EVALUATION OF SURVIVAL AND DETECTION ESTIMATES BASED ON A BAYESIAN CORMACK-JOLLY-SEBER MODEL FOR SPRING CHINOOK SALMON IN THE WILLAMETTE RIVER BASIN

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Background

- Standard statistical framework to estimate survival rates from tagging studies for salmonids is the Cormack-Jolly-Seber model (CJSM) using Maximum Likelihood Estimation
- Estimates also can be carried out using a Bayesian framework. Bayesian analysis allows the “borrowing” of information from other (independent) studies in the form of a prior probability distribution for the estimated parameters.
- Due to the sampling design, the CJSM parameters, “apparent” survival and detection rates, are confounded in the parameter estimation.
- Under the minimum model configuration (e.g., a release site and two detection sites: SUJ and WFF), the CJSM could produce biased or highly imprecise estimates
- A simulation-estimation framework can inform us about the potential bias and imprecision in estimates from a CJSM
- We apply this framework to evaluate bias and precision for the Bayesian CJSM.

Outline

1. Simulation-estimation study
2. CJS estimates for chinook salmon released in the Willamette river basin

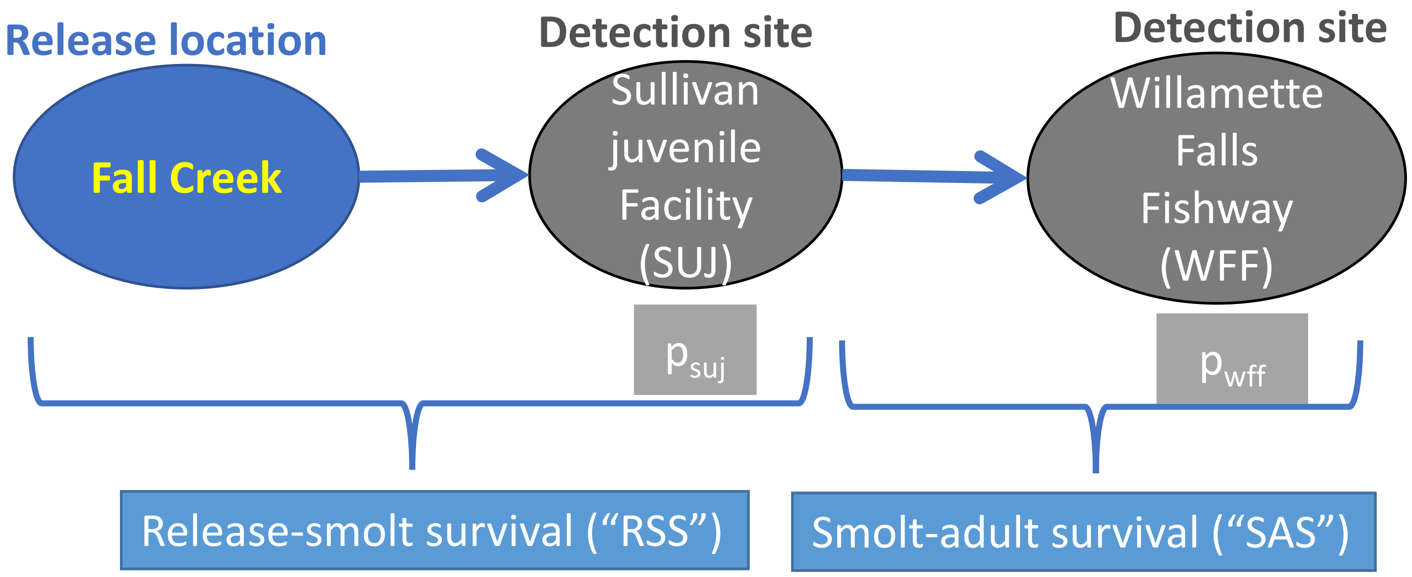
- Objectives
- Methods and Data
- Results
- Discussion/Summary

Simulation-estimation study

Objectives

- 1) Evaluate bias and precision of parameter estimates for a Bayesian CJS model using a simulation-estimation framework

1. Methods and Data



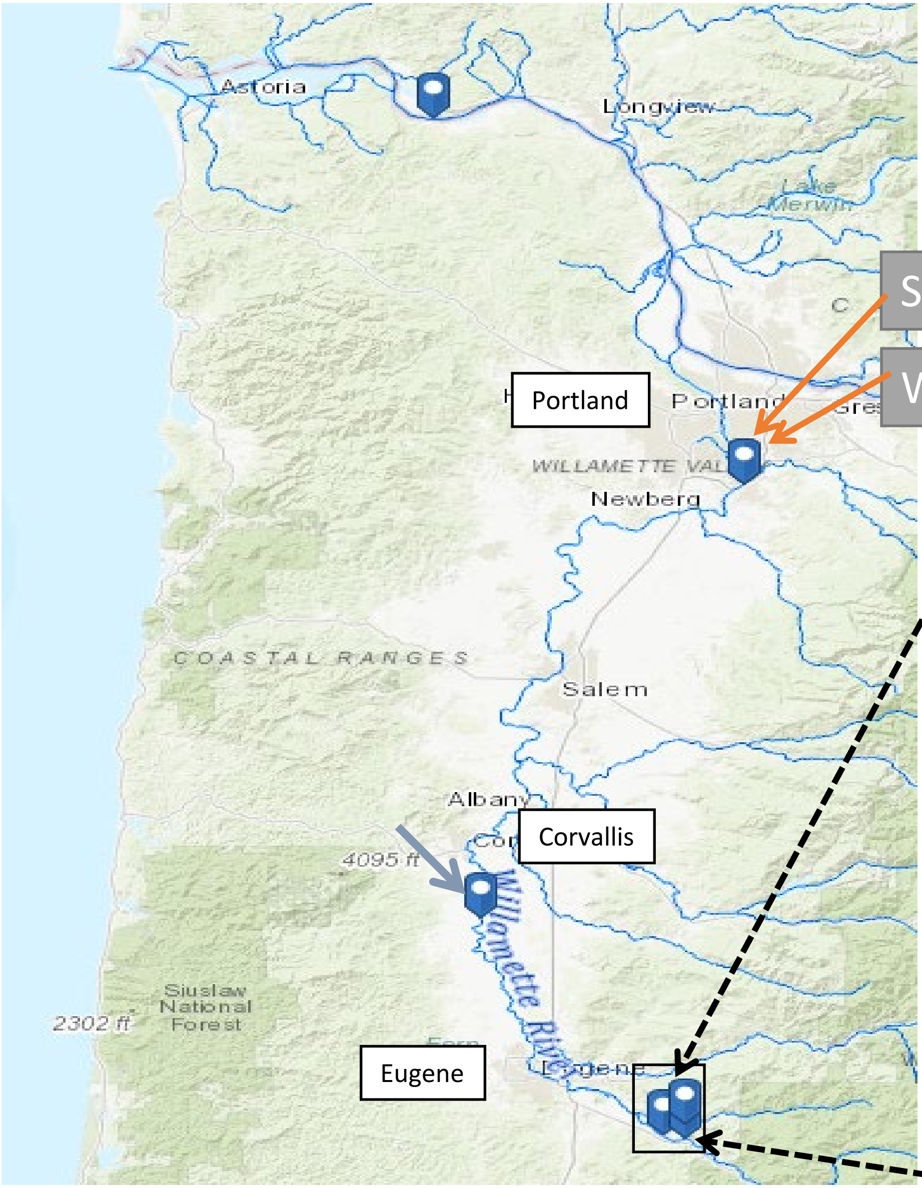
p_{suj} and p_{wff} are the detection rates for smolt and adults, respectively.

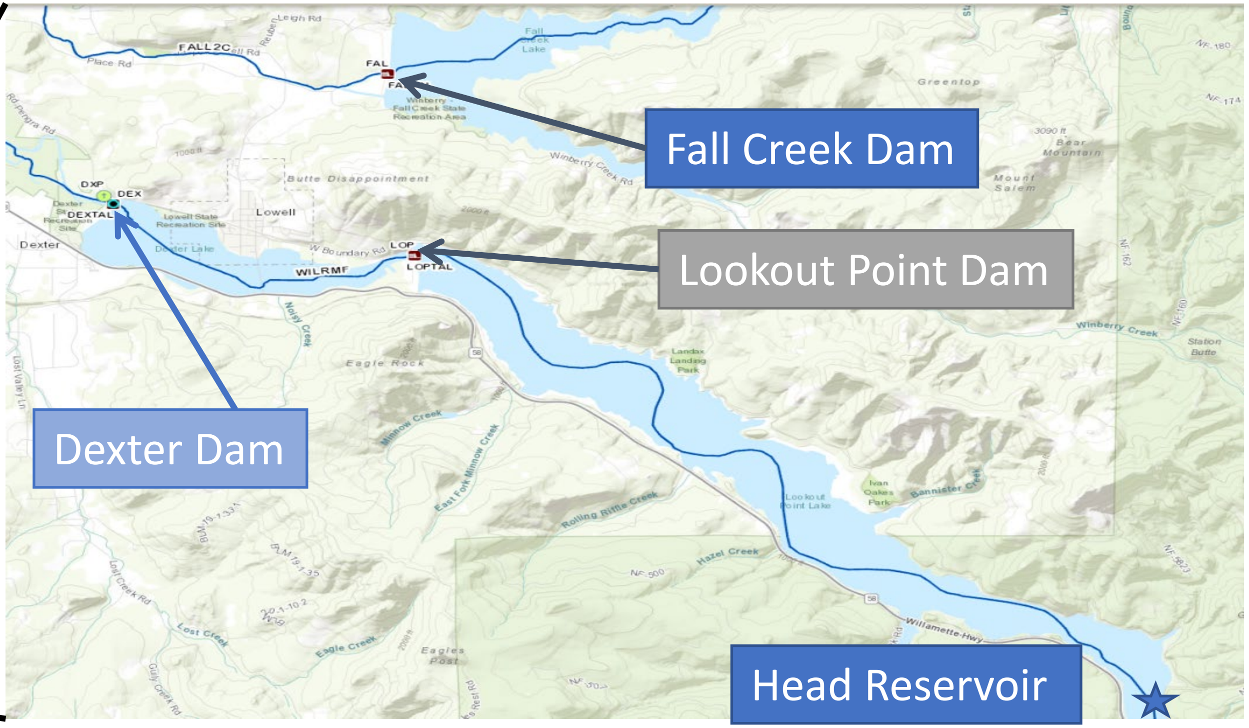
SAS: integrates the survival from smolt leaving SUJ and arrival some years later as adult at WFF

- We simulated data (detection histories) based on CJS parameter estimates from Fall Creek and Lookout Point head of reservoir (Lop-Hor)

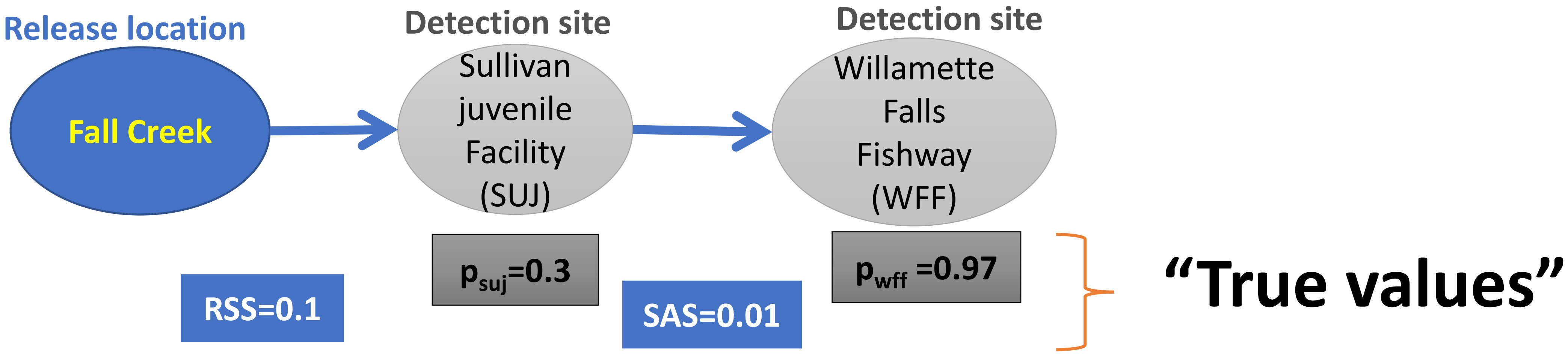
release & detection sites

black: detection sites
Blue: release sites





1. Methods and Data



CJS estimates from Fall Creek and Lop-Hor were established as the "true values" for the simulation. We "released" 5,000 and 10,000 smolts, respectively. Lop-Hor 2013 release data exemplified a "worse case scenario" (many releases but low detections at SUJ and low survivals).

Simulated detection histories	100	110	101	111
Fall Creek	4844	152	3	1
Lop-Hor	9918	80	2	0

e.g., 110: fish released and only detected at SUJ but not at WFF

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1. Methods and Data

- The estimation model (i.e., Bayesian CJSM) was fitted to the simulated data (i.e., detection histories).

- We compared true vs. estimated parameter values as a measure of performance: e.g., [relative bias=(estimated-true)/true].

Important assumptions for the estimation model :

- p_{wff} is close to 1 (i.e., informative prior). This allows separation of SAS from P_{wff}

- We developed a prior for p_{suj}: ~15% (Tom Porteus presentation for details)

- Uninformative priors for Release – Smolt Survival (RSS) and Smolt-Adult Survival (SAS); e.g., Beta(1,1)

1. Results

Simulation results for the Bayesian CJS model (Gibbs sampler) based on Fall Creek release data.

Metric	RSS	p_{suj}	SAS	p_{wff}
true value	0.1	0.3	0.01	0.97
SD	0.14	0.18	0.009	0.03
CV	0.98	0.52	0.72	0.03
median	0.09	0.33	0.0097	0.97
2.5% quantile	0.05	0.08	0.002	0.89
97.5% quantile	0.39	0.67	0.028	0.99

The relative bias was low for both RSS and SAS (-7% and -3%, respectively).
The relative bias for p_{suj} also was low (9%)

Simulated detection histories	100	110	101	111
Fall Creek	4844	152	3	1

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1. Results

Simulation results for the Bayesian CJS model (Hamiltonian Monte Carlo sampler, HMC) based on Lop-Hor 2013 release data.

Metric	RSS	p_{suj}	SAS	p_{wff}
true value	0.05	0.15	0.005	0.97
SD	0.07	0.07	0.004	0.03
CV	0.75	0.57	0.88	0.03
median	0.07	0.11	0.004	0.96
2.5% quantile	0.03	0.03	0.001	0.88
97.5% quantile	0.31	0.29	0.016	0.99

For the Lop-Hor simulation, missing detection histories caused bias in parameter estimation (RSS: 40%, SAS: -28%, and p_{suj}= -28%).

Simulated detection histories	100	110	101	111
Lop-Hor	9918	80	2	0

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1. Discussion

- Minimum configuration for a CJS model could produce biased parameter estimates under missing detection histories, in particular, when 101 or 111 are zero.

- The state-space CSJM version (in Jags) and the multinomial likelihood (in R) produced similar results.

- The bias produced by missing detections could be reduced, but likely not eliminated, using well-informed and empirically-based priors (e.g., Porteus et al. 2021).

- The informative priors for detection at SUJ (p_{suj}) helped MCMC convergence and reduce uncertainty in the release-smolt survival (RSS) estimates.

- The detection prior at WFF (p_{wff}) is key to estimating smolt-adult survival (SAS).
  As far we know, this is a new approach to estimating SAS in the Willamette River basin and it could be applied to other river sub-basins.

CJS estimates for Chinook Salmon Tagged and Released in the Willamette River Basin

Objectives

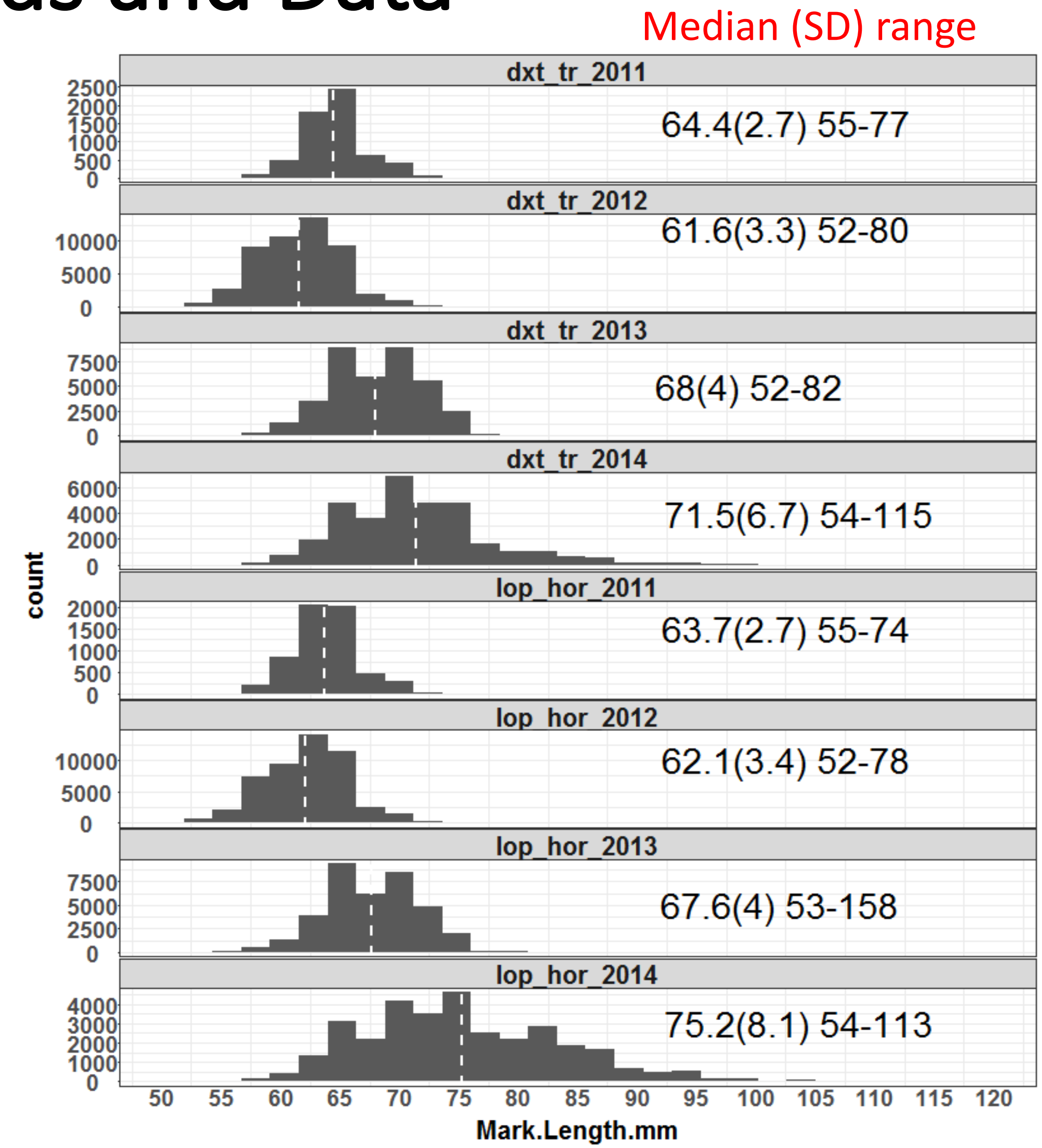
- 2a) Apply the Bayesian CJS model to estimate the survival and detection rates for chinook salmon released in the Willamette river basin
- 2b) Compare survival estimates for fish released above and below dams

2. Methods and Data

- A **subset** of paired release data for Middle Fork Willamette River was used
- These data allow comparison of fish tagged and released above and below dams

Release location	2011	2012	2013	2014
Fall Creek			3,990	
Lookout Point head of reservoir (Lop-Hor)	5967	49,624	37,194	37,194
Dexter tailrace (Dex-Tr)	5958	49,266	37,287	33,517

2. Methods and Data



- The data show variability in terms of size at release
- Estimates should be compared within years but not between years (e.g., Dex-Tr 2011 vs. Lop-Hor 2011)

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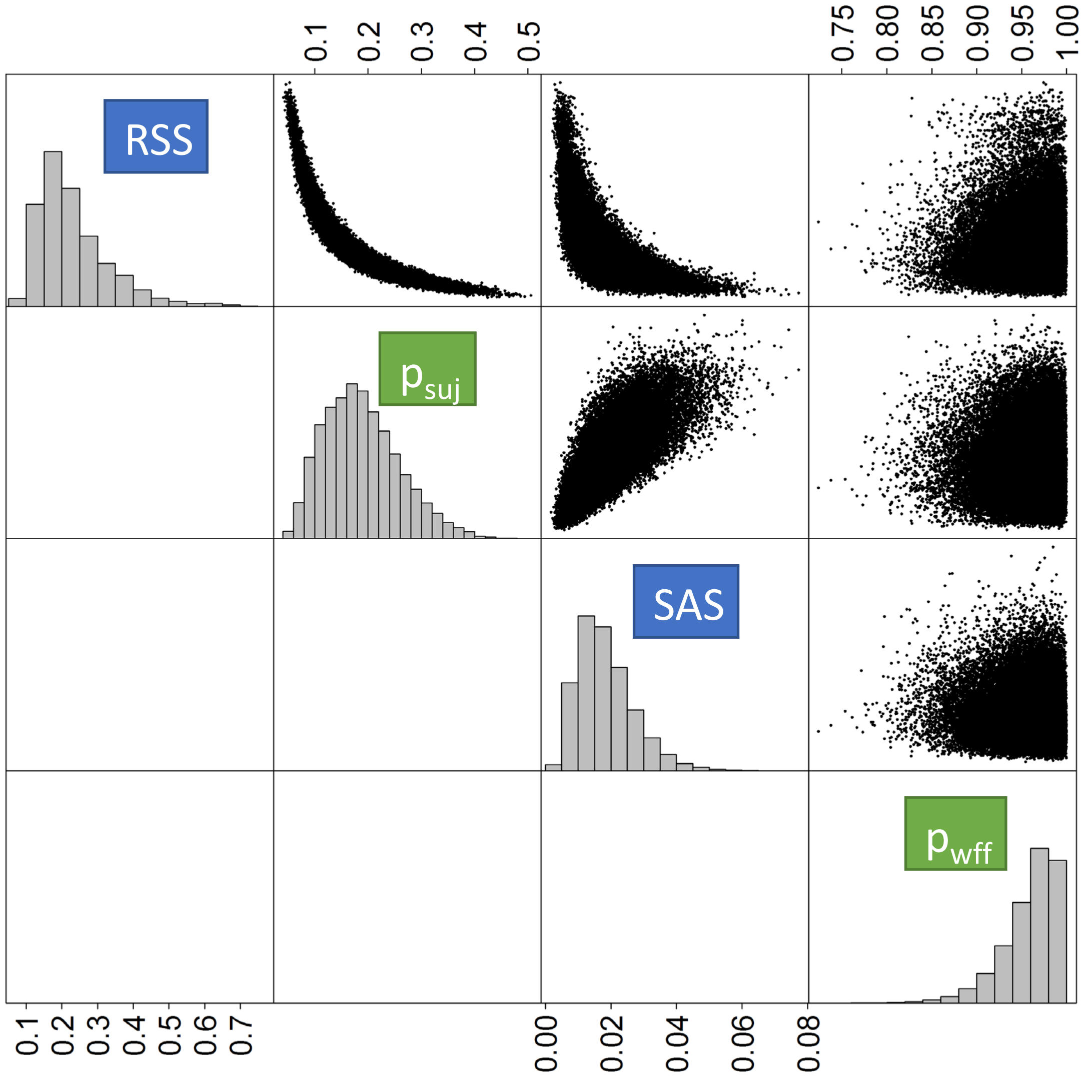
2. Results

Example of posteriors estimates for Fall Creek



Survival or **detection** rates

- Bayesian estimation allows characterization of uncertainty (probability distribution) and correlation of the estimated parameters
- Thus, the MCMC samples can be used to project uncertainty/correlation in population dynamics models

	RSS	p_{suj}	SAS	p_{wff}
RSS	1	-0.87	-0.7	0
P_{suj}		1	0.78	0
SAS			1	-0.07
p_{wff}				1

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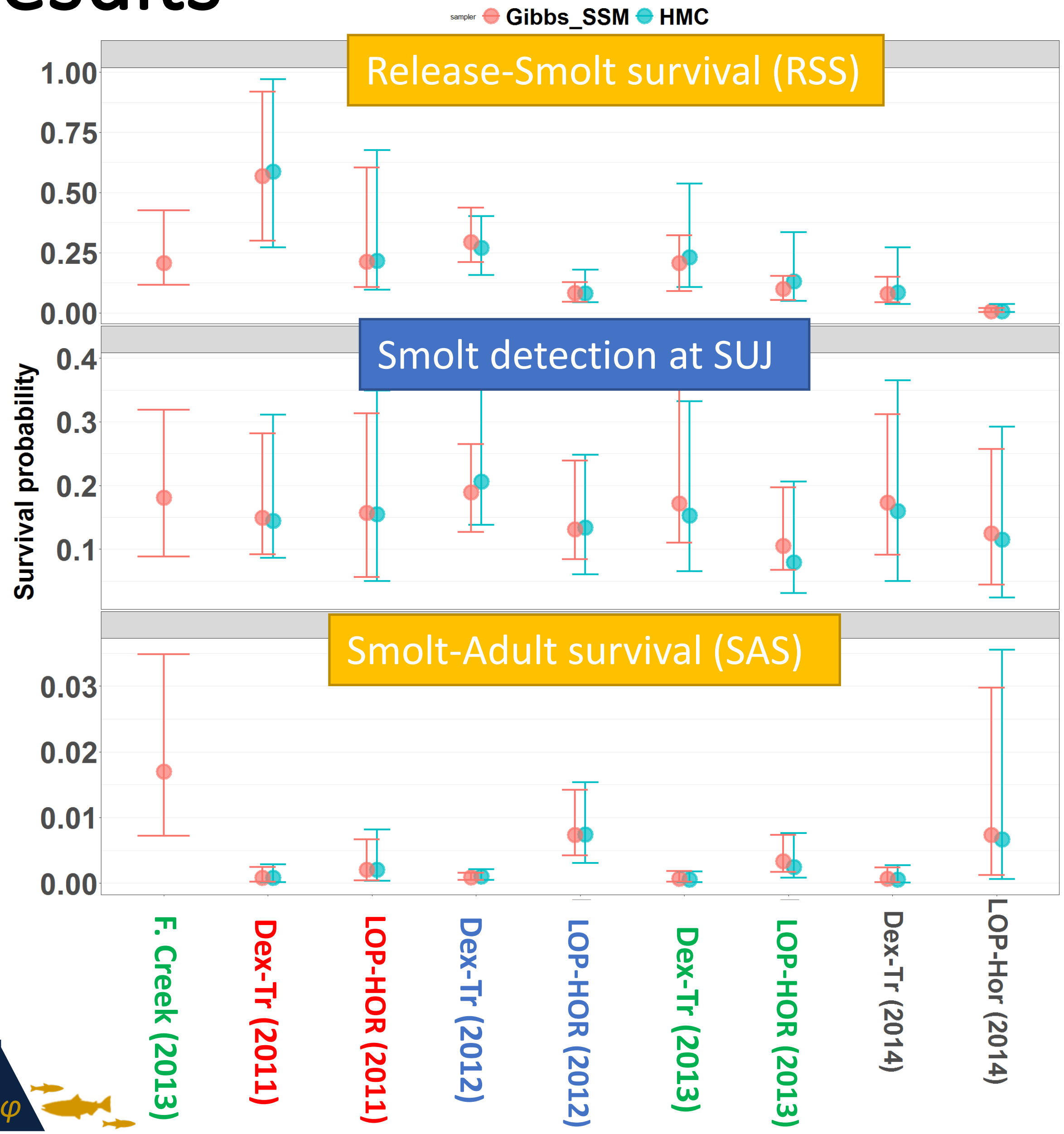
2. Results



- SSM Gibbs and HMC produced similar results but posteriors from the state-space model were typically more precise
- RSS at Dex-Tr is higher than at Lop-Hor
- The RSS at Fall Creek is comparable to fish released at Dex-Tr for 2013

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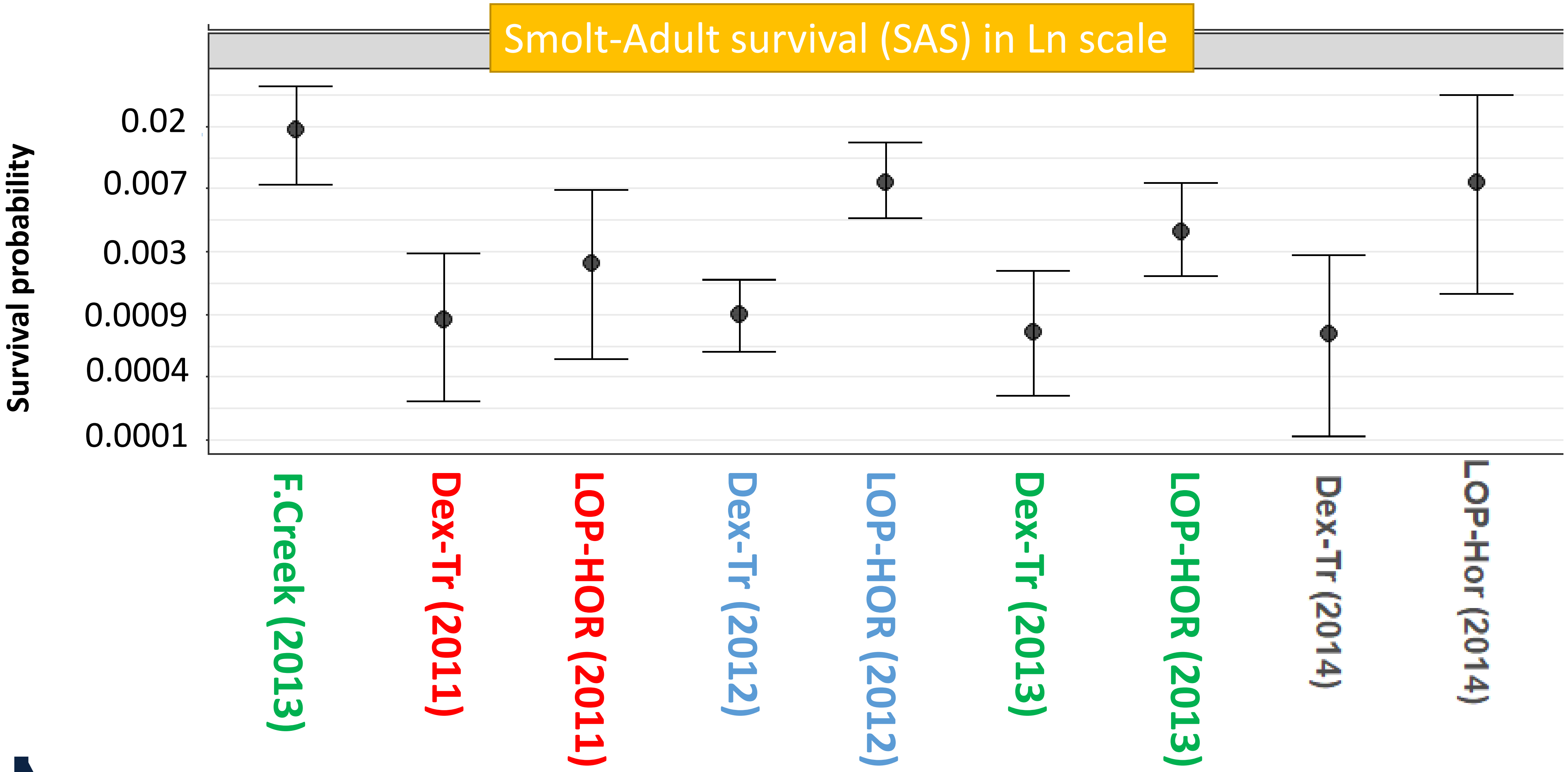
2. Results



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2. Discussion

- Fall Creek has self-sustainable chinook salmon population. The RSS and SAS likely reflect this situation

- The higher SAS at LOP could be explained by the longer time that smolts spend in
the reservoir before the outmigration (i.e., bigger fish have a better survival). This could explain
The higher SAS for Fall Creek.

- More refinements are needed for including tag loss and tag induced mortality rates in the CJS
estimates (Oliver Murray presentation for details)

- further analysis will include covariates to predict the effects of e.g., size, water temperature,
on stage-based survival rates

- Similarly, more refinements are need for the detection prior at SUJ (Tom Porteus’ presentation for details)

- Bayesian CJM estimation can be easily expanded to other river sub-basins.

Acknowledgments

- Oregon State Fish and Wildlife Department for its implementation of the paired release experiments and making the PIT tag data from them available for this study
  - Luke Whitman (ODFW) for helping to provide the data
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