Comparative Survival Study Annual Meeting

Presenter: Jack Tuomikoski

CSS Annual Meeting Apr 12th 2012
Background

- Initiated in 1996 by states, tribes & USFWS to estimate survival rates at various life stages
  - Designed to assess hydrosystem operations on state, tribal, and federal fish hatcheries and LSRCP
  - PATH - “can transportation . . . compensate for the effect of the hydrosystem?”
  - NPCC has established the need to collect annual migration characteristics including survival
  - NOAA biological opinions require research, monitoring and evaluation

- Management-oriented large scale monitoring
  - Observational study
  - Aligned with basin wide monitoring needs (RME)
Background

GOALS

1. Quantify the efficacy of transportation
   - Develop a more representative control group

2. Compare survival rates within and across species

3. Establish long term data set
Background

CSS data is derived from PIT tags

- Tagged specifically for CSS

- Cooperative marking between CSS and other research studies
  - reduce costs/ handling, eliminate duplication

- Groups marked for other studies
Background

- Collaborative scientific process was implemented for study design and to perform analyses

- CSS project independently reviewed and modified a number of times
  - Draft report typically posted - Aug 31st
  - ISAB, ISRP and other entities
History of ISAB/ISRP Reviews of CSS

1997 – **ISAB** First review

1998 – **ISAB** Extend to other species & life history types (Steelhead) nonparametric bootstrap approach

2002 – **ISRP** Additional evaluate bootstrap, compare with likelihood methods, Monte Carlo simulator evaluation
History of ISAB/ISRP Reviews of CSS

2003 – **ISAB Review of flow augmentation**

“understanding of the relation between reach survival, instantaneous mortality, migration speed, and flow”

2006 – **ISAB Review of 2005 CSS report**

1) “finer scale analyses of the relationships between survival and specific operational actions or environmental features”

2) Develop a ten year summary report
History of ISAB/ISRP Reviews of CSS

2007 – **ISAB/ISRP** Review CSS “10-year” report
   1) continue coordination  
       cost savings/ avoid redundancy

   2) Address: Are PIT tag SARs < run reconstruction SARs and conduct a comprehensive study to determine why

2009 – **ISAB** Tagging Report  
Compare CSS SARs with Run Reconstruction SARs

>2009 **ISAB** annually reviews CSS reports
The CSS is a joint project of the state & tribal fishery managers and the USFWS

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

**IMPLEMENTATION & TAGGING**
- FPC: Logistics, coordination
- PTAGIS: Raw Data; FPC: Reports, Estimates

**DATA PREPARATION & ANALYSIS**
- CSS Oversight Committee
- Fish Passage Center

**REGIONAL REVIEW**
- Draft on BPA & FPC websites
- Regional Public Review; ISAB, ISRP, FPAC, NMFS, etc.

**FINAL REPORT**
- Posted on BPA & FPC websites
Stocks Included

■ **Snake River (SARs)** 17 +
  - 8 sp/su Hatchery Chinook
  - 2 natural stocks - (sp/su) Chinook & steelhead
  - 5 + hatchery steelhead groups (by basin and A or B)
  - 2 Hatchery Sockeye
  - Fall Chinook – under development

■ **Upper Columbia River (SARs)** 5
  - 1 sp Hatchery Chinook (Leavenworth)
  - 1 Hatchery steelhead (HxW)
  - 2 natural sp Chinook aggregates
  - 1 natural steelhead aggregate

■ **Middle Columbia River (SARs)** 5
  - 2 sp Hatchery Chinook (Carson, Cle Elum)
  - 2 natural steelhead (Deschutes, John Day)
  - 1 natural sp Chinook (John Day)
Spatial Coverage: Hatchery Chinook
Spatial Coverage: Wild Chinook
Spatial Coverage: Snake River Hatchery Steelhead
Spatial Coverage: Wild steelhead
TEMPORAL COVERAGE

- **Snake River**
  - Longer Time Series
  - More groups developed

- **Mid./ Upper Columbia**
  - Begin in 2000 (BOA adults)
  - Fewer groups developed
  - Still in-work
Smolt Survival

FRESHWATER

ESTUARY

OCEAN

Hydro-system Actions

Rearing Habitat Actions

SR

SLGR-MCN

SMCN-BON

LGR

MCN

BON

16
SARS, TIRS

Transportation
Or Bypass
effects

FRESHWATER

Hydro-
system
Actions

Estuary
Habitat
Actions

Harvest
Management

ESTUARY

LGR

BON

OCEAN

18
Post BON Survival

FRESHWATER

Transportation
Or Bypass effects

Estuary

Hydro-system Actions

Estuary Habitat Actions

OCEAN

SOA, D
What does CSS provide for the region?

- **Long term consistent information collaboratively designed and implemented**
- **Information easily accessible and transparent**
  - CSS PIT-tags accessed by any PTAGIS users, including fisheries managers, researchers, and academics.
- **Long term indices (identify bottlenecks)**:
  - Travel Times
  - In-river Survival Rates
  - In-river SARs by route of passage
  - Transport SARs
  - Adult success, conversion
- **Comparisons of SARs**
  - Transport to In-River
  - NPCC SAR goal
  - By geographic location
  - By hatchery group
  - Hatchery to Wild
  - Chinook to Steelhead
- **Management questions**: hydropower operations, hatchery evaluations, habitat evaluations
2011 CSS Activities

- Workshop (Jul 26th-28th, 2011)
  - GOALS:
    - Expand the scope of CSS review
      - 27 attendees from agencies and universities
    - Synthesize information regarding freshwater and ocean factors that affect survival for Columbia River Basin Salmon and steelhead
  - Opportunity for leading investigators to:
    - share and compare results
    - collaboratively develop priorities for future work in CSS
  - facilitated by ESSA Technologies Ltd.

2011 Annual Report
## 2011 Report

### Snake River (SARs)
- 8 sp/su Hatchery Chinook
- 2 natural stocks - (sp/su) Chinook & steelhead
- 5 + hatchery steelhead groups (basin and A or B)
- 2 Hatchery Sockeye
- Fall Chinook – under development

### Report organization
- Chinook SARs through 2009
- Steelhead SARs through 2008
- Juvenile metrics through 2010
CSS 2011: Chinook Overall SARs

- NPCC GOAL of 2-6 % SAR for recovery; mean = 4

- Sp. Chinook stocks:
  
  RAPH
  DWOR
  CATH
  SAWT

- Nearly all estimates below 2%

- High correlation between stocks
**CSS 2011: Chinook Overall SARs**

- **Su. Chinook stocks:**
  - MCCA
  - IMNA
  - PAHH

- Summer stocks higher than spring

- High correlation between stocks

- 1999, 2000, 2008 some estimates above 2%
CSS 2011: Chinook Overall SARs

- Wild sp/su aggregate
- High correlation across Chinook stocks
- Most are less than 2%
CSS 2011: Chinook Overall SARs

- 12.8% SARs > 2
- 74.4% SARs < 2
- 12.8% SARs = NS

Not meeting NPCC goal
CSS 2011: Steelhead Overall SARs

- Hatchery Steelhead
- Several estimates below 2
- 2008*
  Highest in time series
CSS 2011: Steelhead Overall SARs

- Wild Steelhead
- Less correlated than Chinook stocks
- Several estimates below 2
- 2008* Highest in time series

OVERALL SARs

- Hatchery Steelhead
- Wild Steelhead

[Graph showing LGR-LGR from 1994 to 2010]
12.5% SARs > 2
50% SARs < 2
37.5% SARs = NS
Not meeting NPCC goal
CSS 2011: Sockeye Overall SARs

- First hatchery sockeye SARs
- OXBH, SAWT 2009 MY
CSS 2011: Juvenile Metrics

- Component of RM&E
- Long Term dataset of annual juvenile metrics
  - Emigration rate
  - Arrival time at dams
  - Juvenile survival
- Finer scale analyses: response to ISAB comment
Simultaneous processes

- Migration (FTT) & Mortality

- If we can predict these, we can predict survival

- GOAL: evaluate effects of operational and environmental features
Multiple regression model factors

- Seasonality (Julian Day)
- Temperature
- Turbidity
- Average Percent Spill
- Surface Passage Structures (TSW, RSW)
- Water Transit Time (WTT, days)
- Hatchery Composition
The 2010 juvenile emigration characteristics: Water transit time (flow), spill, and Julian date were key variables affecting fish travel time and juvenile survival.

Juvenile travel times, mortality rates and survival rates through the hydrosystem are strongly influenced by managed river conditions (water transit time and spill levels).

Improvements for in-river survival and fish travel times can be achieved through reductions in water transit time or increased spill.
CSS 2011: TIR

- Used to evaluate transportation program (SR stocks)
- Ratio of Transported ÷ Inriver SARs
CSS 2011: TIR vs. in-river surv.

- TIR is directly related to in-river survival

- As in-river survival increases, TIR decreases

- When in-river surv ~ 55%, transport will not be beneficial (for wild stocks)
3 questions

- Effect of transportation on adult success?
- If so, how does this compare with environmental variables?
- Does transportation affect straying rates?
Transported smolts had a lower success rate
  • Average of ~ 6% lower; up to 29% lower

Transportation was consistently a good predictor of adult success when compared with environmental variables

Transported hatchery Chinook and hatchery or wild steelhead smolts strayed 10-39 times more often than in-river outmigrants (wild Chinook NS)
Introduction

Upper Columbia Chinook & steelhead

Variation in age at maturity for PIT-tagged spring/summer Chinook salmon in the Columbia River Basin

Snake River fall Chinook

Break 15 minutes

CSS workshop: Introduction and Retrospective Analyses

CSS workshop: Prospective Analyses

Questions / Discussion
SARs and Juvenile Metrics of Upper Columbia Stocks

Presenter: Robin Ehlke

CSS Annual Meeting Apr 12th 2012
CSS Objectives
Upper Columbia

- Establish long term survival estimates over full life-cycle for annual generations of upper Columbia salmon and steelhead
- Explore development of SARs to upper most dam
- Explore estimating ocean survival rates for upper Columbia groups
- Utilize additional available mark groups
Upper Columbia Mark Groups

- Five Upper Columbia Mark Groups to develop Upper Columbia River (SARs)
  - Leavenworth Hatchery Spring Chinook
  - Hatchery Wild Cross Steelhead
    - Chelan, Eastbank, Turtle Rock
  - Two natural spring Chinook aggregate groups
    - Wenatchee
    - Entiat/Methow
  - Natural steelhead aggregate group
    - Entiat/Wenatchee/Methow
Upper Columbia juvenile and adult metrics - 2011 CSS

- Utilizing existing PIT Tag groups and supplementing existing tagging programs
  - Juvenile passage metrics, travel time, instantaneous mortality and survival from Rock Island to McNary
  - Smolt to Adult Return rates for these mark groups from McNary to Bonneville Dam.
  - Analyses of passage metrics and SARs relative to environmental variables
1 - Twisp River
2 - Methow Smolt Trap at McFarland Creek Road Bridge
3 - Entiat River
4 - Chiwawa River Hatchery
5 - Nason Creek (tributary to Wenatchee River)
6 - Upper Wenatchee smolt trap just below Lake Wenatchee
7 - Chiwawa River Trap 0.5 km below CHIP acclimation pond
8 - Leavenworth National Fish Hatchery
9 - Wenatchee River trap at West Monitor Bridge
Smolt to Adult Return

- Upper Columbia Smolts from McNary to Bonneville Dam
  - Reported SARs do not include or account for juvenile mortality occurring through the Upper Columbia to McNary
  - For this reason the reported SARs are unrealistically high
  - As an example, for Wenatchee the SARs would be ~ 58% of reported if RIS to MCN juvenile survival were taken into account
Hatchery and Wild Chinook geomean survival 0.57

Hatchery and wild steelhead geomean survival 0.59

Larger mark groups and improved downstream detection would improve precision of estimates

Rock Island to McNary Juvenile Survival
Juvenile Passage Metrics/Environmental conditions

- Fish Travel Time
  - Faster with higher flow and with Julian date

- Instantaneous Mortality
  - Decreased for hatchery and wild yearling chinook in the RIS-MCN reach as spill levels increased at Wanapum and Priest Rapids
  - Increased for hatchery and wild steelhead with increase in Julian date

- Reach Survival
  - Increased with higher flow and spill
SAR MCN to BON
wild and hatchery Chinook

Entiat/Methow River Wild Chinook
0.5% - 3% 2006-2009 in 2008 SARs exceed 2%
❖ Not including juvenile survival through the upper Columbia River Reach

Wenatchee River Wild Chinook
0.5% - 3% 2006-2009 in 2008 SARs exceed 2%
❖ Not including juvenile survival through the Upper Columbia River Reach

Leavenworth Hatchery Chinook
genercic mean
SAR 2000-2009 0.53
❖ Not including juvenile survival through the upper Columbia River Reach
SAR MCN to BON
wild and hatchery steelhead

Wenatchee/ Entiat/ Methow wild Steelhead
2006-2008
geometric mean SAR  3.85
  ❖ Not including juvenile survival through the upper Columbia River Reach

Wenatchee River Hatchery Steelhead
2003-2008
geometric mean SAR 2.09
  ❖ Not including juvenile survival through the upper Columbia River Reach
Conclusion

- The Overall Upper Columbia MCN-BON SARs for 2000-2009 of hatchery spring Chinook were highly correlated with wild and hatchery spring chinook SARs from the Middle Columbia (average $r=0.77$) and with wild and hatchery spring/summer chinook SARs from the Snake River (average $r=0.84$).

- Indication that stocks have similar responses to shared FCRPS migration and ocean life cycle experience.

- Upper Columbia mark groups showed patterns of response to environmental variables consistent with Snake and Middle Columbia mark groups.
Conclusion

- Collaboration and Coordination with other Upper Columbia specific marking efforts increases cost effectiveness and the benefits to the region

- Monitoring the effect of hydro system passage on Upper Columbia population groups from existing marking is value added for managers
Variation in age at maturity for PIT-tagged spring/summer Chinook salmon in the Columbia River Basin

Presenter: Steve Haeseker

CSS Annual Meeting Apr 12th 2012
Age at maturity

Age composition of returning adults

Essential component of most forecasting models

- Survival / SR models allocate BY forecast across return years
- Sibling / cohort models used as independent and dependent variable

Can vary across populations and over time
Questions about age at maturity

Does overall survival or outmigration route affect age at maturity?

What are the patterns of variation?
  - Among stocks
  - Over time

High jack returns in 2009?

How might the results improve forecasting?
## Age at maturity data

**Requires adult sampling**

- Scales
- Coded wire tags
- PIT tags
  - negligible aging error
  - known population and individual ID
  - high sampling rates
  - consistent sampling effort across stocks
  - near real-time observations, non-lethal
  - coverage of several wild stocks

**Potential issues**

- Aging error? Source population?
- Expansion factors, reading tags, requires high sampling effort, little coverage of wild stocks
Summarizing age at maturity data

Mean age (at maturity):
10% age-3, 70% age-4, 20% age-5 = 4.1 years

Proportion age-3 (jacking rate):
age-3 returns / total returns

Sibling relationships:
age-3 v. age-4 and age-4 v. age-5 regressions
Comparative Survival Study PIT-tag analyses

10 stocks, juvenile outmigration years 1997-2008:

Hatchery spring Chinook: Carson, Leavenworth, Cle Elum, Dworshak, Catherine Creek, Rapid River

Hatchery summer Chinook: McCall, Imnaha

Wild spring Chinook: John Day River, Snake River
Mean age versus SAR

**Mean age**

- **Snake wild**
- **Carson**
- **Catherine Creek**
- **Cle Elum**
- **Dworshak**
- **Imnaha**
- **John Day wild**
- **Leavenworth**
- **McCall**
- **Rapid River**

**No relationship between SAR and mean age**
Mean age versus outmigration route

Paired t-test of transported versus in-river outmigration routes

<table>
<thead>
<tr>
<th>Stock</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snake River wild</td>
<td>0.43</td>
</tr>
<tr>
<td>Catherine Creek AP</td>
<td>0.98</td>
</tr>
<tr>
<td>Dworshak</td>
<td>0.76</td>
</tr>
<tr>
<td>Rapid River</td>
<td>0.97</td>
</tr>
<tr>
<td>McCall</td>
<td>0.47</td>
</tr>
<tr>
<td>Imnaha River AP</td>
<td>0.82</td>
</tr>
</tbody>
</table>

No relationship between outmigration route and mean age
Mean age
Mean proportion age-3

Mean age and proportion age-3 varies by stock
Sibling relationships

Log (Age-4)

Log (Age-3)
Sibling relationships vary by stock
Standardized mean age over time and across stocks

Mean age

Standardized mean age
Standardized mean age over time and across stocks
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47% stock effects
39% common year effects
Sibling residuals across stocks

Log (age-3)

Log (age-4)
Sibling residuals across stocks

Log (age-3) vs. Log (age-4) graph with points indicating years 1999 and 2005.
Sibling residuals across stocks

Age-3 v. Age-4 residuals

Outmigration year

Residual

1995 2000 2005

-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

16
Sibling residuals across stocks

Age-4 v. Age-5 residuals

Outmigration year

Residual

How to improve forecasting

Important differences in age at maturity between stocks

- Where possible, stock-specific forecasts
- Understand the run composition of aggregate stock groups
- Monitor changes in age over time, especially compared to other stocks

Common year effects on age at maturity across stocks

- Allow for temporal variation in models (e.g., Kalman filter)
- Recent age composition may be better than long-term average
- Evaluate candidate environmental factors that may be associated with observed changes in age at maturity
Snake River Fall Chinook

Modeling Holdover Probability

Presenter: Jerry McCann

CSS Annual Meeting Apr 12th 2012
Background

- CSS was requested to develop estimates of subyearling fall Chinook SARs.

- CSS approach compares SARs for transported fish to fish undetected in-river (C0) at transport dams.

- Holdover fish can bias estimates of C0 SARs.
Background

- In 2011 CSS developed models for predicting holdover probability.
- This approach was used to identify release groups that are most likely to holdover.
Subyearling Fall Chinook PIT-tag Releases

Wild
Research
Production
What is a holdover?

Holdover, or yearling migration, is when fish migrate past some dams as yearlings - the year after release/emergence.
Observed holdover detect proportions in Snake River PIT releases

Observed holdover detect proportions in Clearwater River PIT releases

Production

Researcha

Wild

Proportion holdover detections

Release date and length at release for PIT tagged Ch0 in 2009

Later releases at shorter lengths = Higher Holdover Probability
Proportion Holdovers by release date for PIT tagged Ch0 in 2009

Later releases at shorter lengths = Higher Holdover Probability
Analytical Approach

- **Logistic model:** Model holdover probability using holdover detection probability

1. **Holdover Det (Y/ N) = Rel_date + Rel_length + date*length**
   - Typically research/surrogate and wild releases included in this Modeling group

2. **Holdover Det (Y/ N) = Rel_date**
   - Usually Production releases in this Modeling group

- **Fitted models successfully for 7 out of 9 years**
  - Measured Fit Using Somer’s D, p values for effects.
Observed vs predicted holdover detection probability by year

Sample size ~10,000 or greater for production hatchery releases
Observed vs predicted holdover detection probability by year

Sample size ~10,000 or greater for production hatchery releases
Conclusions

- Models successfully predicted holdover detection probability using length and release date.

- Holdover probability appears to be related to release date and release length.

- We can estimate relatively unbiased SARs on PIT-tagged subyearling Chinook.

Next steps
- Identify groups for SAR estimation.
- Add years of juvenile data to HO analysis.
Introduction:
Approaches for assessing hydrosystem effects in the face of variable marine conditions

Charlie Petrosky, Idaho Department of Fish and Game
Comparative Survival Study 2012 Annual Meeting
April 12, 2012
Objectives:

1. Synthesize recent evidence & insights on:
   a. What is relative importance of various factors (FCRPS operations, freshwater/ocean conditions, fish attributes) in determining salmon & steelhead survival rates?
   b. How to use retrospective analysis to build tools that evaluate & optimize FCRPS operations to meet NPCC SAR objectives?
   c. Implications of questions a and b on identifying additional populations that need estimates of SAR and $S_R$ through FCRPS to meet CSS objectives?

2. Provide opportunity for leading investigators to share & compare recent results, & collaboratively develop priorities for future CSS work.
   Broaden scope of review of CSS work by incorporating input from other researchers doing similar types of analyses
Comparative Survival Study Workshop
July 26-28, 2011

• 27 scientists, US & Canada, 9 agencies, 3 universities & ESSA

• Presentations:
  • Delayed Hydrosystem Mortality Hypothesis
  • CSS survival rate patterns
  • Environmental variability throughout life cycle of Oregon coastal coho
  • Life stage specific survival and factors influencing performance
  • Spatial & temporal patterns in SR residuals, SARs, marine survival rates
  • Freshwater & marine influences on life-stage specific survival rates
  • Bypass effects on SARs
  • Adult success and stray rates as function of passage history
  • Tools to analyze existing and alternative FCRPS operations
  • Generating SARs and $S_R$ for populations lacking such estimates

• Workshop report Marmorek et al. 2011; App. G in CSS 2011 annual report
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• Workshop report Marmorek et al. 2011; App. G in CSS 2011 annual report
Decline in salmon abundance associated with dam construction ...

Salmon River spring/summer Chinook

IDFG index redd counts
Dramatic changes in outmigration conditions with dams...

marine conditions were not static...

Need to account for both
Lower Granite Dam
Lower Monumental Dam
Ice Harbor Dam
McNary Dam
John Day Dam
The Dalles Dam
Bonneville Dam

Freshwater

Ocean

Estuary

SAR

S.o1

S.r

S/S

R/S
Linking SARs and Life Cycle Survival Rates...

- 2-6% SAR objectives (ave. 4% SAR; NPCC 2009)
  - Evaluate SARs in face of varying ocean conditions
  - Adapt freshwater management actions (tributaries & FCRPS)
- SARs to meet NMFS (interim) survival and recovery criteria (2000 BiOp)*
  - 2% SAR - meets long-term (100 yr) survival
  - 4% SAR - meets (48 yr) recovery
  - 6% SAR - meets short-term (24 yr) survival
- Other goals: ICTRT (2007) viability, broad-scale recovery, sustainable fisheries, etc.
  - Regardless of goals, similar analyses needed to link SARs and life cycle survival rates

*Marmorek et al. 1998 - PATH FY98 Final Report
2000 FCRPS BiOp

- Management options to meet NMFS (interim) survival and recovery criteria
  - A1 - status quo
  - A2 - maximize transport
  - A3 - Snake River dam removal

- Ability to meet criteria
  - A3 > A1 or A2 across hypotheses (most likely to meet & least risk)

- Key uncertainty = amount of hydrosystem delayed mortality
  - Mortality that occurs in marine environment as consequence of hydrosystem experience
  - Transported fish relative to in-river migrants
  - In-river migrants

Marmorek et al. 1998 - PATH FY98 Final Report
Evidence for Hydro-Related Delayed Mortality $H_A$

- **Mechanisms (literature review)**
  - Stress at dams, crowding, disease exposure, migration delay, energy loss, altered estuary timing

- **Direct Evidence**
  - Delayed mortality of transported smolts ($D < 1$), and in-river smolts (especially collection/bypass)

- **Indirect Evidence** of substantial delayed mortality
  - Temporal and spatial patterns of population response; declines in SAR; response to good flows

Budy et al. 2002
A decade later...

Spawners & recruits:
• 10 more brood years
• 18 Snake River & 3 John Day River Chinook populations
• Contrast in ocean conditions
• Continue/expand long-term data sets (input from States, Tribes, ISAB)

Comparative Survival Study:
• PIT tag SARs:
  • Snake River wild & hatchery Chinook & steelhead
  • John Day River wild Chinook and steelhead
• In-river survival rates
• Transport to in-river SAR ratios (TIRs)
• Differential delayed mortality of transported smolts ($D$)
• Increased detection sites
• Court-ordered spill program (contrast in river conditions)

Additional & more specific M&E data across variable river & ocean conditions
Assessment approaches depend on the data

Life stage

Life cycle

CSS: in-river survival, SARs by route of passage, transport evaluations...

John Day Sthd

Snake Sthd PIT SARs

John Day SPCH

Snake SPCH PIT SARs

Snake River Sthd SARs (run rec.)

Snake River SPCH SARs (run rec.)

John Day River SPCH spawner:recruit

Snake River SPCH spawner:recruit

Environmental contrast
Assessing hydrosystem mortality

Address past criticisms:
• Spawner-recruit estimates - precision, uncertainty in models, number of populations
• Use of reference populations - same response to ocean conditions as Snake populations?
• Past estimates of differential & delayed mortality during period of poor ocean conditions

Recent CSS analyses:
• Estimate hydrosystem effects with & without using reference populations
  • Differential mortality (8 vs. 3 dam)
  • Hydrosystem delayed mortality (in ocean)
• CSS PIT tag data - increased precision, overall SARs & by passage route, isolate mechanisms
• Examine multiple lines of evidence - consistent results?
Weight of Evidence Framework -

Multiple lines of evidence for relative importance of major factors

Plausible mechanism?
Exposure to causal factor?
Correlation/consistency of response?
Threshold for response?
Specificity of response?
Experiments lead to similar response?
Response to removal of stressor?

Comparative Survival Study Workshop Report - Marmorek et al. 2011

Summary

• **CSS Workshop background and description of approaches for assessing hydrosystem effects in face of variable marine conditions**
  - Broaden scope of review for CSS work by incorporating input from other researchers doing similar analyses

• **Hydrosystem delayed mortality** - occurs in marine environment as consequence of hydrosystem experience
  - i.e., is marine survival independent of river conditions?

• **Weight of evidence:** retrospective analyses (multiple approaches & scales), testable $H_a \rightarrow$ experimental management

• **CSS Workshop Results:**
  - *Retrospective analyses* - assessing freshwater and marine influences on survival rates of Snake River Chinook salmon and steelhead
    • Howard Schaller
  - *Prospective analyses* - tools to explore operational alternatives
    • Steve Haeseker
Retrospective analysis of survival rates for stream-type Chinook salmon and steelhead in the Snake and John Day rivers

CSS Annual Meeting
April 12, 2012
Key Concepts:
Is there evidence linking estuary and early-ocean mortality to the migration experience through the hydrosystem?

DELAYED Hydrosystem MORTALITY
• Similar concept to smoking/lung cancer
• How can you measure this?
• How to evaluate the hypothesis?

Potentially 8 Dams
Challenges and management objectives

Multiple factors operating at same time
  • Capitalize on temporal patterns of variation
  • Capitalize on spatial patterns of variation
  • Consistency from multiple lines of evidence
  • Delayed mortality decrease with improved ocean

SAR objectives of 4% average, 2% minimum
**Approach**

**Weight of evidence** Multiple lines of evidence for relative importance of major factors influencing survival rates

- Estimate hydrosystem and ocean effects without using reference populations
  - Temporal approach evaluating river variables influence on ocean survival (SoA & So1)
  - Contrast period before major hydro impact with the present

- Estimate hydrosystem and ocean effects using a reference populations
  - Spatial and Spatial/Temporal approaches evaluating river & ocean variables influence on survival (SAR & SRI)
  - Contrast populations through 8 vs. 3 dams

- Examine multiple lines of evidence – consistent results
What factors influence survival at each life stage?
Data

CSS PIT-tag SARS for multiple cohorts per year
Long time series of annual Spawner/Recruit and SARs

\[
S_{OA} = \frac{SAR}{S_H}
\]

\[S_{OA}\]

\[S_{H}\]

\[SAR\]

\[So1\]
Factors examined

Hatchery
- Hatchery %

Seasonality
- Julian day
- Percent spill
- Spillway surface passage
- Water transit time (WTT)

Freshwater
- Near shore (upwelling)
- Water transit time (WTT)

Ocean
- Broad scale (PDO)

Conducted multiple linear regressions between environmental factors and survival rates using multimodel inference tools.
Steelhead

$S_H$

Year:

1997 1999 2001 2003 2005 2007 2009 2011
Temporal Analyses

- Influence of river & ocean conditions on survival rates
  - Employ long time series:
    - Pre & post Snake River dam completion
    - Survival rates for different life stages (SRI,SAR,So1)
    - Variables for ocean conditions
    - Variables for river conditions during seaward migration

- For different life stages & species - contrast the set of ocean & river conditions that explain variation in survival rates (temporal)

- Temporal/spatial contrasts to estimate FCRPS impacts - differential and delayed hydrosystem mortality
California Current brings cold polar water from the north keeping coastal temperatures cool.

**Broad scale:**
- Pacific Decadal Oscillation

**Near shore:**
- Coastal Upwelling
- Spring Transition
- Near shore Temp.
Candidate River Variables

**Water travel time** (Lewiston - BON Dam):
- 2 days pre-dam
- 10-40 days (19 day ave.) post-dam

In-river migrants now pass through:
- up to 8 powerhouses
- up to 4 turbines
- depending on spill

**Collection and transport:**
- 25% - 99% of smolts transported (1977-2006)

**Mean daily maximum temperature**
- Snake River mean maximum temperature at Lewiston 9.9 to 13.2°C
  
  Petrosky & Schaller 2010
Multiple Regression Analysis

• Evaluate multivariate models of SRI, SAR & So1

• Best fit models to isolate influence of ocean and in-river conditions on survival rates
  • Coefficients and consistency of results across species and life stages

• Use models to estimate FCRPS impacts - differential and delayed hydrosystem mortality
Marine survival (So1)

River & Ocean important

Best fit, simplest models exhibit lower marine survival for:

- Warm PDO (Spring)
- Reduced Upwelling (April)
- Increased WTT (slower velocity)
- 72% reduction in marine survival due to hydrosystem impacts
- Similar results for steelhead

So1 Chinook

Petrosky & Schaller 2010
SRIs Chinook

River & Ocean important

Best fit, simplest models exhibit lower survival for:

- Warm PDO
- Reduced Upwelling (Apr)
- Increased Powerhouse encounters & WTT
- Increased Proportion transported

SARs showed similar results (Chinook & steelhead)
Spawner-recruit spatial contrast

**Treatment** = Snake populations
  • (3 dams → 8 dams)

**Reference** = John Day populations
  • (2 dams → 3 dams)

• Spawner-recruit residuals or multi-stock model

• Estimate **differential** mortality

• Estimate **total** mortality for Snake (differential + JDA passage mortality)

• Estimate **delayed** mortality for Snake (total mortality - passage mortality)

---

e.g., Schaller et al. 1999; Deriso et al. 2001; Schaller & Petrosky 2007
**SAR spatial contrast**

(*↑ Precision-PIT tags*)

**Treatment** = Snake aggregate

- (8 dams)

**Reference** = John Day aggregate

- (3 dams)

- Shorter time series, life stage specific

- Estimate **differential** mortality between ESUs

---

e.g., Schaller et al. 2007 – CSS 10-yr report; Schaller & Petrosky 2007; Schaller, Petrosky & Tinus in prep.
Conclusions from Spatial Analysis

• Differential mortality from wild SARs (↑ precision) corresponds with estimates from S-R models (↑ contrast)

• Snake River wild Chinook survived 1/4 to 1/3 as well as downriver populations since hydropower system completion
Estimates of differential mortality
wild spring/summer Chinook populations

Blue = spatial, Gray = temporal, and blue hatch = temporal/spatial
Differential Mortality

• Differential mortality from temporal analysis correspond with estimates from spatial analysis

• All studies: survival of fish passing through the complete hydrosystem is 28% of those populations that pass through 5 fewer dams

• Outlier
  • assumes common productivity (Ricker “a”) for all populations
  • passage survival of downriver population ~ 100%
Estimate Delayed Hydrosystem Mortality

- Temporal - regression models for So1 & SoA
- Spatial - delta model S/R contrast
Estimates of delayed mortality of Snake River wild spring/summer Chinook

Solid = delta model S-R contrast, hatch = regression approach using Snake populations

Slide # 32
• **Effect of increased Hydrosystem Development:**
  • >3 fold decline in Chinook 1\textsuperscript{st} year ocean survival rate
  • >5 fold decline in Chinook SRIs

• **Evidence of Delayed Hydrosystem Mortality**
  • estimate of delayed mortality from temporal analysis was similar to spatial/temporal comparisons (Schaller and Petrosky 2007)

• **Outlier** – inconsistent with empirical information:
  • assumes common productivity for all populations
  • and survival of downriver population ~ 100%
How is ocean survival related to freshwater survival?

PIT-tag mark-recapture data from migration years 1998-2009

\[ S_{OA} = \frac{SAR}{S_{H}} \]
Ocean survival related to Freshwater survival

**Steelhead**

Logit ($S_{OA}$) vs Logit ($S_{H}$)

$r = 0.57, P < 0.02$

**Chinook**

Logit ($S_{OA}$) vs Logit ($S_{H}$)

$r = 0.44, P < 0.01$
Bypass events influence ocean survival?
Bypass events influence ocean survival?

- Logistic regression
- Yearling Chinook and steelhead, MYs 2000-2009
- Analyzed hatchery and wild, accounted for differences
- Model-averaged the estimated bypass effects

<table>
<thead>
<tr>
<th></th>
<th>JDA</th>
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<th>IHR</th>
<th>LMN</th>
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</table>
Spring/summer Chinook salmon
   Each bypass event reduced post-BON SARs by 10%

Steelhead
   Each Snake bypass event reduced post-BON SARs by 9%
   Each McNary or John Day bypass event reduced post-BON SARs by 20%

Management implications
   Direct and route-specific survival estimates unlikely to reflect full impacts of passage routes
   Actions that reduce powerhouse passage (bypass + turbine) expected to increase SARs
Conclusions

- NPCC 2%-6% SAR goal - extremely difficult to achieve without major changes to seaward migration conditions in the mainstem

- Especially in face of climate change (e.g. warming & increased variability in ocean conditions)

- River conditions during seaward migration have strong influence on survival rates at later life stages

- Analyses of Snake River population performance continued to show the hydrosystem is a key factor influencing delayed mortality - Multiple methods, independent data (SRI,SAR, & So1)

- CSS Workshop 2011
  - "The evidence presented for ... delayed mortality arising from earlier experience in the hydrosystem is strong and convincing."
  - "It is difficult to imagine how [other factors] would align so well both in time and space with the establishment of the hydro system."
Conclusions

Tools to improve understanding role of hydropower management on overall survival in the face of variable ocean and climate conditions:

- reduced WTT
- reduced number of powerhouse passage (↑spill)
- other actions to speed migration of juvenile migrants
Prospective Analyses from the CSS Workshop

Presenter: Steve Haeseker

CSS Annual Meeting Apr 12th 2012
Looking back over the data and analyses...

We have learned a lot over last 10 years!

Life-cycle data and analyses were responses to agency/tribal/ISAB requests and questions.

CSS Workshop provided additional opportunity for broad review-
Prospective analyses synthesize the retrospective work in a manner that may be useful in a variety of applications in the region.

Workshop Question:

How can we use recent analyses to build tools that evaluate and optimize FCRPS operations for the above-listed groups of anadromous fish to meet established NPCC objectives for listed Snake and upper Columbia River salmon and steelhead SARs?
1) How do changes in juvenile and ocean survival rates influence SARs?

Which juvenile survival values (if any) achieve 4% average SARs?
1) How do changes in juvenile and ocean survival rates influence SARs?

\[ S_H \times S_{OA} = SAR \]

50% * 4% = 2%
Positive correlations between juvenile and ocean survival rates

Steelhead

Ocean survival vs. Juvenile survival

$r = 0.57, \ P < 0.02$

Chinook

Ocean survival vs. Juvenile survival

$r = 0.44, \ P < 0.01$
Chinook salmon

Ocean survival

Juvenile survival
Chinook salmon

Ocean survival

Juvenile survival

Low

High

Low

High
Chinook salmon

Ocean survival vs. Juvenile survival

Low

High

30% ↔ 70%

Juvenile survival

Low

High
Juvenile survival

Ocean survival

Chinook salmon

5% 95%

Low High

Low High
Juvenile survival

Steelhead

Ocean survival

High

Low

Juvenile survival

Low

High

10
Juvenile survival

Ocean survival

Steelhead

Low

High

Low

High

Juvenile survival
Juvenile survival

Ocean survival

Steelhead

High

Low

Juvenile survival

Low

High

3% 65%

Low

High

12
**Approach**

Allow juvenile survival to vary between 5% and 95%

Simulate ocean survival rate using regression with observed variability

Calculate mean SAR associated with each juvenile survival rate
Chinook salmon

Juvenile survival vs. SAR

> 85%
Steelhead

Juvenile survival

SAR

> 85%
Reasonable predictions?

Chinook salmon

SAR

Juvenile survival
Reasonable predictions?

Chinook salmon

SAR

Juvenile survival

John Day R. (3 dams)

Yakima R. (4 dams)

Snake R. (8 dams)
Reasonable predictions?

Steelhead

SAR

Juvenile survival
Reasonable predictions?

Steelhead

SAR

Juvenile survival

John Day R. (3 dams)
Yakima R. (4 dams)
Snake R. (8 dams)
Expectations if meeting performance standards (with zero reservoir mortality):

**Chinook salmon**

**Steelhead**

Juvenile survival
Expectations if meeting performance standards (with zero reservoir mortality):

Chinook salmon

Steelhead

SAR

Juvenile survival
2) What operations might achieve 85% juvenile survival rates?
**Approach**

Used model-averaged coefficients

Held WTT and spill percentages at fixed levels

Calculated mean juvenile survival rates
## Steelhead

### Spring flow levels

<table>
<thead>
<tr>
<th>Spill (%)</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
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## Steelhead

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## Chinook salmon

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Chinook salmon

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3) What operations might achieve SARs averaging 4%?
Approach

Used model-averaged coefficients

Maintained historical patterns in ocean conditions (1998-2009)

Held WTT and spill percentages at fixed levels

Calculated mean SAR
Steelhead

Spring flow levels

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# Steelhead

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### Chinook salmon

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Conclusions

Snake River simulations and data from other stocks both indicate that juvenile survival rates need to be > 85% to achieve 4% SAR goals.

Juvenile models indicate that spill levels of 55-60% may achieve 85% juvenile survival across a range of flow conditions.

SAR models indicate that spill levels of 55-60% may achieve the 4% SAR goal under a similar series of ocean conditions.

Analyses highlight need for active Adaptive Management experiments. Existing/enhanced PIT releases provide monitoring framework for testing predictions.