COMPARATIVE SURVIVAL STUDY
Ten-year Retrospective Summary Report

Presentation to the
Independent Scientific Advisory Board
September 14, 2007
CSS Authors:

- Howard Schaller, Paul Wilson, and Steve Haeseker, U.S. Fish and Wildlife Service
- Charlie Petrosky, Idaho Department of Fish and Game
- Eric Tinus and Tim Dalton, Oregon Department of Fish and Wildlife
- Rod Woodin, Washington Department of Fish and Wildlife
- Earl Weber, Columbia River Inter-Tribal Fish Commission
- Nick Bouwes, EcoLogic
- Thomas Berggren, Jerry McCann, Sergei Rassk, Henry Franzoni, and Pete McHugh, Fish Passage Center

Project Leader: Michele DeHart, Fish Passage Center
CSS Background

• 1996 by states, tribes & FWS to estimate survival rates at various life stages

• Develop a more representative control for transport evaluations

• Compare survival rates for Chinook from 3 regions

• Information derived from fish PIT tagged above dams

• Collaborative process implemented for design and analyses

• Project reviewed (ISAB, ISRP, etc.) and modified
  – focusing on CIs about survival estimates
  – documenting methods
CSS joint project of the state, tribal, and federal fishery managers

- **Design**
  - WDFW, CRITFC, USFWS, ODFW, IDFG

- **Review**
  - Regional review, ISAB, ISRP, FPAC, NMFS

- **Implementation**
  - FPC - logistics, coordination, e.g.
    - PITAGIS - data management

- **Data Preparation**
  - FPC

- **Analysis**
  - CSS Oversight Committee, FPC - coordinates

- **Review**
  - Regional Review public review
  - Drafts posted on FPC and BPA websites

- **Final Report**
  - Posted on BPA and FPC websites
Objectives

• **CSS evaluates two aspects of transportation**
  – empirical SARs compared to those needed for survival and recovery (NPCC 2-6% objective)
  – SAR comparisons between transport and in-river migration routes

• **Evaluate effects of the hydrosystem on Snake River populations**
  – evaluate environmental conditions & hydro operations on in-river survivals
  – compare Snake & downriver population performance
    • evaluate biological differences between groups
  – indirect hydrosystem effects on estuary/early ocean life stage
Tasks

• Develop long-term index of transport and in-river survival rates for Snake River wild and hatchery spring/summer Chinook and steelhead
  – Mark at hatcheries > 220,000 PIT tags
  – Smolts diverted to bypass or transport from study design
  – In-river groups SARs from never detected & detected ≥ 1 times
  – SARs from Below Bonn for Transported & In-river groups (TIR and Differential delayed mortality-\(D\))
  – Increase marks for wild Chinook to compare hatchery & wild Chinook > 23,000 added wild PIT tagged fish
  – Begin marking of steelhead populations in 2003

• Develop long-term index of survival rates from release to return

• Compare overall survival rates for upriver and downriver spring/summer Chinook hatchery and wild populations

• Provide a time series of SARs for use in regional long-term monitoring and evaluation
Map 1 -- CSS PIT-tag release locations and PIT-tag detection sites in the Columbia River Basin.
What does CSS project provide?

- Long-term consistent information collaboratively designed and implemented
- Information easily accessible and transparent
- Long-term indices:
  - Travel Times
  - In-river Survival Rates
  - In-river SARs by route of passage
  - Transport SARs
- Comparisons of SARs
  - Transport to In-River
  - By geographic location
  - By hatchery group
  - Hatchery to Wild
  - Chinook to Steelhead
Conclusions:

– Council should view the CSS as a good long-term monitoring program - results should be viewed with increasing confidence

– Project has received a high level of independent and outside review

– Definitely worth funding
ISAB/ISRP Recommendations

- CSS produce a ten-year summary report
  - in-depth description of methods and analyses
    - consolidate descriptions in the ten-year summary
  - interpretation of the data in a retrospective style
    - include key data and summaries in report or appendices

- Test assumptions inherent in the analyses

- Emphasize more diverse metrics of differential survival

- Analyses by grouping data for environmental and operational factors

- Evaluate size at release on survival of PIT-tagged fish

- Do PIT-tagged fish survive as well as untagged fish?

- Pre-assigning the intended routes of passage at the time of release

- Add more downriver sites in the future
Organization of Presentation

• Overview & Background
• ISAB Recommendations
• Chapter by Chapter
  – Overview
  – Key questions & ISAB recommendations
  – Methods & results
  – Response to Regional Review
  – Conclusions
• Overall Conclusions & Future
Chapters

1. Introduction, Overview, & Organization
2. Travel Time, Survival, and Instantaneous Mortality Rates
3. Annual SAR by Study Category, TIR, S_R, and D
4. Estimating Environmental Stochasticity in SARs, TIRs and Ds
5. Evaluation and Comparison of Overall SARs
6. Partitioning Survival Rates-Hatchery release to return
7. Simulation Studies to Explore Impact of CJS Model Assumption
8. Conclusions & Future Direction
Appendices

A. Logistical Methods

B. Analytical Methods: Statistical Framework

C. 2006 Design and Analysis Report

D. Tables of PIT-Tag Marking Data

E. Groups of PIT-tagged Chinook and Steelhead SARs

F. Cumulative passage distributions

G. Comments and Response from ISRP/ISAB

H. Response to Comments - DRAFT CSS 10 Year Report
Rationale:

- CSS objective to characterize fish responses

- ISAB 2006-3: “The data could be aggregated to more closely meet the needs of hydrosystem managers...as data are accumulated over more years, it may be feasible to partition analyses into environmental or operational categories across years to obtain more functional correlations.”

- ISAB 2003-1: “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.”
Chapter 2 - Contents

• Retrospective summary of fish travel time, survival, and instantaneous mortality rates, both within- and across-years

• Develop models characterizing the associations between environmental and management factors and fish responses

• Evaluate three approaches for modeling survival rates
ISAB recommendations addressed in Chapter 2

- Detailed analyses and interpretation of the data in a retrospective style
- Analyze data with respect to environmental and operational factors
- Supplement annual analyses with finer-scale analyses
Methods:

- Two reaches: LGR-MCN (CHW, CHH, STH&W)  
  MCN-BON (CHH&W, STH&W)
- Weekly release cohorts of PIT-tagged fish
- Estimated median fish travel time (FTT) and survival rate
  Instantaneous mortality rate
- Evaluated models using AICc and BIC
Environmental and Management Factors:

- Temperature
- Turbidity
- Flow (kcf/s)
- Flow $^{-1}$
- Water travel time (WTT, days)
- Average percent spill
- Seasonality (Julian Day)
Yearling Chinook median fish travel times

Environmental and management factors: WTT, percent spill, Julian day
Steelhead median fish travel times

Environmental and management factors: WTT, percent spill, Julian day
Instantaneous mortality

Exponential law of population decline:

\[
\frac{N_t}{N_0} = S = e^{-Z \cdot t}
\]

Rearranging:

\[
Z = \frac{-\log_e(S)}{t}
\]

ML estimate of \(Z\):

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

In this application:

\[
\hat{Z}_{LGR-MCN} = \frac{-\log_e(\hat{S}_{LGR-MCN})}{FFT_{LGR-MCN}}
\]
Yearling Chinook instantaneous mortality rates ($Z$)

**Factors:** WTT, Julian day

$LGR-MCN$  
$r^2 = 0.48$

$MCN-BON$  
$r^2 = 0.15$
Steelhead instantaneous mortality rates (Z)

Factors: flow $^{-1}$, Julian day, spill

Factors: temperature

$LGR-MCN \quad r^2 = 0.54$

$MCN-BON \quad r^2 = 0.51$
Daily percent mortality by species and reach:

<table>
<thead>
<tr>
<th>Daily percent mortality (mean Z)</th>
<th>LGR-MCN</th>
<th>MCN-BON</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CHW</td>
<td>STH&amp;W</td>
</tr>
<tr>
<td></td>
<td>3.0%</td>
<td>6.7%</td>
</tr>
</tbody>
</table>
Predicted relationship for instantaneous mortality

Predicted LGR-MCN Z for wild Chinook.

- Triangles: 5 days
- Squares: 10 days
- Triangles: 15 days
- Squares: 20 days

The graph shows the predicted mortality rate over Julian days for April and May.
Predicted relationship for instantaneous mortality

H&W steelhead

Predicted LGR-MCN Z

July day

April

May
Survival

Evaluated three approaches:

Standard survival approach

$$\log_e(S) = \beta_0 + \beta_1 \cdot X_1 + \beta_2 \cdot X_2 + ...$$

$$S^* = e^{(\hat{\beta}_0 + \hat{\beta}_1 \cdot X_1 + \hat{\beta}_2 \cdot X_2 + ...)}$$

Constant Z survival approach

$$S^* = e^{\bar{Z} \cdot FTT^*}$$

Variable Z survival approach

$$S^* = e^{-Z^* \cdot FTT^*}$$
Survival approach comparison - Results

variable $Z >$ standard $>>$ constant $Z$

Variable $Z$ approach had best RMSE and $R^2$ values in 4 of 5 cases and best AIC in 2 of 5 cases

Variable $Z$ approach accounted for 51-80% (64% on average) of the variation in survival rates

Standard approach had fewest parameters and best AIC in 3 of 5 cases
Environmental and management factors consistent across survival approaches

<table>
<thead>
<tr>
<th>CHW, LGR-MCN</th>
<th>STH&amp;W, LGR-MCN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Z</td>
<td>Standard</td>
</tr>
<tr>
<td>WTT</td>
<td>WTT</td>
</tr>
<tr>
<td>Spill</td>
<td>Spill</td>
</tr>
<tr>
<td>Julian day</td>
<td>Julian day</td>
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<tr>
<td>Flow $^{-1}$</td>
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<tr>
<td>Spill</td>
<td>Spill</td>
</tr>
<tr>
<td>Julian day</td>
<td>Julian day</td>
</tr>
</tbody>
</table>
Yearling Chinook survival

\[ r^2 = 0.63 \]

\[ r^2 = 0.51 \]
steelhead survival

LGR-MCN

\[ r^2 = 0.80 \]

MCN-BON

\[ r^2 = 0.71 \]
Regional review comments

Instantaneous mortality (Z)

Mathematically the analysis based on Z is invalid
Z is biased
Analyses based on Z should be deleted from the report
PIT-tag data are incapable of estimating instantaneous mortality rates
In fact, trends in Z are nothing more than inverse trends in travel times misinterpreted or misconstrued as survival effects
Z is independent of survival
Problems are encountered when Z is related to a variety of factors
Actions to decrease FTT would increase Z
instantaneous mortality ($Z$)

Chinook

LGR-MCN

Early

steelhead

Late

FTT
Regional review comments

Results

Eliminate 20-d WTT curve from graph

CSS model is incapable of capturing the pattern of survival in 2001
Conclusions

Juvenile travel times, instantaneous mortality rates, and survival rates through the hydrosystem are strongly influenced by managed river conditions including flow, water travel time, and spill levels.

Statistical relationships were developed that can be used to predict the effects of environmental factors and management strategies on migration and survival rates of juvenile yearling Chinook and steelhead.

Analyses indicate that improvements in in-river survival and travel times can be achieved through management actions that reduce water travel time or increase the average percent spilled. The effectiveness of these actions varies over the migration season.
Chapter 3

Annual SAR by Study Category, TIR, $S_R$, and $D$: Patterns and Significance
Chapter 3 - Overview

- Estimate and compare annual SARs for hatchery and wild groups of smolts with different hydrosystem experiences ($T_0$, $C_0$, $C_1$ groups)
- Evaluate effectiveness of transportation relative to in-river migration via annual SAR ratios between $T_0$ and $C_0$ fish (TIR)
- Partition differential survival of transported & in-river fish by estimating $S_R$ and $D$
ISAB recommendations addressed in Chapter 3 & Appendices B-E

- In-depth description of methods and detailed analyses and interpretation of data in a retrospective style
- Consolidate and effectively present methodologies used in analyses, clarifying notation
- Show key data and data summaries in body of report or appendices
- Investigate potential bias of analytical approaches
Chapter 3 - Methods

- CJS method for in-river survival rate estimates, with extrapolation when necessary
- Estimation of number of smolts in study categories, and resulting SARs described
- Estimation of TIR and $D$
- Bootstrap program to estimate confidence intervals around $S_s$, SARs, TIRs, and $D_s$ (Appendix B)
- Detailed statistical framework & equations in Appendix B, with table showing timeline of method development
- Methodology for obtaining unbiased TIRs (Appendix C)
Results: Appendices D and E tables

- Appendix D: supporting tables of PIT-tag data and estimates of major parameters for analyses presented in Chapters 3, 4, 5, & 6
- Appendix E: Initial estimates, std devs, CIs from bootstrap program for major parameters, organized by Species, Rear-type and Migration Year
Results: $T_o$ and $C_o$ SARs

Wild Spring/Summer Chinook

Wild Steelhead
Results: Comparing wild and hatchery Chinook SARs
Results: Wild Chinook TIRs and Ds

Wild Chinook TIR


Wild Chinook D

Results: Wild steelhead TIRs and Ds

Wild Steelhead TIR

Wild Steelhead D

Migration Year

Migration Year
Results: Wild vs. hatchery $S_R$

Hatchery & Wild Chinook $S_R$

$S_R$ for Hatchery and Wild Steelhead
Results: Steelhead vs. Chinook $S_R$
Results: Comparing hatchery and wild TIR

Hatchery & Wild Chinook

Hatchery and Wild Steelhead

ln(TIR)

Wild
DWOR
RAPH
MCCA
IMNH
CATH

ln(TIR)

Wild
Hatchery
Regional Review comments

Comment: Bootstrap confidence intervals not superior to theoretical normal CIs from mark-recapture data analyzed with CJS model

Response: Bootstrap for CIs was recommendation of ISAB
- Bootstrap to produce CIs for more complex parameters
- Parametric variance of S estimates used in Chapter 2
- Bootstrap CIs for reach $S \approx$ CJS CIs
- Bootstrap CIs for several quantities were compared to estimates from profile likelihood in 2002 CSS Annual Report
Regional Review comments, cont.

Comment: Use of the geometric mean needs justification, since geometric mean will always be lower than the arithmetic mean

Response: TIR and $D$ both represent ratios of survival rates, for which the ordering (numerator vs. denominator) is arbitrary

- Example: two years of equal credibility, one with TIR = 5.0, other with TIR = 0.2
- Zar (1984): “[The geometric mean] finds use in averaging ratios where it is desired to give each ratio equal weight”
Regional Review comments, cont.

Comment: Use of $C_1$ fish would provide insight into temporal changes in return rates of transported and non-transported fish

Response: Temporal variation in SARs of transported and in-river fish is investigated using $C_1$ fish in Chapter 4
Comment: That SAR are lower than objectives provides no evidence that FCRPS related mortality is the reason

Response: Efficacy of transportation-based recovery strategies cannot be judged only from TIR
- Absolute values of SAR, or alternatively “hydrosystem survival”, must be considered
- Other information, including historical Snake River SARs and downriver SARs, suggests FCRPS is a major factor in depressing SARs (e.g. Chapter 5)
Chapter 3: Findings

- Annual SARs for wild Chinook have been highly variable, but far below NPCC target range.
- Annual SARs for wild steehead higher, exceeding the lower end of NPCC target range 4/6 years.
- Little or no benefit of transporting wild Chinook in most years; CIs usually overlap 1 (2001 is exception).
- Transport beneficial most years most hatcheries (Chinook).
- Transport beneficial most years wild & hatchery steelhead.
Chapter 3: Findings, cont.

- CIs on TIRs and $D$s wide most years; especially wide in 2001, with high point estimate

- Lowest $D$ values for wild Chinook; highest for wild steelhead

- Higher TIR values for wild steelhead (compared to wild Chinook) are due to both lower steelhead in-river survival and higher steelhead $D$. 
Extras
Calculation of $D$

$$D = \frac{SAR(T_0) \cdot S_R}{SAR(C_0) \cdot S_T} = TIR \ast \frac{S_R}{S_T}.$$
Chapter 4

Estimating environmental stochasticity in SARs, TIRs, and $Ds$
Chapter 4 - Overview

- Can we get a better estimate of central tendency of SARs, TIRs, & Ds for wild fish, given large process error and large variation in sample size?
- Annual CIs of TIRs often overlap 1—can combining data from all years and removing sampling variance from SARs lead to tighter distributions of TIR (and D)?
- Can covariance between annual estimates of SARs of transported and untransported fish be incorporated to narrow CIs of TIR and D?
ISAB recommendations addressed in Chapter 4

- In-depth description of methods & detailed analyses and interpretation of data in a retrospective style
- Consolidate & effectively present methodologies used in analyses, clarifying notation
- Supplement with analyses that group data on environmental or operational factors amenable to control
- Investigate potential bias of analytical approaches
- Diverse metrics – passage routes, # dams bypassed
Chapter 4 – Methods for SARs

- Assume SAR measurement error is independent binomial sampling error
- Use method of Akçakaya (2002) – estimate & remove sampling variance from total variance
- Sample size influences mean, total variance, & sampling variance of time series
- Fit resulting SAR mean and variance, reflecting environmental variance alone, to beta distribution (Morris & Doak 2002, Kendall 1998)
Chapter 4 – Methods for TIRs & Ds

- Model ratio of resulting SAR distributions to get project-specific TIR distributions
- Include covariance between SAR(T) and SAR(C)—tends to reduce variance of ratio
- Estimating Ds: Need environmental variance distributions of $S_R$
- Multiply distribution of $S_R$ by TIR dist to get $D$ distribution
Results: LGR TIR distributions


Wild steelhead (1997-2002)
Results: LGR D distributions

Wild Chinook

Wild steelhead
Results: Overall SAR distributions

Wild Chinook

Wild steelhead
Within season variation in SARs - Chinook

Transported from LGR

In-river from LGR ($C_1$)
Within season variation in SARs - Steelhead

Transported from LGR

In-river from LGR ($C_1$)
Effect of detection history on in-river SAR – wild Chinook

Probability density functions of C0 and C1 SARs of wild chinook for migration years 1994-2002

- C0
- C1
Comment: Akçakaya method inappropriate for mark-recapture; should use Gould and Nichols (1998) approach

Response:
- G&N deal with two sources of “sampling” variability
- In CSS, no sampling variance of the first kind, since all survivors “recaptured” by PIT-tag detection at LGR—only demographic stochasticity
- Therefore, more involved methods of G&N for estimating the first kind of sampling variance and its covariance with the second kind are not required
- Sampling variance in estimate of $C_0$ addressed next
Comment: SARs do not have a binomial sampling variance, for both the numerator and denominator (i.e., $C_0$ fish) are estimated random variables.

Response:

- Numerator of each SAR is count of PIT-tagged fish with relevant capture history
- Effect of variance in $C_0$ can be investigated, using:

$$Var\left(\frac{X}{Y}\right) \approx \left(\frac{\mu_X^2}{\mu_Y^4}\right)\sigma_Y^2 + \frac{\sigma_X^2}{\mu_Y^2} - 2\left(\frac{\mu_X}{\mu_Y^3}\right)\rho\sigma_X\sigma_Y$$
Response cont.:  
- Estimated actual sampling variance for 2 $C_0$ estimates: 1) lowest $C_0$, highest CV; 2) highest $C_0$, lowest CV  
- Binomial variance very slightly overestimates actual sampling variance of SAR($C_0$)

<table>
<thead>
<tr>
<th>Mean $C_0$</th>
<th>CV of $C_0$</th>
<th>SAR est.</th>
<th>$\rho$</th>
<th>Actual variance</th>
<th>Actual CV</th>
<th>Binomial variance</th>
<th>Binomial CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td>10%</td>
<td>2.91%</td>
<td>0.17</td>
<td>$2.66 \times 10^{-4}$</td>
<td>56%</td>
<td>$2.74 \times 10^{-4}$</td>
<td>57%</td>
</tr>
<tr>
<td>8879</td>
<td>1.5%</td>
<td>0.33%</td>
<td>0.08</td>
<td>$3.68 \times 10^{-7}$</td>
<td>18%</td>
<td>$3.70 \times 10^{-7}$</td>
<td>18%</td>
</tr>
</tbody>
</table>
Comment: Estimated demographic variance is greater than total variance [for steelhead transported from LMN], suggesting something is wrong and thus casting doubt on all methods and results in this chapter.

Response:

- Gould and Nichols (1998) found estimated sampling variance > total variance for a number of their sample data sets.
- G&N reference literature indicating that negative estimates of variance are not uncommon in the variance components literature.
- Consequence of large sampling variation due to low # of PIT-tagged steelhead transported from LMN.
- Used observed inter-annual variance as an estimate of environmentally driven variance.
Comment: Such small transport groups [PIT-tagged steelhead] produce unreliable parameter estimates that can seriously distort interpretation of results

Response:

- Uncertainty in parameter estimates explicitly estimated and accounted for Chapter 4 procedures
- Effects of small sample sizes seen in the resultant wide confidence intervals for SARs of LGS- and LMN-transported steelhead
- Effect of this uncertainty is carried into estimates of TIR and $D$ for these projects and explicitly presented
Chapter 4 - Conclusions

- Realized SARs have been considerably below NPCC target range for Chinook, and generally below for steelhead.
- Transportation as currently implemented does not benefit wild Chinook (compared to in-river migrating $C_0$ fish).
- Transportation, especially from LGR, appears to benefit wild steelhead.
- Substantial delayed mortality of transported wild Chinook.
- Lower, more uncertain levels of delayed mortality for transported wild steelhead.
Patterns in decline in SAR of in-river ($C_1$) of both species as the migration season progresses consistent with hypothesis of delayed mortality of in-river fish due to protracted migration.

Pattern of SARs over season suggests that Chinook TIRs could be improved by delaying transportation until later in season, but also that maximizing SARs of both wild steelhead and Chinook cannot be accomplished through transportation.*

*Unless steelhead $S_R$ ↑ and/or Chinook can be separated from steelhead before barging.
Comparative Survival Study
Chapter 5

Evaluation and Comparison of Overall Smolt-to-Adult Return Rates
Chapter 5 - Contents

• Wild vs. hatchery SAR trends

• Compare wild SARs to NPCC 2 to 6% SAR objectives
  – evaluate the overall effectiveness of F & W program
  – evaluate effectiveness of the transportation program

• Compare wild Mid-Columbia (downriver) to Snake River Chinook populations
  – is the upriver/downriver difference in SARs consistent with differential mortality from spawner-recruit data?

• Compare biological characteristics of upriver and downriver populations

• Compare downriver and Snake River hatchery SARs

• Examine relationships of wild Chinook SARs to ocean and river conditions
ISAB recommendations addressed in Chapter 5

- Detailed analyses and interpretation of the data in a retrospective style
- Add more downriver sites in the future
- Specific section in the report focusing on the potential effects of size at release on survival of all PIT-tagged fish
- Analyze survival data with respect to environmental and operational factors
- Analyses could emphasize more diverse metrics of differential survival
- Evaluate if PIT-tagged fish survive as well as untagged fish
Retrospective Analysis

Snake Wild Populations

Wild Snake River spring/summer Chinook

Snake River wild Steelhead
Retrospective Analysis

Snake Hatchery & Wild Populations

Snake River spring/summer Chinook

McCall hatchery Chinook
Snake River vs Downriver Wild Chinook

Snake vs. John Day wild stream-type Chinook (PIT tags)

PIT tag studies:
Downriver SARs are 3-4X Snake SARs
Snake River SARs generally < 2 to 6% SAR
Spawner-Recruit analysis vs SAR comparisons: estimated differential mortality - Snake vs. downriver

![Graph showing differential mortality over migration years from 1970 to 2005. The graph includes a line for Spawner-recruit and a dotted line for PIT tags.](image-url)
Comparison of Biological Characteristics for Snake and Downriver stream-type wild Chinook populations
Juvenile Length Distribution for Snake vs downriver wild Chinook populations

2000

2001

2002

2003

2004

2005
Juvenile Chinook emigration distributions for Snake vs downriver populations
Wild Chinook salmon smolt downriver migration rates

![Graphs showing migration rates for different years (2000-2005). Each graph displays migration rates for six release sites: CLWTRP, GRNTRP, IMNTRP, JDAR1, SALTRP, SNKTRP. The y-axis represents migration rate (km/d), and the x-axis represents the year (2000-2005). The bars indicate the mean migration rate with error bars showing the standard deviation.](image-url)
First-to-third dam migration duration as a function of water travel time

Release site:
- CLWTRP
- GRNTRP
- IMNTRP
- JDAR1
- SALTRP
- SNKTRP
Estuary arrival timing distributions

* Snake River Water Travel Time (Lewiston-Bonneville):
  pre-dam less than 3 days and present condition 10-40 days
Biological Characteristics for Snake vs Downriver wild Chinook Populations

- No evidence for difference in size-at-migration existing

- No evidence for differences in departure from natal streams
  - evidence for greater variation in outmigration timing for upriver populations

- No evidence for differences in smolt migration rates
  - rates were a function of water travel velocity

- Despite similar size, emigration timing, and downriver migration rate, Snake River smolts arrived at the estuary later (~7-10 days) than downriver populations

- Given similarities in biological characteristics and the increase in water travel times due to hydropower, discrepancy in arrival timing at BON for Snake River vs downriver populations is likely a result of the FCRPS
SARs for Snake River and John Day River wild Chinook for smolts passing Bonneville Dam during the same period

SAR for Bonneville arrivals Apr 16 - May 31

Migration year

SAR (BON-BON)

John Day

C0
C1
T0
Estimated differential mortality - Snake vs. downriver hatchery and wild populations

Differential mortality: wild and hatchery Chinook

Migration year

Differential mortality

-2.0
-1.0
0.0
1.0
2.0
3.0

2000 2001 2002 2003 2004

wild
DWOR
RAPH
MCCA
IMNA
CATH
Multiple Regression Analysis: SARs vs migration and ocean/climatic indices

Snake River spring/summer Chinook Smolt-to-Adult Return Rates (SAR)
**Water Travel Time**: Lewiston to Bonneville Dam

pre-dam ~2 days;
current ~ 19 days (10-40 days)

1938 (BON), 1953 (MCN), 1957 (TDD), 1961 (IHR), 1968 (JDA), 1969 (LMN), 1970 (LGS), 1975 (LGR)
**Coastal Upwelling Process**

- **Pacific Decadal Oscillation**
  - Interdecadal climate variability in the North Pacific – (Sea Surface Temperature)

- **Coastal Upwelling Index**
  - based upon Ekman's theory of mass transport due to wind stress - 45°N – (productivity)

- **“Good Ocean”**
  - Cool phase PDO
  - April Upwelling
  - Oct Nov Downwelling
Expected change in SARs vs. WTT, PDO & Upwelling

Response to WTT - similar to results using upriver/downriver populations

- average PDO & Upwell
- good ocean SepPDO = -1; NovUp = -116
- poor ocean SepPDO = 1; NovUp = -33

Best fit (adj. $R^2=0.64$), best 3 parameter model
Do PIT tag SARs represent SARs of the run at large?

- Run reconstruction (RR) SARs slightly larger than point estimate PIT SARs
- RR SARs fell within the 90% CIs of PIT SARs for 5 of the 8 years
- Unresolved issues with wild adult accounting for RR SARs
- Given unresolved issues for RR SARs, and lack of ability to place confidence bounds on RR SARs; assessing bias is difficult
- For analyses using ratios of SARs, this issue is of little concern
Regional Review- Chapter 5

- **PIT Tag vs Run Reconstruction (RR) SARs**
  - Need more attention to evaluate discrepancies between PIT-tagged and untagged fish SARs
  - Region needs to examine the assumptions and data adjustments to estimate SARs of untagged group
    - resolution requires collaboration among several technical groups
  - RR SARs fell within the 90% CIs of PIT SARs for 5 of the 8 years
  - Not an issue for analyses using ratios of SARs
  - Identified tasks to help resolve this issue

- **Delayed Mortality**
  - investigated hypotheses for possible non-hydrosystem causes (including hypotheses previously suggested by NWFSC)
    - consistent pattern of differential mortality across poor and favorable ocean conditions
    - estimates of in-river survival and relative survival of transported smolts
    - indirect evidence that the magnitude of delayed hydrosystem mortality is large
    - estimation of delayed or latent mortality (of in-river migrants) was not an objective of CSS
  - SAR PIT-tag analyses provides independent estimates of differential mortality, for comparison with published SR analyses
    - SAR estimates are free of assumptions related to the form of SR function
    - estimates are differential mortality - not delayed mortality
Regional Review- Chapter 5

• Upriver/downriver population performance comparison
  – a “natural” experiment – some design limitations
  
  – addressed each past criticism for the upriver-downriver approach
    • compared biological characteristics of the two population groups
    • SARs ~ 4-fold higher for downriver populations, none of the biological characteristics exhibit differences to explain this level of differential mortality
  
  – reviewers claim Bristol Bay data invalidate comparing performance of different populations from the same region
    • BB sockeye salmon exhibit common annual survival patterns
    • correlations between stocks for BB ranged from 0.23 to 0.75 (geomean 0.44)
    • BB sockeye diversity attributed to varying challenges imposed by freshwater spawning and rearing environments
    • CSS comparison extends SR analyses of differential mortality using PIT-tag SARs, and life-history characteristics which may support alternative hypotheses of differential mortality - consistent with Hilborn et al. (2003)
Conclusions Chapter 5

- SARs of Snake River wild spring/summer Chinook < NPCC objective & met the 2% minimum 1 of 11 years
- SARs of Snake River wild steelhead < NPCC objective & met the 2% minimum 4 of 7 years
- SARs of hatchery spring/summer Chinook tracked closely with those of the aggregate Snake River wild population
- Higher Snake River wild spring/summer Chinook SARs were related to faster water travel time experienced during the smolt migration, cooler phases of the ocean, and stronger down-welling in the fall during the first year of ocean residence
- SARs of downriver wild spring Chinook ~ 4 X greater than Snake River SARs
  - consistent with previous findings of differential mortality derived from spawner and recruit analyses
  - upriver and downriver hatchery spring/summer Chinook SARs did not show the same level of differential mortality as wild
Conclusions Chapter 5

• No evidence for consistent and/or systematic difference between upriver and downriver wild Chinook salmon for the following biological characteristics:
  – size-at-migration,
  – tributary emigration timing
  – migration rates in the hydrosystem

• Delayed timing to the estuary of Snake River smolts due to the FCRPS

• Snake River SARs < downriver SARs when these wild Chinook populations arrived at the estuary during the same time period
  – disparity provides support for mechanisms of delayed hydrosystem mortality in addition to alteration of estuary entry
Comparative Survival Study
Chapter 6

Partitioning survival rates – hatchery release to return
Chapter 6 - Contents

• Survival from hatchery release to LGR

• Adult survival from LGR to hatchery

• Detection of PIT adults at hatchery rack for transported and in-river groups

• Adult migration survival
  – Transport vs In-river groups
  – Relation to environmental and management indices
ISAB recommendations addressed in Chapter 6

- Detailed analyses and interpretation of the data in a retrospective style
- Analyze survival data with respect to environmental and operational factors
Retrospective Analysis

Hatchery release to LGR

Survival (S1)

Migration year


RA PH
DWOR
CA TH
MCCA
IMNA
Proportion of PIT-tagged adults and jacks detected at LGR that were subsequently detected at the hatchery racks
Percent of hatchery and wild adult Chinook salmon that were successful in migrating from BON to LGR

On average, 10% lower adult migration success for LGR transport
Parameter estimates for the top logistic regression model describing BON-LGR migration success for CSS hatchery Chinook

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>SE</th>
<th>T</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.410</td>
<td>0.285</td>
<td>4.95</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LGR</td>
<td>-0.446</td>
<td>0.092</td>
<td>-4.84</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LGStdown</td>
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<td>0.123</td>
<td>-1.73</td>
<td>0.085</td>
</tr>
<tr>
<td>Spill</td>
<td>-0.016</td>
<td>0.008</td>
<td>-2.04</td>
<td>0.041</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.057</td>
<td>0.020</td>
<td>2.87</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Transportation from LGR primary factor describing adult migration success
Regional Review - Chapter 6

- **NWFSC analysis found that unmarked hatchery Chinook salmon returned at higher rates than PIT-tagged fish**
  - Reviewers did not weight the C0 and T0 groups according to their actual proportions for the run at large, and the C1 group is overrepresented in the NWFSC analysis
  - SARs of the C1 group are substantially lower than those of C0, a negative bias
  - Investigate potential issues of PIT-tag detection and recovery at hatchery weirs

- **Pooling adult migration success data across juvenile migration year and return year - only if those factors are non-significant**
  - CSS analyzed adult success on a year-by-year (migration or return) and hatchery-specific basis
  - Conclusions that outmigration experience was primary factor would not change with formal test for year effects (a secondary factor)
  - Logistic regression supports conclusion outmigration experience is primary factor
Chapter 6 Conclusions

• Adults transported from LGR as smolts exhibited 10% lower upstream migration survival than either in-river or transported from LGS or LMO smolt history
  – logistic regression suggest lower passage rates for adults of juvenile cohorts that migrated during periods of high spill and cold temperatures

• Increased straying may influence populations out of the Snake Basin (e.g. high out-of-basin strays into mid-Columbia steelhead and spring Chinook populations)

• Hatchery adult survival upstream of LGR was not associated with transport or in-river smolt histories

• Lack of evidence for a survival difference upstream of LGR indicates CSS SAR evaluations reasonably describe the relative performance of transported and in-river migrants
Comparative Survival Study

Chapter 7

Effects of CJS model assumption violations on parameter estimation
Background

CJS model used extensively within Region and in the CSS.

A primary assumption of the CJS estimation methodology is that all members of a tagged group have a common underlying probability of survival and of collection at dams.

Violations of this assumption could occur if survival or collection probabilities change over time.

Objective was to explore how changes over time may influence CJS estimates, and CSS estimates that are used.
ISAB recommendations addressed in Chapter 7

Assumptions inherent in the analyses should be specifically tested, with continued vigilance toward avoiding bias

Research analytical methods that can improve the mathematical and statistical approaches currently in use
**Methods**

Developed a simulator program to generate data sets of fish capture histories given known values for various CSS parameters.

Simulated twelve alternative scenarios of increasing/decreasing trends over time in survival and collection probabilities.

1,000 replicates per scenario, 12,000 replicates in total.

For each replicate, calculated CJS parameter estimates and CSS parameter estimates.

Compared parameter estimates to known values to evaluate bias.
Twelve scenarios reflected a range of temporal trends
Simulated trends relative to observed trends
Simulated trends relative to observed trends

Week at LGR

Survival Rate

1 2 3 4 5 6

default

slow decrease
Simulated trends relative to observed trends

Survival Rate

Week at LGR
Simulated trends relative to observed trends

Survival Rate

Week at LGR

default

slow increase

slow decrease
Results

CSS study groups

Percent difference

-25% -20% -15% -10% -5% 0% 5%

C0_cjs
EC0_cjs
C1_cjs
EC1_cjs
T0_cjs
ET0_cjs

default_PS
constant_PS
default_P+decr_S
default_P+incr_S
decr_P+decr_S
decr_P+incr_S
incr_P+default_S
incr_P+incr_S
decr_P+default_S
decr_P+incr_S
incr_PS_steep
decr_PS_steep
Results

Percent difference of estimated $TIR$ and $D$ from known $TIR$ and $D$

![Graph showing percent difference of $TIR$ and $D$ with various conditions like default, constant, $P+\text{decr}_S$, $\text{decr}_P+\text{incr}_S$, $\text{incr}_P+\text{decr}_S$, $\text{decr}_P+\text{default}_S$, $\text{incr}_P+\text{default}_S$, $\text{incr}_P+\text{decr}_S$, decr $PS$ steep, incr $PS$ steep. The graph has a y-axis labeled 'Percent difference' ranging from -20% to 5% and an x-axis labeled with conditions. The lines depict the percent difference for $TIR$ and $D$.]}
Regional review comments

Clarification questions about default values used in simulations
Conclusions

Only under the most extreme conditions of steep linear trends in collection and survival probabilities was substantial bias in CSS study groups (C0, C1, T0), SAR, \textit{TIR}, or \textit{D} estimates evident. Trends as steep as those simulated have rarely been observed during the study period.

The simulations provide confidence that bias due to survival rates and collection probability parameters changing over time is low enough to give reasonably accurate estimates of SAR for each study group, and for \textit{TIR}, \textit{SR}, and \textit{D}.
CSS Response to Regional Review
CSS Response to Regional Review:

Three categories
(all addressed in Appendix H)

• Implemented several suggestions that improved the strength of the final report

• Presented response to key criticisms Chapter by Chapter

• Response to general comments
General Regional Review

• Transparency, reproducibility, data, and detailed methods
  – data, detailed methods and mathematical derivations are available
  – provided specific capture history input files for each of the 2,413,209 fish to reviewers
  – indicated that staff are available to answer additional questions
  – with the input and the formulas, should be able to reproduce results with widely available MARK or SURPH
  – lack of specificity from BPA on information needed for reproducibility
  – formulas for calculating SARs were provided - mathematical derivations in appendix B & formulas in Ch. 3
General Regional Review

- Non-standard modeling practices
  - Used accepted standard statistical methods & analyses:
    - estimation
    - hypothesis testing
    - model-building
    - associated analyses
  - New analyses
    - extensions to methods from peer-reviewed literature
    - methods and assumptions are clearly documented
  - Extensive peer-review of past CSS analyses
General Regional Review

• Latent Mortality
  – CSS found difference in mortality rates between Snake and downriver populations
  – similar in magnitude to estimates in published literature from spawner-recruit data
  – BPA adjustment to differential mortality has two major flaws
    • inconsistent with the definition of differential mortality
    • fails to account for passage survival of transported smolts
General Regional Review

• Upstream downstream comparison - data do not support an upriver/downriver comparison is not accurate
  – differential mortality is estimable from both PIT-tag and spawner-recruit data
  – additional downriver populations would strengthen analysis
  – CSS Oversight Committee proposed, but not received BPA funding, to PIT-tag additional downriver populations
Chapter 8

Conclusions & Future Direction
Accomplishments

• Began in response to key management-oriented questions concerning salmon response to hydrosystem operations
  – Questions developed collaboratively by fish managers & tribes
  – Collaborative study design
  – Collaborative implementation
  – Collaborative analysis and reporting

• CSS uses diversity of skills and perspectives from fish agencies & tribes

• Many ISAB/ISRP and Regional Reviews
  – Because of diversity of skills and perspectives, recommendations were rapidly incorporated
  – Constant improvement with numerous reviews
  – Responsive to changes in hydrosystem operations
Accomplishments

• Large scope of study
  – Addressed highly complex issues over wide geographic range
  – Consistent implementation and collection of data over long time period
  – Multiple agency participation
    • willingness of partners to participate in marking
    • consistency in implementation of marking
    • efficiencies in the use of PIT-tag groups
    • consistency in database management
  – Transparency in methods and wide distribution of reports and reviews on the Web

• Assisted state agencies with key information on hatchery populations
  – Real-time fisheries harvest management
  – Run size projections
Conclusions

• Report analyzes the available PIT-tag data within- and across-years, assessing the effects of migration routes, environmental conditions and migration timing on juvenile reach survival rates and SARs.

• Analyses provide for improved understanding of survival rates and the effects of various environmental conditions and management actions on those rates.
Conclusions

• Juvenile travel times, instantaneous mortality rates and survival rates influenced by managed river conditions including flow, water travel time and spill levels

• Developed relationships for predicting the effects of environmental factors and management strategies on migration and survival rates

• $TIR$s varied across species and between wild and hatchery origins.
  – Wild Chinook on average showed no benefit
  – Hatchery Chinook had higher $TIR$ averages than wild Chinook
  – Wild and hatchery steelhead had the highest $TIR$s
  – Substantial differential delayed transport mortality ($D < 1.0$) was evident for both wild and hatchery species

• Overall SARs for wild Chinook and wild steelhead fell short of the NPCC SAR objectives (2% minimum, 4% average for recovery).
Conclusions

• Snake River Chinook SARs were only one quarter those of similar downriver populations that migrated through a shorter segment of the FCRPS

• The above lines of evidence for Snake River reach survivals, SARs by passage route, overall SARs, and downriver SARs relative to the NPCC objectives, indicate that collecting and transporting juvenile Chinook and steelhead at Snake River Dams did not compensate for the effects of the FCRPS

• Adult upstream migration survival is affected by the juvenile migration experience.
Conclusions

• Simulations results indicate that Cormack-Jolly-Seber parameter estimates are robust in the presence of temporal changes in survival or detection probabilities.

• Given the different responses of wild Chinook and wild steelhead to transportation, it would seem that maximization of survival of both species cannot be accomplished by transportation as currently implemented.

• Improvements in in-river survival can be achieved through management actions that reduce the water travel time or increase the average percent spilled. The effectiveness of these actions varies over the migration season.

• Higher SARs of Snake River wild yearling Chinook were associated with faster water travel times during juvenile migration through the FCRPS, cool broad-scale ocean conditions, and near-shore downwelling during the fall of the first year of ocean residence.
Future Direction

• Activities for the continuation of the CSS and to guide the future direction
  – Extend the time series of PIT-tag information to provide reach survivals, annual and seasonal transport SARs, in-river SARs, and overall SARs for hatchery and wild Snake River spring/summer Chinook and steelhead. Expand the time series of PIT-tag information to provide overall SARs for John Day spring Chinook and steelhead and Carson hatchery spring Chinook. Also, augment hatchery and wild Snake River spring/summer Chinook PIT-tag groups to improve reach survival estimates for the McNary to Bonneville reach.
  – Identify additional downriver wild and hatchery Chinook populations to PIT-tag and provide additional downriver overall SARs.
  – Identify additional Snake River hatchery steelhead populations to PIT-tag at levels necessary to provide reach survivals, annual and seasonal transport SARs, in-river SARs, and overall SARs.
  – Identify downriver wild and hatchery steelhead populations to PIT-tag and provide downriver overall SARs.
  – Augment existing PIT-tag groups of Snake River hatchery and wild steelhead populations to levels necessary to provide reach survivals (particularly in the McNary to Bonneville reach), annual and seasonal transport SARs, in-river SARs, and overall SARs.
Activities for the continuation of the CSS and to guide the future direction

– Investigate how to improve adult LGR to hatchery rack return estimates.

– Continue to evaluate the key assumptions of the CJS model in relation to constraints placed on the experimental design given limitations for hydrosystem operations, with continued diligence to minimize bias.

– Continue to evaluate the relationships between reach survivals and environmental conditions within hydrosystem.

– Continue to evaluate the relationships between population overall SARs and environmental conditions within and outside the hydrosystem.

– Evaluate the relationships between seasonal SARs and environmental conditions within and outside the hydrosystem.

– Develop techniques to evaluate the relationships between overall SARs and recruit/spawner information.

– Continue to coordinate the CSS with other research and monitoring programs in the Columbia Basin to provide and improve efficiencies for PIT-tagging, tag detections, data management, and data accessibility.