71.5%) returned to Lower Granite Dam or Snake River tributaries.

Table 12. Summary of known-origin steelhead fates by natal basin, rearing type (hatchery or naturally produced (wild), and use of cool-water tributaries in the Bonneville or The Dalles reservoir (Table 2 copied from Keefer et al (2009)).

				Fate					
Stock	Rearing type	Tributary use	*n*	Successful	Main stem harvest	Nonnatal tributary[a]	Main stem unknown	χ^2	*P*
UpperColumbia	All	No	234	76.5	14.1	1.3	8.1	25.3	<0.001
		Yes	228	63.6	13.2	12.7	10.5		
	Hatchery	No	226	76.1	14.2	1.3	8.4	25.1	<0.001
		Yes	217	64.1	12.4	13.4	10.1		
	Wild	No	8	87.5	12.5			2.7	0.263
		Yes	11	54.6	27.3		18.2		
Snake (barged)	All	No	170	72.9	12.9	2.4	11.7	17.6	<0.001
		Yes	248	66.1	6.5	11.7	15.7		
	Hatchery	No	24	83.3	4.2	4.2	8.3	2.8	0.424
		Yes	42	66.7	7.1	16.7	9.5		
	Wild	No	146	71.2	14.4	2.1	12.3	16.3	0.001
		Yes	206	66.0	6.3	10.7	17.0		
Snake (in-river)	All	No	114	75.6	17.5	0.9	7.0	10.6	0.014
		Yes	144	79.9	8.3	6.9	4.9		
	Hatchery	No	28	75.0	14.3	3.6	7.1	6.8	0.077
		Yes	48	83.3	2.1	12.5	2.1		
	Wild	No	86	74.4	18.6		7.0	5.3	0.154
		Yes	96	78.1	11.5	4.2	6.3		
Snake (other[b])	All	No	50	78.0	14.0	2.0	6.0	2.3	0.514
		Yes	86	77.9	8.1	5.8	8.1		

Note: Steelhead in the Snake River barged and in-river groups were PIT-tagged at Lower Granite Dam and either transported downstream or released back to the river. Those in the Snake River (other) group were PIT-tagged in tributaries or at hatcheries upstream from Lower Granite Dam. Statistical results from Pearson χ^2 tests.

[a]Permanent strays to nonnatal basins and fish reported harvested inside monitored tributary refugia.
[b]Clearwater (*n* = 56), Grande Ronde (*n* = 23), Salmon (*n* = 30), and Imnaha (*n* = 27).

Mortality
Keefer et al.'s third objective was to assess associations between refugia use and fate of known-origin fish. Their results suggest that use of a thermal refuge might carry an additional mortality risk; fish that used thermal refugia had were about 8% less likely to complete their migration through the hydrosystem and were significant for both hatchery (11%) and wild fish (5%). They concluded that the extra mortality appeared to be most related to fisheries inside of the refuge areas, and that ***for UCR steelhead, the harvest rate they calculated was 13% compared to 4-17% for SR fish***. They also considered these estimates to be conservative:

> *Overall, we believe that differences in overall mortality estimates between fish that did or did not use refugia may be conservative for two reasons. First, information returned with transmitters suggested that some ''non-thermoregulating'' fish harvested in the main stem were almost certainly caught in cool-water plumes from refugia tributaries (i.e., they were incorrectly identified as not using refugia). Second, several dozen known-origin fish were harvested in the main stem before they had an opportunity to enter refugia, a bias that would lead to underestimation of refugia effects.*

Conclusion
We cannot reject or not reject the null hypotheses. Information presented in Keefer et al. (2009) suggests that UCR steelhead may, on average spend more time in cool-water tributaries than SR fish, and potentially be harvested at higher rates because of it. Whether this one factor can explain the differences in survival between the two groups of fish migrating through the lower Columbia River FCRPS is not clear, but certainly suggests that it is a contributing factor.

3.2.7 $H_0$7- Stray rates of UCR spring Chinook salmon and steelhead through the effect zone equals SR spring/summer Chinook salmon and steelhead

We define straying as: *where a fish spawns in a non-natal stream*. Keefer et al (2005) may be the best information on known-origin fish straying through the lower Columbia River FCRPS. However, Keefer et al (2005) defined straying as:

> *Permanent straying status was designated for those fish with final records (telemetry or recapture) in river basins outside their natal basins, as identified by juvenile PIT-tag location. Because monitoring of small tributaries was limited, we only considered straying at the large-river scale. For example, we generally did not examine straying within or between Snake River tributaries, but instead considered the Snake River basin as a whole.*

Within basin stray rates may have made this study more applicable to testing the hypothesis, but it is still the best information we have.

3.2.7.1 Methods

To assess permanent straying, Keefer et al (2005) radio-tagged known-source adult spring–summer and fall Chinook salmon and steelhead during 2000-2003 migration years. Fish origins were identified from PIT tags implanted when the fish were juveniles. Most of these PIT-tagged fish were from the Snake, upper Columbia, Yakima and Wind river basins.

3.2.7.2 Results

For Keefer et al.'s analysis, spring/summer Chinook salmon, it appears that most fish from the UCR were most likely summer-run fish (ocean-type), based on their origin. It is quite possible that most of the fish that Keefer et al. (2005) used were fish that were used as part of the UCR PUD's survival studies in the late 1990s, early 2000s (C. Peven, personal communication). These fish were not released in areas to increase natural production, but were test animals and held in various locations prior to release.

Regardless, straying for spring/summer Chinook salmon was generally below 2.5% for all stocks, and known spring Chinook from the UCR (Icicle River - Leavenworth NFH), showed no straying although sample sizes were small.

For steelhead, stray rates of UCR and SR fish were very close (either 7.0 vs 6.8%, respectively for total stray rate or 3.0 vs 4.7% accounting for mainstem harvest). As with Chinook salmon, some of the steelhead released in the UCR were most likely used in PUD survival studies and were released differently than normal hatchery fish.

Conclusion
Do not reject the null hypothesis. The information available does not suggest that there is a difference between stray rates of the two ESUs/DPSs.

3.2.8 $H_0$8-Survival through the effect zone for spring (spring/summer) Chinook jack salmon equals adult Chinook salmon

The reason for this hypothesis is to test whether there is a basic size affect of harvest.

3.2.8.1 Methods

See section 3.1.1.

3.2.8.2 Results

For both Chinook salmon and steelhead, the results show 1-ocean fish had significantly higher survival from BON to MCN than their 2+ ocean cohorts (Appendix B).

Conclusion
Reject the null hypothesis, there is a significant difference between the survival of 1-ocean fish compared to older (larger) members of the same species.

3.2.9 $H_0$9- Abiotic factors affect survival through the effect zone differently for UCR spring Chinook salmon and steelhead than SR spring/summer Chinook salmon and steelhead

3.2.9.1 Methods

To test this hypothesis, we again used logistic regression, as when we analyzed differences in upstream survival. The only difference is that for this hypothesis, we interacted ESU with flow, spill, and any other relevant abiotic factors that could affect survival.

3.2.9.2 Results

The results (Appendices C1 and C2) show that for Chinook salmon, there was a significant interaction between turbidity and ESU, while for steelhead there were significant interactions between DPS and gas, turbidity, and flow. However, the interaction results should be viewed with caution, since the main effect of ESU/DPS is now negative for both species (i.e., Snake fish seemingly survive at a lower rate than UCR fish). This results from correlations among the environmental variables, not because Snake fish actually have lower survival (see Section 3.1.1.3 and earlier regression results in Appendices A and B).

Conclusion
Reject the null hypothesis. Snake and UCR fish appear to react differently to flow, spill, etc., but correlations among environmental conditions make this conclusion weaker than the simpler survival differences investigated earlier.

4. Overarching Conclusion

Through the analysis above, there does not appear to be a clear understanding of what may be causing differential mortality of UCR fish compared to SR fish. Differences in timing of entry into freshwater and subsequent use of different thermal refuges for steelhead appears to be one potential factor (assumes that these fish may be more vulnerable to tributary harvest), but it is unlikely that this would explain the consistent difference in survival observed.

Currently, there are no reliable methods available to segregate the steelhead run at BON into individual DPS's. Additional information pertaining to distinct DPSs would aid in our understanding of the factors that may be affecting survival of steelhead as they pass through the lower Columbia River FCRPS.

Additional information is need in regards to the effects of harvest on total survival of the stocks from the two basins. Because we did find that there is a significant difference between the survival of 1-ocean fish (even though the harvest rate appeared lower) compared to older (larger) members of the same species, the effects of harvest on fish from the two basins is suspected as an important factor in the survival difference, but additional information is needed to verify this.

5. Recommendation

Our recommendation is to develop and implement a large-scale telemetry study with known origin fish through the lower Columbia River FCRPS. We also recommend that additional information is collected for harvest to better understand the survival differences between adult fish as they ascend through the lower Columbia River FCRPS, and reiterate the following list to ensure that the appropriate information is collected:

- More DPS/ESU specific rates of harvest by all tribal and non-tribal fishers,
- Additional information from C&S fisheries in regards to specific ESU/DPS,
- PIT tag detection for all fisheries,
- Increased level of effort (survey) for some fisheries,
- Increased level of CWT marking for UCR steelhead,
- CWT tag detections of adipose clipped, non-adipose clipped steelhead and spring Chinook with Treaty and non-Treaty fisheries,
- Development of similar methods for harvest surveys for Treaty and non-Treaty fisheries, including Catch per Unit Effort (CPUE) and total estimated harvest effort by fishery type (recreational, commercial and ceremonial/subsistence) and harvest method (hook and

line, gillnet, hoop net and dip net), and standardized methods of CWT and PIT tag evaluations of fish harvested (i.e. because not all UCR steelhead and spring Chinook are adipose clipped to indicate CWT, scan all fish encountered in fisheries for presence of CWT and or PIT tag),

- Increase the level of creel monitoring effort for Treaty and non-Treaty fisheries in Zone 6.

In addition, we suggest that PIT tag detectors be installed at John Day and The Dalles dams to ensure that additional information can be gleaned as to where some of the mortality may be occurring.

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7. Appendices

Appendix A. Descriptive statistics for each ESU.

Appendix B1. Chinook salmon BON-MCN survival regression results. Bolded estimates significantly different from zero at 5%.

Appendix B2. Steelhead BON-MCN survival regression results. Bolded estimates significantly different from zero at 5%.

Appendix C1. Yearling Chinook ESU environmental values results. Bolded estimates significantly different from zero at 5%.

Appendix C2. Steelhead ESU environmental values results. Bolded estimates significantly different from zero at 5%.

Appendix A. Descriptive statistics for each ESU.

Variable	N	N Miss	Minimum	Mean	Max.	Std Dev
SR steelhead						
Hatchery Origin	21280	0	0	0.64	1	0.48
Wild Origin	21280	0	0	0.36	1	0.48
Inriver Migrant	21280	0	0	0.38	1	0.48
Barged Downstream	21280	0	0	0.62	1	0.48
Ocean_Age_1	21280	0	0	0.61	1	0.49
Ocean_Age_2_Plus	21280	0	0	0.39	1	0.49
1 if detected at MCN Ladder, else 0	21280	0	0	0.71	1	0.45
Travel time (days), BON to MCN, missing for dead ones	15200	6080	4	29.63	169	22.93
BON Outflow KCFS	21280	0	71.1	134.72	416	40.41
BON Spill KCFS	21280	0	0.2	62.94	211.8	34.58
BON Gas (percent)	21280	0	96.97	105.30	119.54	3.56
BON Turbidity (Secchi Feet)	21280	0	2	5.92	8	1.13
BON WQM Temp (degrees C)	21280	0	4.25	20.52	23.5	1.42
SR Chinook yearlings						
Hatchery Origin	20119	0	0	0.87	1	0.33
Wild Origin	20119	0	0	0.13	1	0.33
Inriver Migrant	20119	0	0	0.56	1	0.50
Barged Downstream	20119	0	0	0.44	1	0.50
Ocean_Age_1	20119	0	0	0.21	1	0.41
Ocean_Age_2_Plus	20119	0	0	0.79	1	0.41
1 if detected at MCN Ladder, else 0	20119	0	0	0.82	1	0.39
Travel time (days), BON to MCN, missing for dead ones	16407	3712	3	6.94	108	4.03
BON Outflow KCFS	20119	0	71.1	246.59	418.6	66.47
BON Spill KCFS	20119	0	0	96.41	230.9	35.70
BON Gas (percent)	20119	0	98.63	111.85	120.53	3.25
BON Turbidity (Secchi Feet)	20119	0	2	4.17	14	1.01
BON WQM Temp (degrees C)	20119	0	5.05	12.70	23.16	2.46
UCR spring Chinook						
Hatchery Origin	2435	0	0	0.87	1	0.34
Wild Origin	2435	0	0	0.13	1	0.34

Variable	N	N Miss	Minimum	Mean	Max.	Std Dev
Inriver Migrant	2435	0	0	0.92	1	0.28
Barged Downstream	2435	0	0	0.08	1	0.28
Ocean_Age_1	2435	0	0	0.12	1	0.32
Ocean_Age_2_Plus	2435	0	0	0.88	1	0.32
1 if detected at MCN Ladder, else 0	2435	0	0	0.76	1	0.43
Travel time (days), BON to MCN, missing for dead ones	1852	583	3	6.83	70	3.75
BON Outflow KCFS	2435	0	95.9	237.50	417.7	64.34
BON Spill KCFS	2435	0	0	87.17	211.8	30.71
BON Gas (percent)	2435	0	100.05	111.90	119.54	2.99
BON Turbidity (Secchi Feet)	2435	0	2	4.36	7	1.12
BON WQM Temp (degrees C)	2435	0	3.8	12.26	21.91	2.11
UCR steelhead						
Hatchery Origin	18922	0	0	0.97	1	0.16
Wild Origin	18922	0	0	0.03	1	0.16
Inriver Migrant	18922	0	0	0.93	1	0.25
Barged Downstream	18922	0	0	0.07	1	0.25
Ocean_Age_1	18922	0	0	0.57	1	0.49
Ocean_Age_2_Plus	18922	0	0	0.43	1	0.49
1 if detected at MCN Ladder, else 0	18922	0	0	0.71	1	0.45
Travel time (days), BON to MCN, missing for dead ones	13506	5416	4	18.39	143	14.46
BON Outflow KCFS	18922	0	71.1	148.8	417.5	36.61
BON Spill KCFS	18922	0	1	73.14	217.3	28.73
BON Gas (percent)	18922	0	97.38	105.57	120.53	3.05
BON Turbidity (Secchi Feet)	18922	0	2	6.13	8	0.94
BON WQM Temp (degrees C)	18922	0	5.17	20.92	23.5	1.30

Appendix B1. Chinook salmon BON-MCN survival regression results. Bolded estimates significantly different from zero at 5%.

Analysis of Maximum Likelihood Estimates							
Parameter		**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	**Pr > ChiSq**	**Exp(Est.)**
Intercept		1	-0.8947	0.6925	1.6692	0.1964	0.409
Life Stage	**1- Ocean**	1	**0.8258**	0.0606	185.8781	<.0001	2.284
Rearing Type (H or W)	**H**	1	**-0.2589**	0.0571	20.5536	<.0001	0.772
Year At BON	**2002**	1	**-0.2879**	0.0723	15.8514	<.0001	0.750
Year At BON	**2003**	1	-0.0992	0.0753	1.7342	0.1879	0.906
Year At BON	**2004**	1	-0.0191	0.0774	0.0606	0.8055	0.981
Year At BON	**2005**	1	-0.00038	0.0935	0.0000	0.9968	1.000
Year At BON	**2006**	1	**-0.8376**	0.0954	77.0151	<.0001	0.433
Year At BON	**2007**	1	**-0.3523**	0.0990	12.6624	0.0004	0.703
Year At BON	**2008**	1	**-0.4300**	0.0662	42.2308	<.0001	0.650
Year At BON	**2009**	1	**-0.3191**	0.0682	21.8942	<.0001	0.727
ESU	**Snake Yearling Chinook**	1	**0.2783**	0.0562	24.5156	<.0001	1.321
Transported	**NO**	1	**0.1756**	0.0372	22.2872	<.0001	1.192
BON Flow		1	**0.00537**	0.000565	90.4652	<.0001	1.005
BON Spill		1	**-0.00221**	0.000890	6.1466	0.0132	0.998
BON Gas		1	0.00431	0.00650	0.4406	0.5068	1.004
BON Turbidity		1	**0.1092**	0.0250	19.0797	<.0001	1.115
BON WQM Temp.		1	**0.0219**	0.00944	5.3605	0.0206	1.022

Appendix B2. Steelhead BON-MCN survival regression results. Bolded estimates significantly different from zero at 5%.

Analysis of Maximum Likelihood Estimates							
Parameter		**DF**	**Estimate**	**Standard Error**	**Wald Chi-Square**	**Pr > ChiSq**	**Exp(Est.)**
Intercept		1	**2.1845**	0.5145	18.0279	<.0001	8.886
Life Stage	**1- Ocean**	1	**0.2960**	0.0259	130.2299	<.0001	1.345
Rearing Type (H or W)	**H**	1	**-0.1548**	0.0334	21.4958	<.0001	0.857
Year At BON	**2002**	1	**0.6132**	0.0655	87.5852	<.0001	1.846
Year At BON	**2003**	1	**0.7087**	0.0878	65.1457	<.0001	2.031
Year At BON	**2004**	1	**0.4440**	0.0615	52.0875	<.0001	1.559
Year At BON	**2005**	1	**0.3664**	0.0505	52.5835	<.0001	1.442
Year At BON	**2006**	1	**0.4386**	0.0501	76.6666	<.0001	1.551
Year At BON	**2007**	1	**0.5622**	0.0543	107.2957	<.0001	1.755
Year At BON	**2008**	1	**0.3752**	0.0490	58.5626	<.0001	1.455
Year At BON	**2009**	1	**0.5129**	0.0407	159.0604	<.0001	1.670
ESU	**Snake Steelhead**	1	**0.1606**	0.0395	16.5631	<.0001	1.174
Transported	**NO**	1	**0.4240**	0.0291	212.2386	<.0001	1.528
BON Flow		1	-0.00013	0.000642	0.0396	0.8423	1.000
BON Spill		1	**-0.00126**	0.000625	4.0949	0.0430	0.999
BON Gas		1	0.00268	0.00527	0.2580	0.6115	1.003
BON Turbidity		1	0.000608	0.0124	0.0024	0.9610	1.001
BON WQM Temp.		1	**-0.1081**	0.0125	74.6656	<.0001	0.898

Appendix C1. Yearling Chinook ESU * environmental values results. Bolded estimates significantly different from zero at 5%.

Parameter		DF	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept		1	**4.4796**	2.0636	4.7122	0.0299
Life Stage (1-ocean or 2+)	1- Ocean	1	**0.8283**	0.0608	185.5906	<.0001
Rearing Type	H	1	**-0.2511**	0.0573	19.2305	<.0001
Year at BON	2002	1	**-0.3019**	0.0724	17.3684	<.0001
Year at BON	2003	1	-0.1017	0.0755	1.8177	0.1776
Year at BON	2004	1	-0.00532	0.0784	0.0046	0.9459
Year at BON	2005	1	0.0166	0.0942	0.031	0.8603
Year at BON	2006	1	**-0.8482**	0.0988	73.7667	<.0001
Year at BON	2007	1	**-0.3635**	0.0994	13.3679	0.0003
Year at BON	2008	1	**-0.4321**	0.0664	42.3259	<.0001
Year at BON	2009	1	**-0.3236**	0.0683	22.4618	<.0001
ESU	Snake Chinook	1	**-5.7839**	2.1711	7.0974	0.0077
Transported	NO	1	**0.1677**	0.0373	20.2223	<.0001
Flow (KCFS)		1	0.00268	0.00139	3.7076	0.0542
Spill (KCFS)		1	-0.0015	0.0024	0.3916	0.5315
Gas Staturation %		1	-0.0304	0.0194	2.4508	0.1175
Turbidity		1	**-0.1445**	0.0624	5.3632	0.0206
Temp (Degrees C)		1	0.0372	0.0253	2.1527	0.1423
bon_flow*ESU	Snake Chinook	1	0.00312	0.00143	4.7372	0.0295
bon_spill*ESU	Snake Chinook	1	-0.0008	0.0024	0.1109	0.7392
bon_gas*ESU	Snake Chinook	1	0.0389	0.0204	3.6201	0.0571
bon_turb*ESU	Snake Chinook	1	**0.2939**	0.0663	19.6751	<.0001
bon_wqm_temp*ESU	Snake Chinook	1	-0.0191	0.027	0.5002	0.4794

Appendix C2. Steelhead DPS * environmental values results. Bolded estimates significantly different from zero at 5%.

				Standard	Wald	
Parameter		DF	Estimate	Error	Chi-Square	Pr > ChiSq
Intercept		1	**4.0055**	0.7602	27.764	<.0001
life_stage	1- Ocean	1	**0.293**	0.0264	122.901	<.0001
Rearing Type	H	1	**-0.1598**	0.0338	22.3223	<.0001
Year at BON	2002	1	**0.6022**	0.0662	82.8563	<.0001
Year at BON	2003	1	**0.6206**	0.0884	49.2538	<.0001
Year at BON	2004	1	**0.4874**	0.0625	60.8105	<.0001
Year at BON	2005	1	**0.3264**	0.0516	39.9613	<.0001
Year at BON	2006	1	**0.4052**	0.0511	62.9951	<.0001
Year at BON	2007	1	**0.4984**	0.0548	82.615	<.0001
Year at BON	2008	1	**0.3702**	0.0493	56.4179	<.0001
Year at BON	2009	1	**0.4455**	0.0412	117.1723	<.0001
ESU	Snake Steelhead	1	**-2.1303**	1.0376	4.2155	0.0401
Transported	NO	1	**0.4178**	0.0292	205.1847	<.0001
Flow (KCFS)		1	-0.00112	0.000859	1.7134	0.1905
Spill (KCFS)		1	-0.00175	0.000933	3.4984	0.0614
Gas Staturation %		1	0.00994	0.00725	1.8784	0.1705
Turbidity		1	**0.0486**	0.0201	5.8611	0.0155
Temp (Degrees C)		1	**-0.2348**	0.0184	163.7182	<.0001
bon_flow*ESU	Snake Steelhead	1	0.00202	0.00115	3.1149	0.0776
bon_spill*ESU	Snake Steelhead	1	0.0009	0.00117	0.5858	0.4441
bon_gas*ESU	Snake Steelhead	1	**-0.0209**	0.0102	4.1588	0.0414
bon_turb*ESU	Snake Steelhead	1	**-0.0571**	0.025	5.2146	0.0224
bon_wqm_temp*ESU	Snake Steelhead	1	**0.2161**	0.0223	94.246	<.0001