DETECTING SALMON POPULATION RESPONSES TO CHANGES IN DAM PASSAGE IN THE UPPER WILLAMETTE RIVER (UWR)

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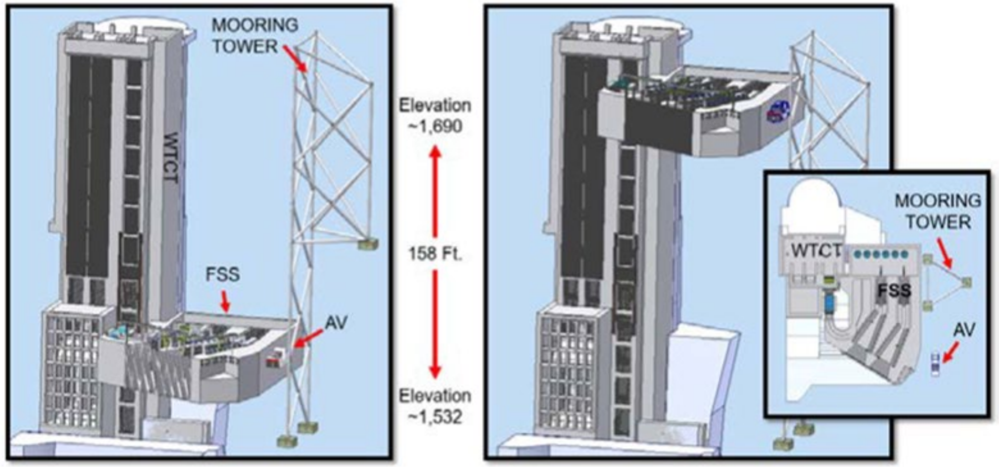


Monitoring of responses to Dam Passage Measures (DPMs) in Spring Chinook Salmon and Winter Steelhead in UWR

- ***With the recent implementation of interim DPMs, the USACE has been preparing to monitor fish population responses***
- ***Evaluation of effectiveness of DPMs within an Adaptive Management Framework***

Spring Chinook Salmon

- Fry, subyearling and yearling juvenile life history types
- N. Santiam, S. Santiam, McKenzie, Middle Fork Sub-basins

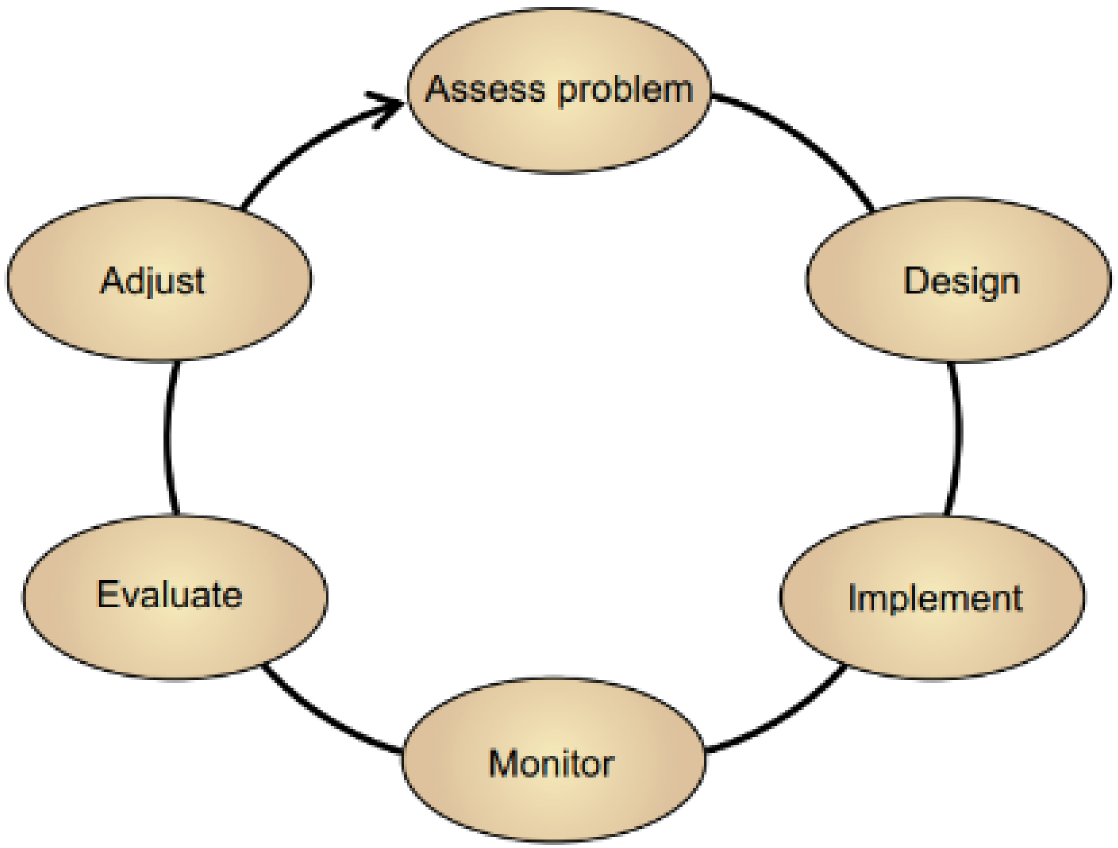
Winter Steelhead Trout

- Predominant juvenile life history smoltifies at age 2
- N. Santiam, S. Santiam Sub-basins

Annual Adaptive Management (AM) Framework

- **AM = Annual assessment and decisions for achieving goals and objectives given uncertainty**

1. ***Collect data on migratory fish population responses, many other variables***
2. ***Analyze the data to evaluate whether goals and objectives are being met with the implemented measures***
3. ***Decide whether to modify the measures based on the evaluation***



Williams 2009 Adaptive Management-The U.S. Department of the Interior Technical Guide

Performance metrics previously identified

1. **Injury rates of juveniles**
2. **Passage rates of juveniles**
3. **Survival rates of juveniles**
   - ***Route specific concrete survival rates***
     - ***Dam forebay to tailrace***
   - ***Reach-specific survival rates***

     e.g., Dam forebay to mainstem

Desired features of monitoring metrics

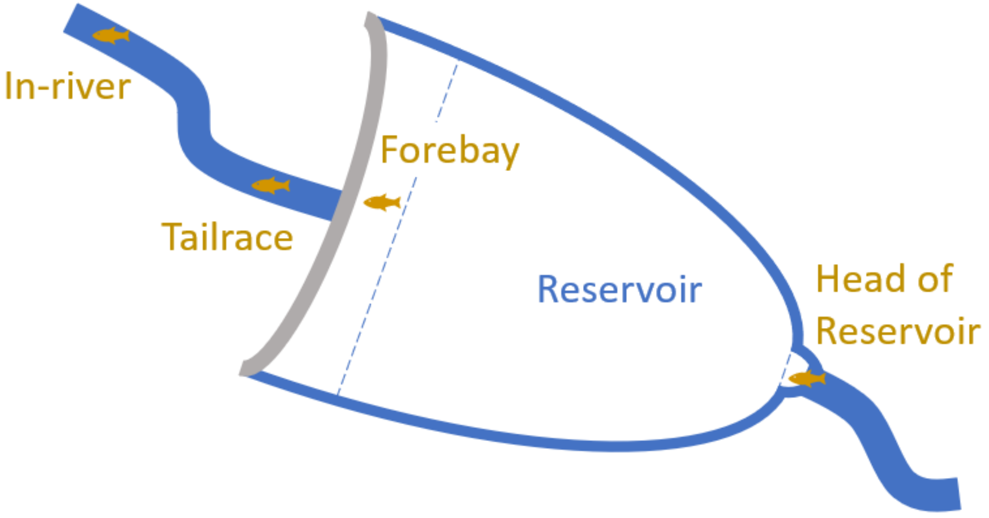
Metrics adopted for monitoring should

- **Give accurate and precise feedback on implemented measures**
- **Meet a desired level of precision considering**
  1. **The sampling error variance associated with the field sampling methods**
     - ***Assumptions of the methods of estimation (e.g., Skalski 2016)***
  2. **Uncontrolled sources of seasonal and interannual variation in the response variable**

     e.g., effects of seasonal and interannual differences in water-year type

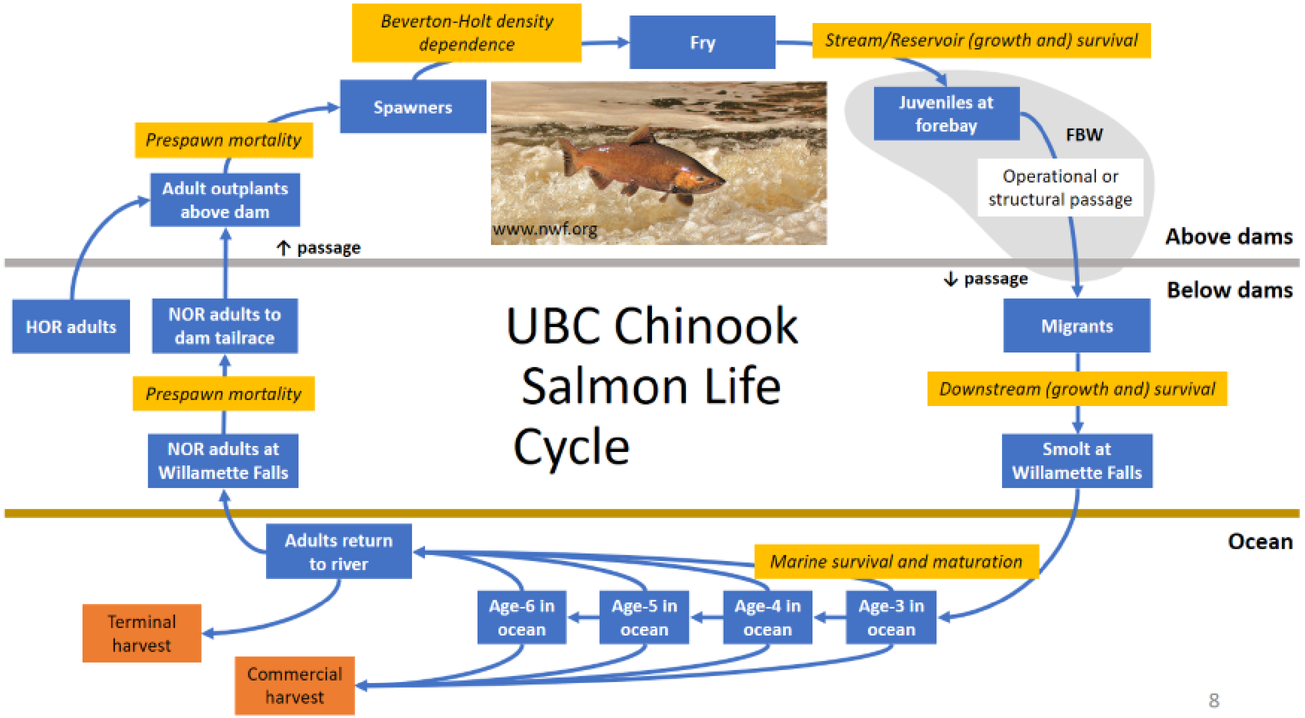
PTAGIS

Focus of talk



- **Two contrasting categories of population responses:**
  1. ***Survival rates at particular life stages at particular locations***
  2. ***Composite population response that may span more than one life stage***

     e.g., the cohort replacement rate (CRR)
- **How might candidate monitoring metrics perform in assessing population responses to a new passage measure?**



Questions addressed

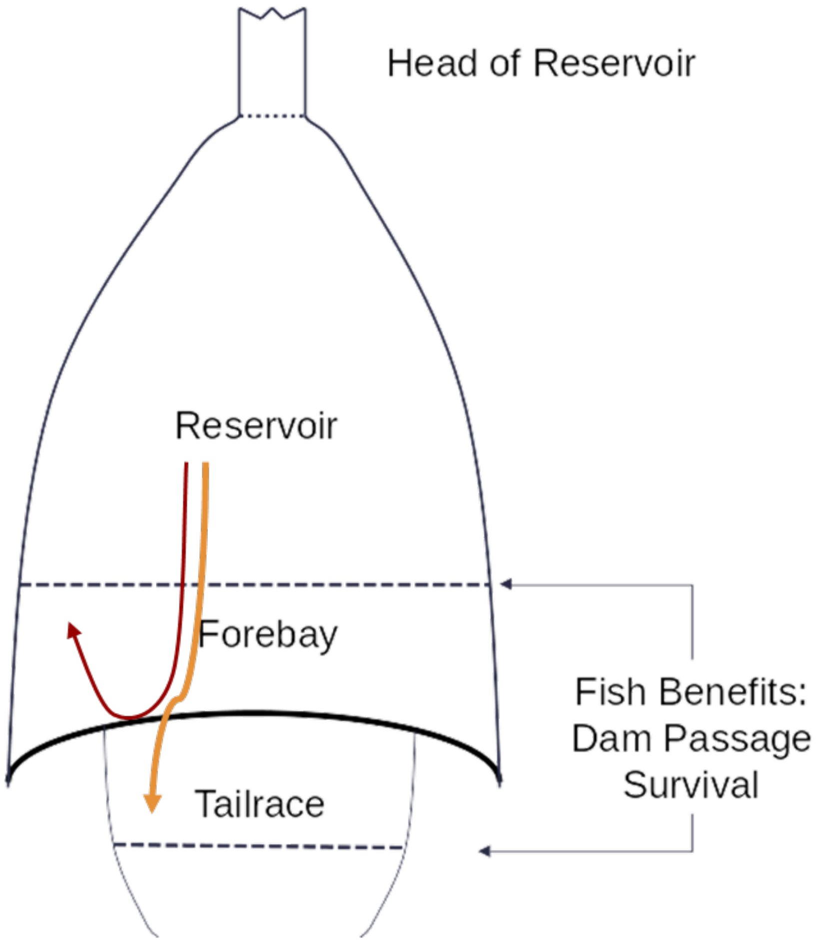
1. ***Considering the different sources of variance, what might be the precision in estimates of***
    - ***Stage-specific versus***
    - ***Composite population responses?***
2. ***Which population monitoring metrics could be most informative?***
3. ***Are there some candidate monitoring metrics may be too noisy?***
4. ***Could there be some new metrics that may be useful for adaptive management?***

Biological performance measures to consider in evaluating dam passage options

Dam passage metrics

1. *Efficiency at getting fish above the dam to pass through (DPE)*
2. *Survival rate of juveniles that pass through the dam (DPS)*
3. *DPE*DPS*

- ***By dam operation, species, juvenile stage, fish passage specifications, pool level, water year type, season***



USACE Portland (2012)

Dam Passage Efficiency and Passage Survival

- **Monitoring DPE and DPS offers to provide**
  - ***An initial proof of concept for the dam passage measure***
- **Active tag study estimates of DPE and DPS can be quite precise (Liss et al. 2020)**
- **Estimates can be quite variable depending on conditions for dam passage, e.g., water levels, flow conditions, route passed**

Pacific Northwest
NATIONAL LABORATORY

PNNL-29587

Evaluation of Foster Dam Juvenile Fish Passage, 2018

Final Report

January 2020

SA Liss
KR Znotinas
JS Hughes
BJ Bellgraph
CR Vernon
RA Harnish
ES Fischer
SE Blackburn

Table S.5. Estimated Route-Specific Survival for Study Fish during Each Project Study Period in 2015, 2016, and 2018. Survival was estima from Foster passage to the Primary Array, located ~19 rkm downstream, using the CJS model. Liss et al. (2020)

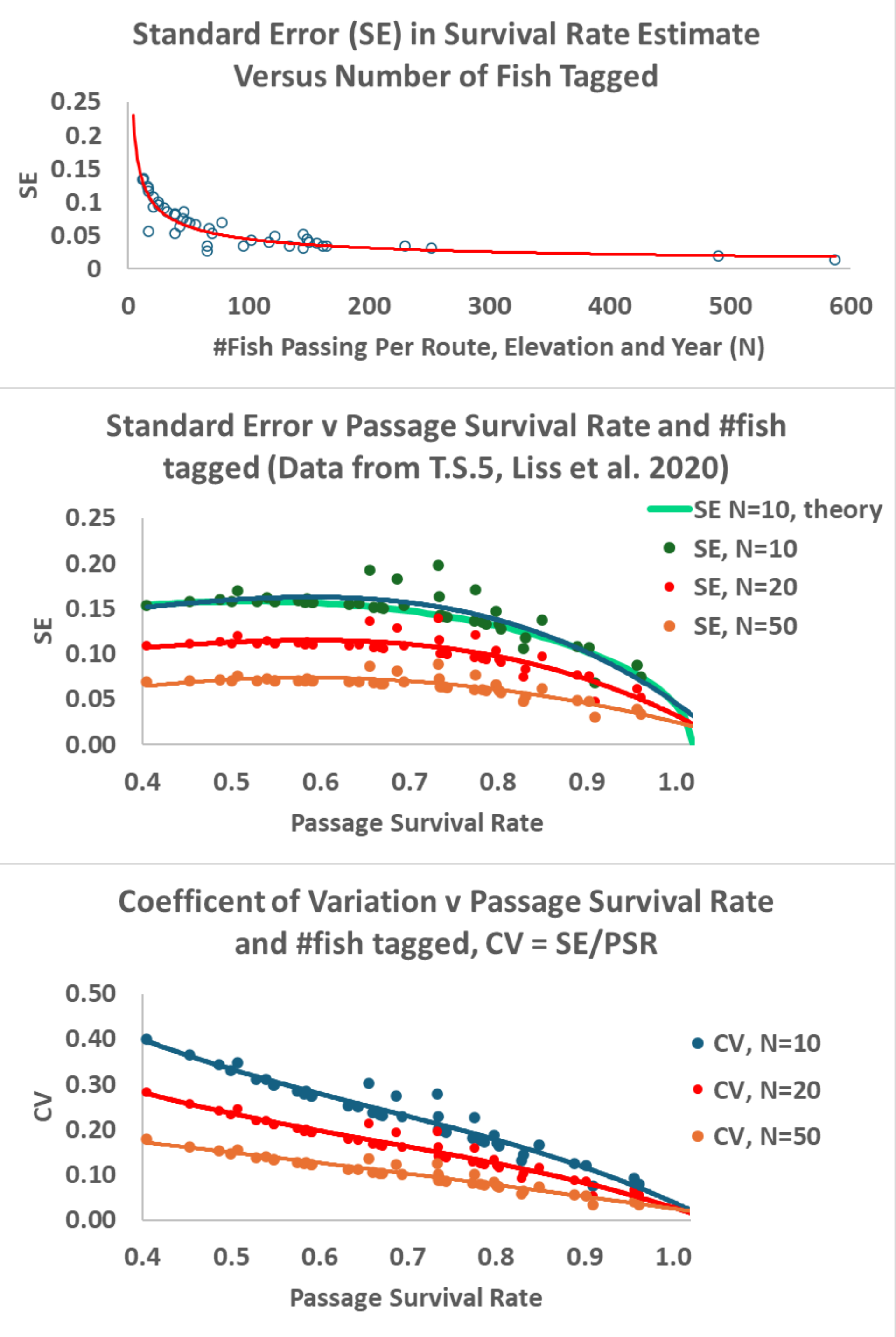
CH1	2015				2016				2018			
	Low Pool		High Pool		Low Pool		High Pool		Low Pool		High Pool	
Route	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)
Turbine Unit 1	149	0.487 (0.044)	2	*	51	0.529 (0.070)	8	*	25	0.480 (0.100)	–	–
Turbine Unit 2	–	–	–	–	49	0.571 (0.071)	3	*	17	0.529 (0.121)	1	*
Fish Weir	78	0.636 (0.069)	39	0.467 (0.081)[b]	12	0.778 (0.134)	72	0.809 (0.049)[a]	150	0.613 (0.040)	252	0.624 (0.031)[b]
Spill Bay 3	230	0.714 (0.034)	66	0.936 (0.034)	157	0.651 (0.038)	116	0.889 (0.029)	70	0.715 (0.054)	17	0.941 (0.057)
Spill Bay 2	–	–	–	–	–	–	–	–	–	–	21	0.762 (0.093)

STH2	2015				2016				2018			
	Low Pool		High Pool		Low Pool		High Pool		Low Pool		High Pool	
Route	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)
Turbine Unit 1	16	0.563 (0.124)	1	*	13	0.385 (0.135)	–	–	39	0.520 (0.082)	2	*
Turbine Unit 2	–	–	–	–	5	*	–	–	25	0.640 (0.096)	–	–
Fish Weir	46	0.667 (0.085)	145	0.713 (0.052)	30	0.433 (0.091)	139	0.811 (0.035)	67	0.509 (0.061)	102	0.829 (0.043)
Spill Bay 3	45	0.565 (0.076)	4	*	21	0.572 (0.108)	4	*	56	0.555 (0.067)	–	–
Spill Bay 2	–	–	–	–	–	–	–	–	17	0.648 (0.116)	1	*
Spill Bay 1	1	*	–	–	–	–	–	–	4	*	–	–

CH0	2015		2016		2018	
	Low Pool		Low Pool		Low Pool	
Route	*n*	S_1 (SE)	*n*	S_1 (SE)	*n*	S_1 (SE)
Turbine Unit 1	122	0.755 (0.049)	165	0.718 (0.035)	134	0.783 (0.036)
Turbine Unit 2	32	0.674 (0.086)	117	0.753 (0.040)	3	*
Fish Weir	96	0.869 (0.035)	43	0.767 (0.064)	236	0.818 (0.025)
Spill Bay 3	587	0.882 (0.014)[a]	490	0.781 (0.019)[b]	12	0.833 (0.108)[ab]
Spill Bay 2	15	1.001^{+} (0.107)[a]	162	0.723 (0.035)[b]	4	*

Precision in estimates of DPS from radio telemetry

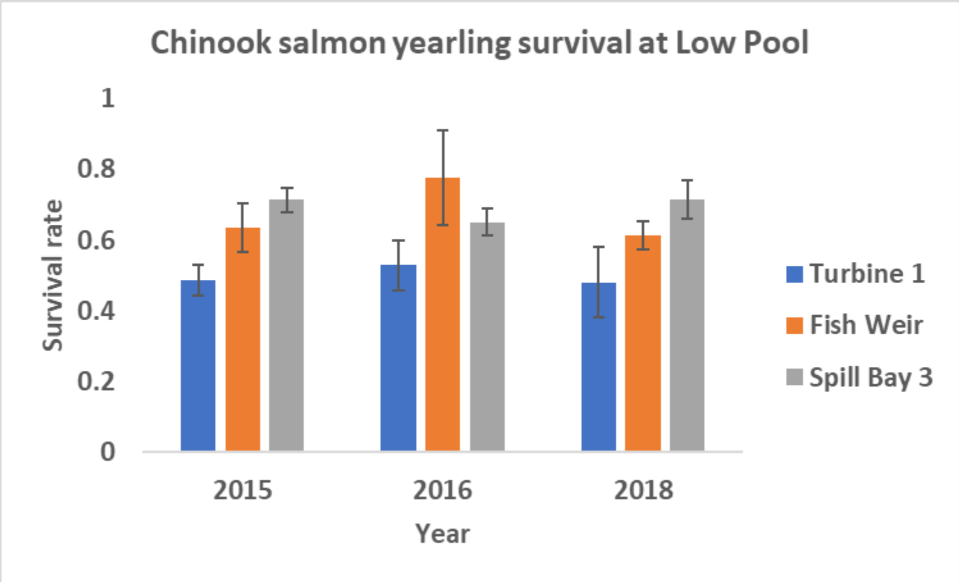
- **CJS estimates of passage survival at Foster Dam from Liss et al. (2020) Table S.5**
- **SE in estimates drops with increasing N**
- **Recomputed SEs, accounting for #fish passing per route, N, using SE = SD/√N**
- **Coefficient of Variation, CV = SE/estimate of passage survival**
- **Sample sizes (#fish passing/ route)**
  - **≤ 20 give CVs > 20%**
  - **≥ 50 give CVs ≤ 20%**

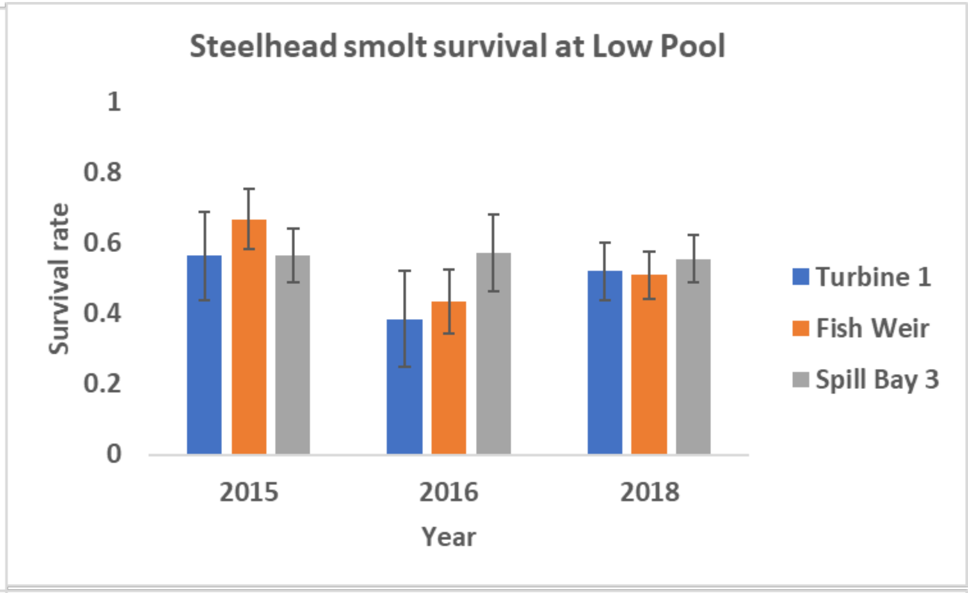


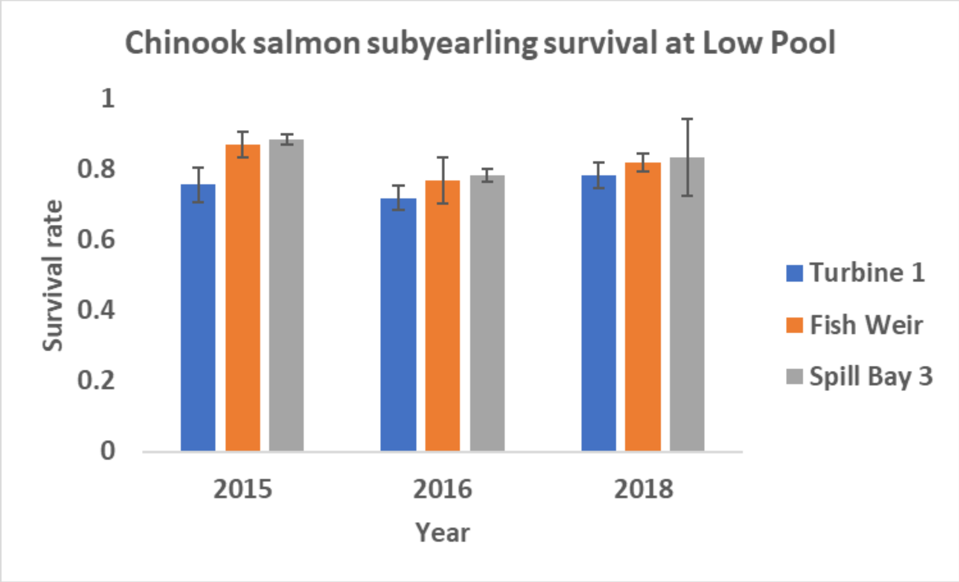
Between-year variation in route-specific survival rates

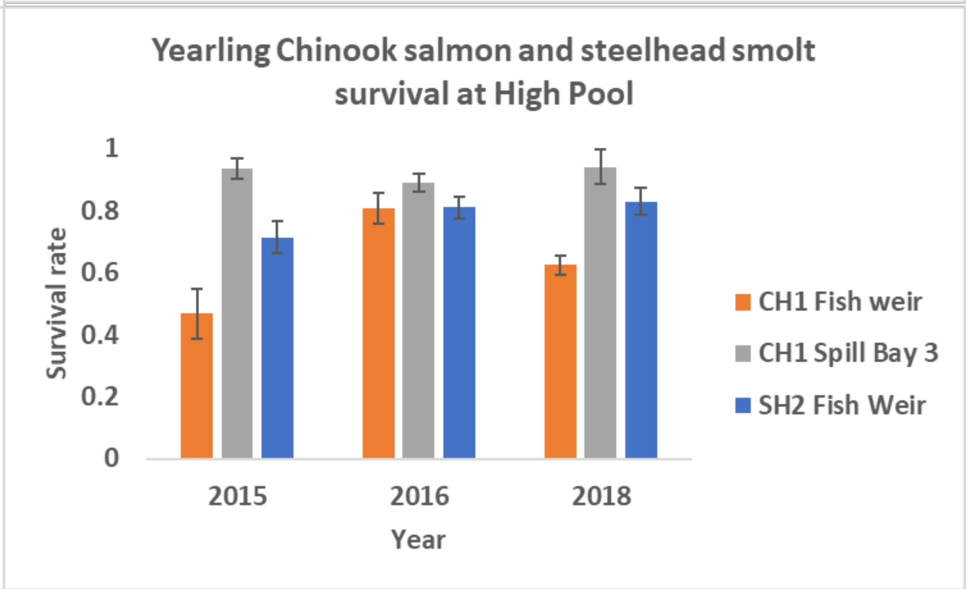
- **In some instances estimates consistent across years by route**
- **Route-specific survival can vary significantly between years depending on species, stage and pool level**

Liss et al. (2020)



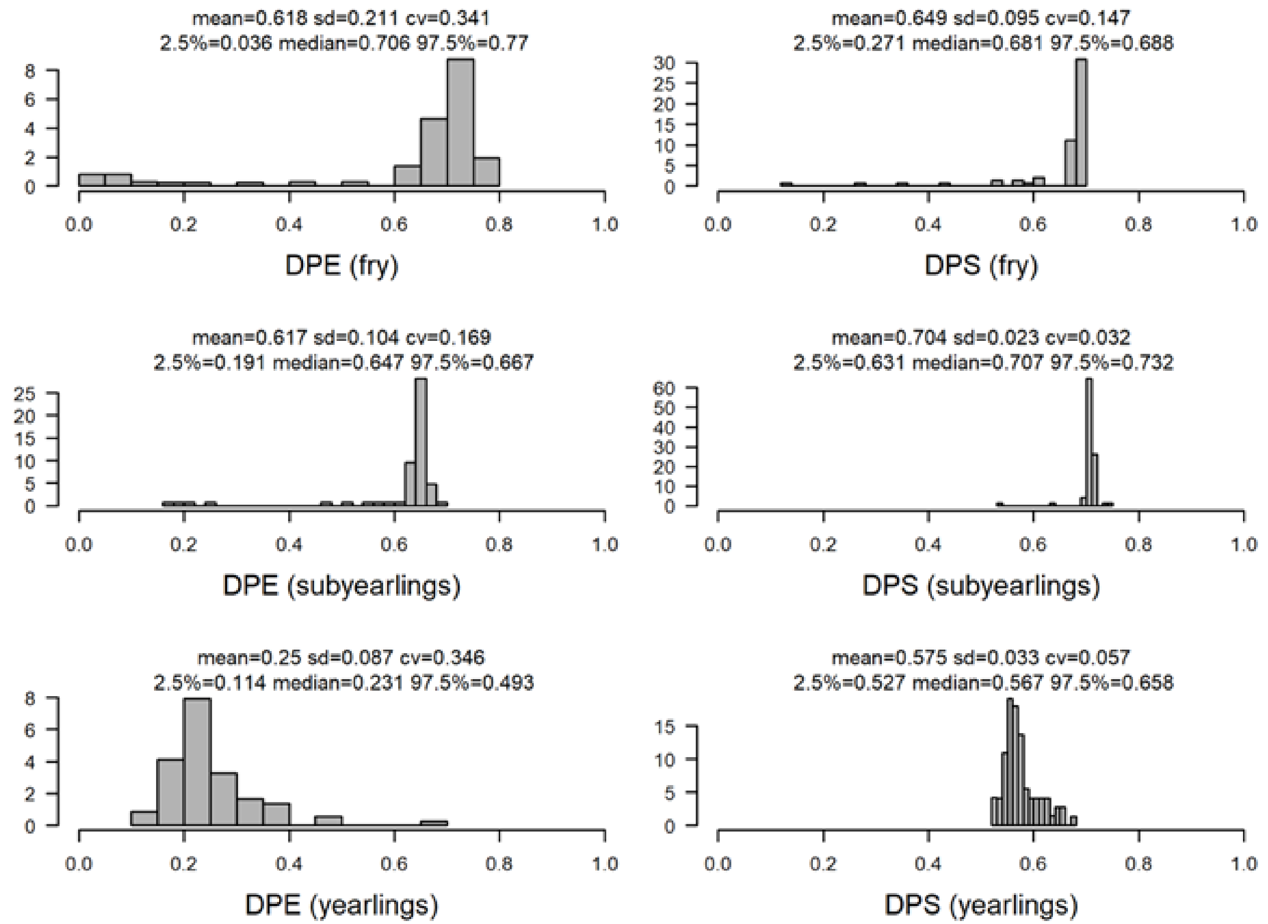






Density histograms of average annual DPE and DPS for spring Chinook salmon passing through the Detroit Dam under spring spill at Detroit and Big Cliff, and fall drawdown at Detroit

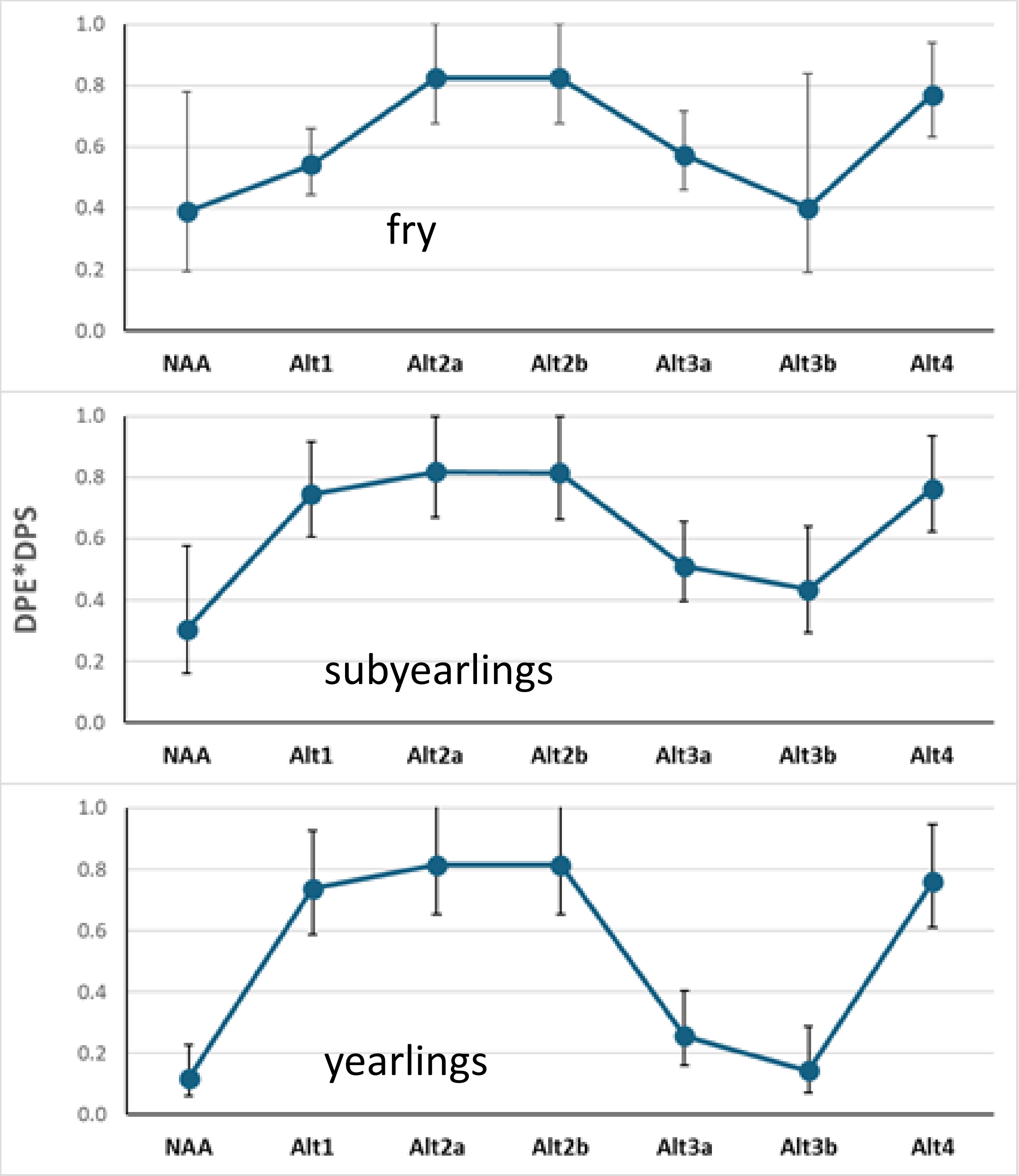
- **FBW runs using historical records of flow**
- **Average DPE and DPS can be quite variable from different flow conditions and reservoir pool levels between years**



(Fish Benefits Workbook (FBW) Corps 2012)

Prediction of 95% intervals in DPE*DPS in one year from both sampling error and variable conditions

- **For chinook salmon fry, subyearling and yearling migrants at the Detroit Dam**
- **Based on FBW runs in the EIS, and assuming sampling CV of 10% in estimates**
- **Potential for low precision in DPE*DPS estimates for fry and subyearlings under NAA and operational measures**
  - ***Due to variable flow conditions between year***

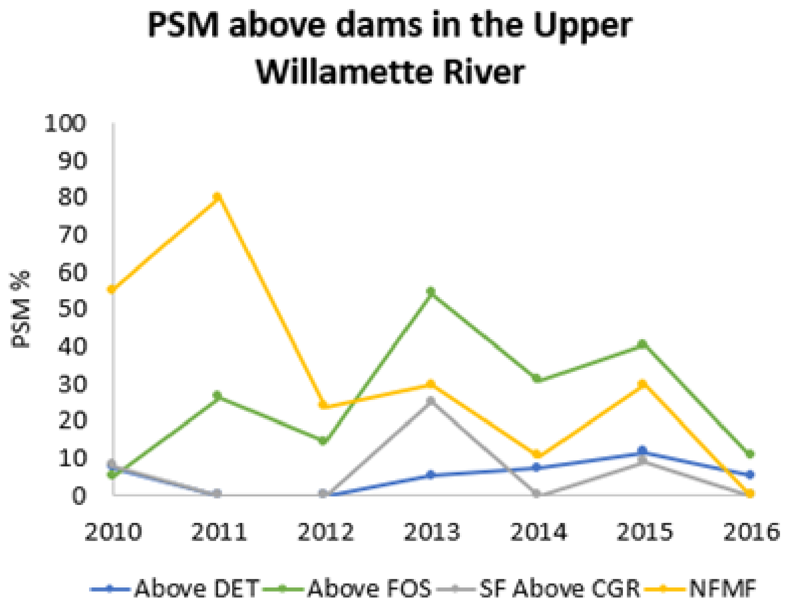


LCM simulation results from 2020 EIS, USACE

Monitoring Metrics for population responses at other life history stages

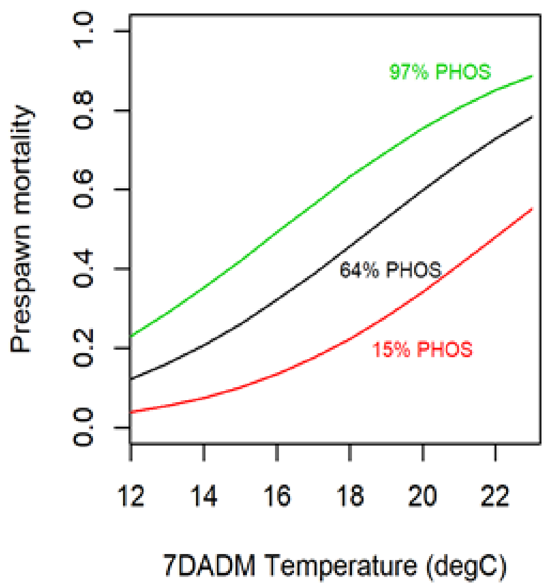
1. *In-reservoir survival rates of juveniles*
2. *Downstream of tail race survival rates of juveniles*
3. *Marine survival rates*
4. *Pre-spawn mortality rates (PSM) in returning adults*

- Responses can trade-off against each other
  - *Depending on measures implemented, e.g. spring surface spill and draw down*
    - *Juvenile DPE and DPS v. TDG mortality*
    - *Juvenile DPE and DPS v. Adult PSM*
  - *Can create challenges for assessing life-cycle wide responses*



Mean: 5% 26% 6% 35%

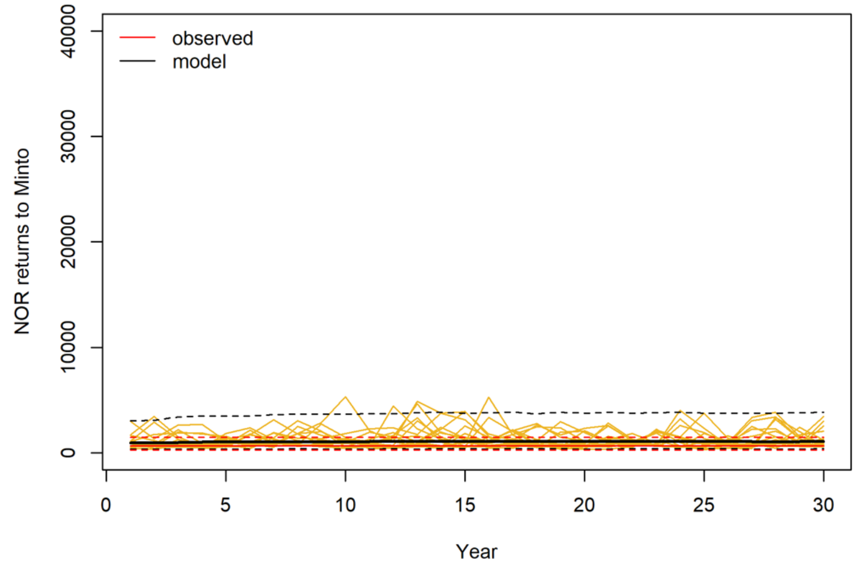
Source: Cannon et al. 2011; Sharpe et al. 2013, 2014, 2015, 2016, 2017



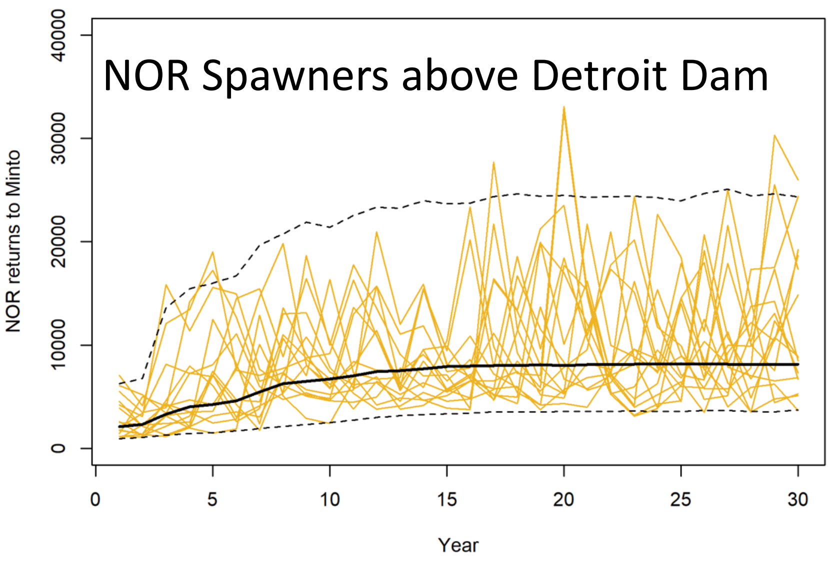
Measure	Flow year	Maximum 7DADM temperature (°C): 1 May - 2 Aug North Santiam (below Big Cliff)	South Santiam (below Foster)
No Action	High	18.7	19.5
	Normal	19.3	20.8
	Low	23.5	23.5
Structural	High	19.9	21.3
	Normal	22.1	23.5
	Low	22.5	24
Spring Spill + Fall Drawdown	High	19.2	19.7
	Normal	21.4	22.9
	Low	21	22.3
Spring Drawdown + Fall Drawdown	High	18.6	17.8
	Normal	24.5	24
	Low	25.8	25.3

Biological performance measures evaluated using Life Cycle Models (LCMs)

1. *Average long-term abundance of natural origin (NOR) spawners*
2. *Near-term population productivity*
3. *Long-term probability of quasi extinction (Prob NOR < Quasi Extinction Threshold or PQE)*
4. *Long-term juvenile life history diversity (Chinook salmon only)*

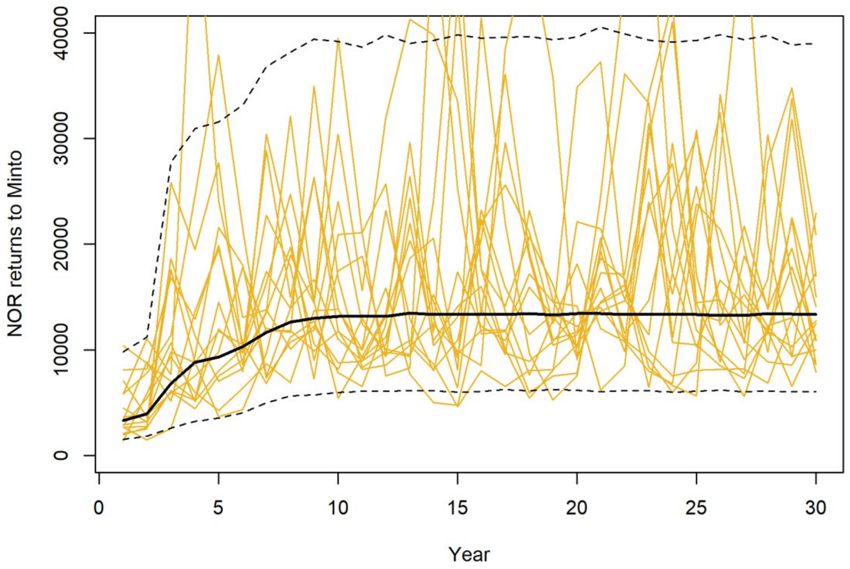


No change in dam passage



Spring, autumn drawdowns

- **8x No change**



Floating Screen Structure

- **13x No change**
- **1.65x drawdowns**

Examples of Performance Metrics (PMs) from the UBC LCM for spring Chinook salmon and winter steelhead: above dam populations

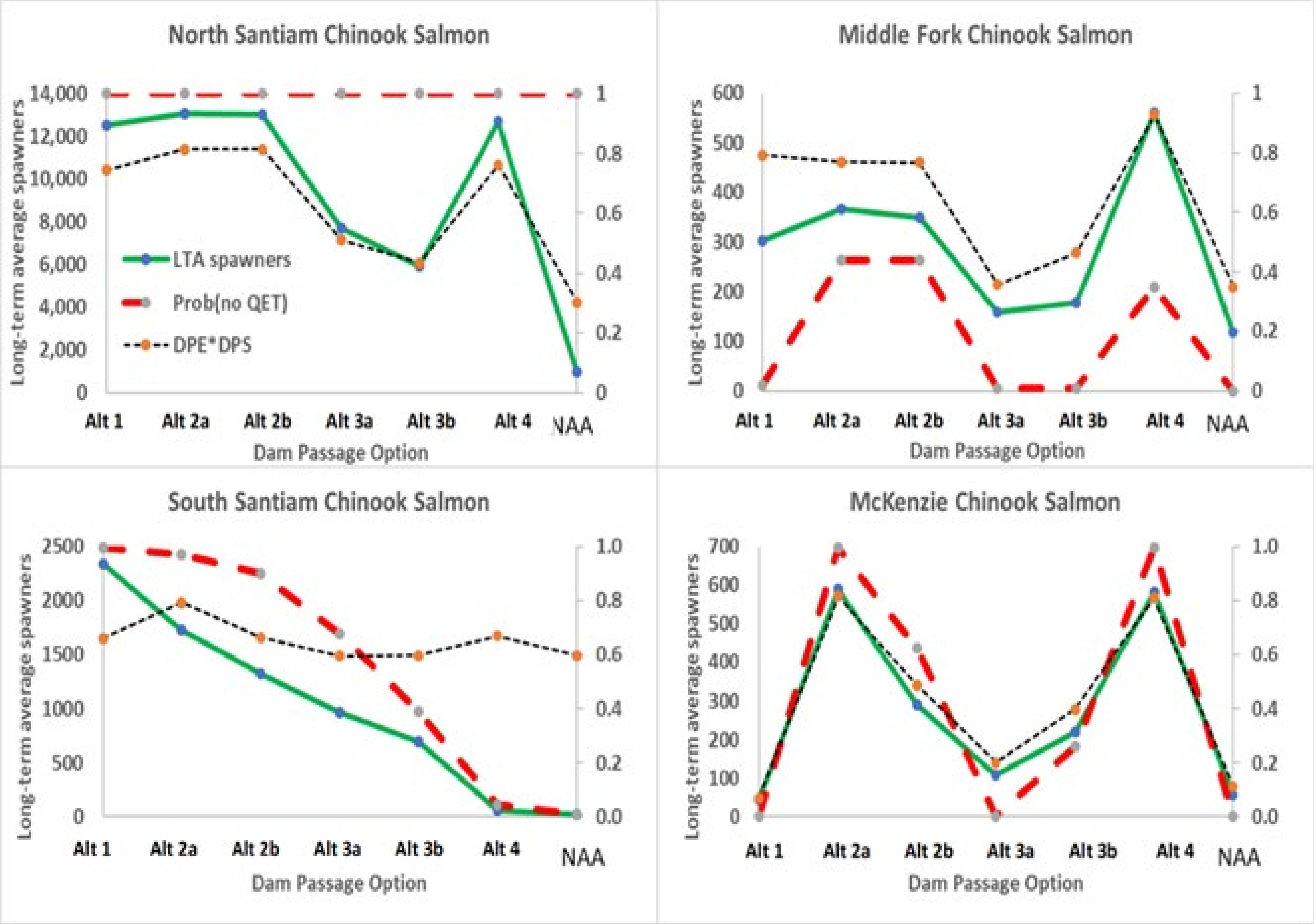
Performance Metric	Description	Statistic
Abundance	NOR spawners	Geometric mean of year 16-30
Productivity	R/S SAR Fry-smolt survival	Geometric mean of year 1-5 Mean of year 1-5 Mean of year 1-5
Extinction risk	P(NOR) < QET	4-yr mean, year 16-30

- ***Responses to a new DPM at different life stages in combination may determine both the short-term and long-term population responses***

R/S = Recruits-per-spawner; SAR = smolt-adult return rate, pHOS = proportion of hatchery-origin spawners; P(NOR) < QET = probability that NOR returns are less than the Quasi-Extinction Threshold (QET).

Population Performance Metrics for Spring Chinook Salmon

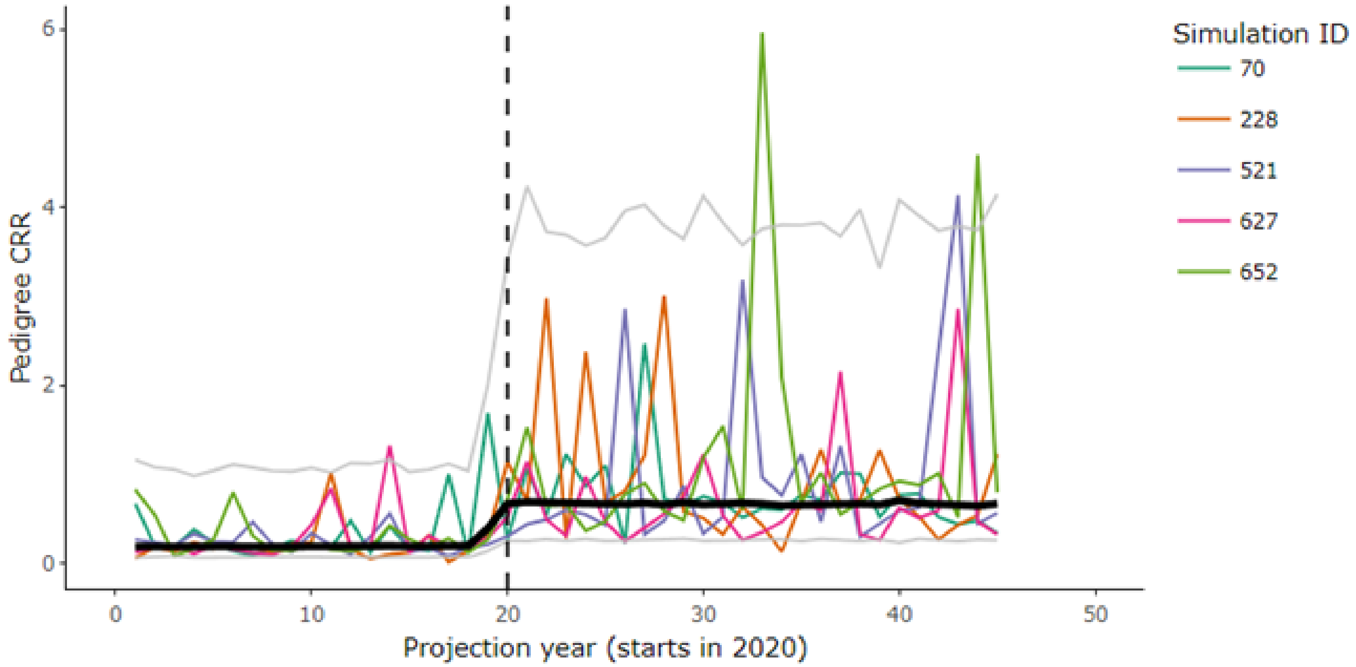
- <u>Acceptability</u> of a measure may differ for a given DPM depending on the performance metric
- <u>Ranking</u> of DPMs can depend on the performance metric
- **DPE*DPS cannot reliably predict long-term population outcomes**

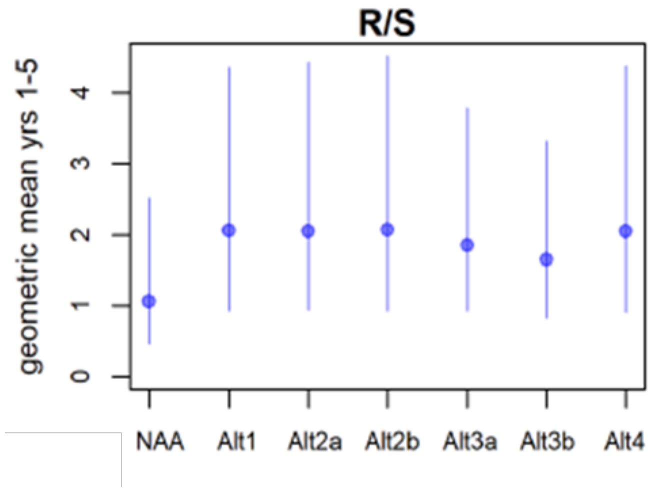


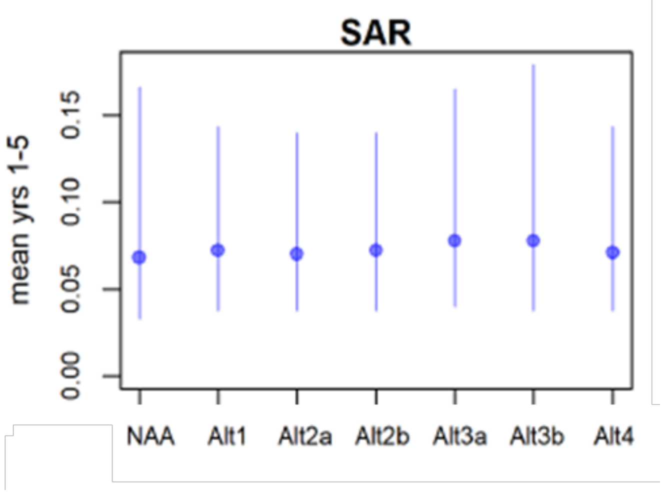
Which population metrics could be considered to be appropriate measures of a life cycle response?

Population metrics to measures a full life cycle response?

1. **Cohort Replacement Rate via Genetic Parentage/ Pedigree Analysis, CRRp**
   - ***Uses genetic samples from populations of spawners in each year (O'Malley et al 2015)***
   - ***Based on pedigree analysis of the resulting offspring that spawn in future years***
2. **CRR via recruits per spawner, $CRR_{R/S}$**
   - ***Direct count of number of recruits per spawner associated with each brood year***
   - ***Requires accurate***
     - ***Counts of the number of natural origin spawners in each year***
     - ***Age composition of spawners associated with each historical brood year***





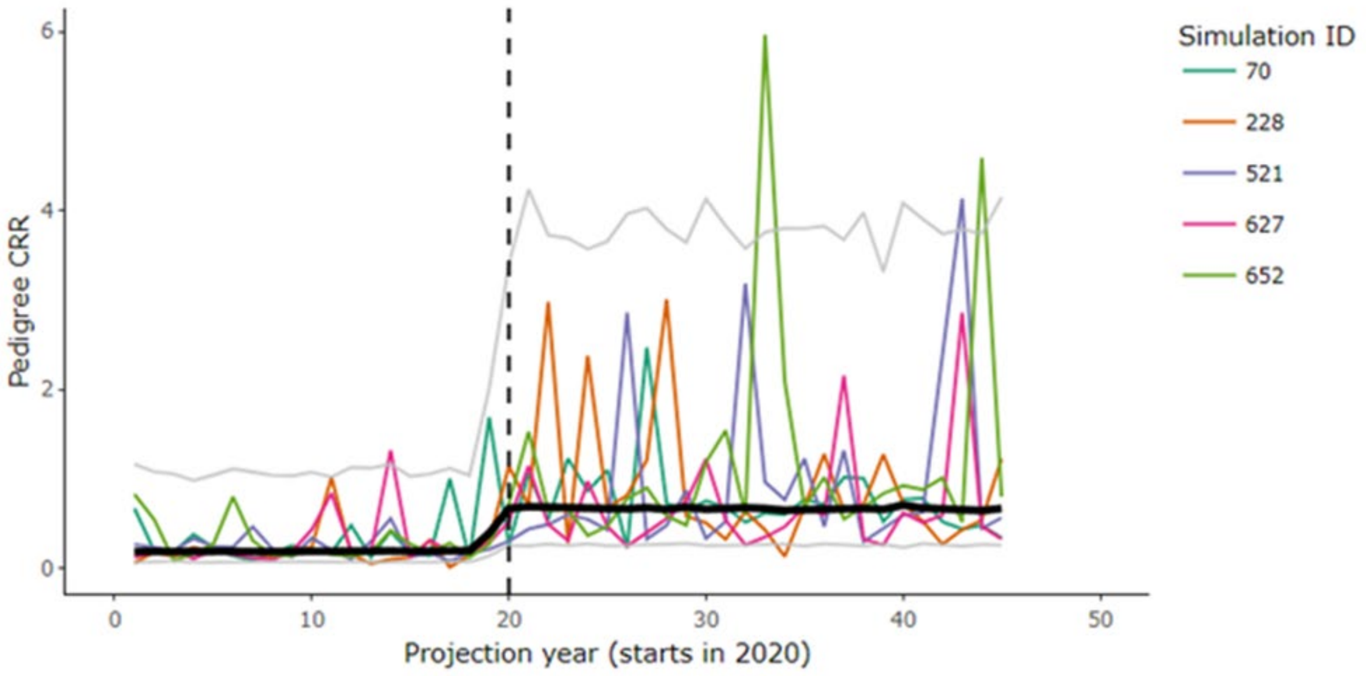


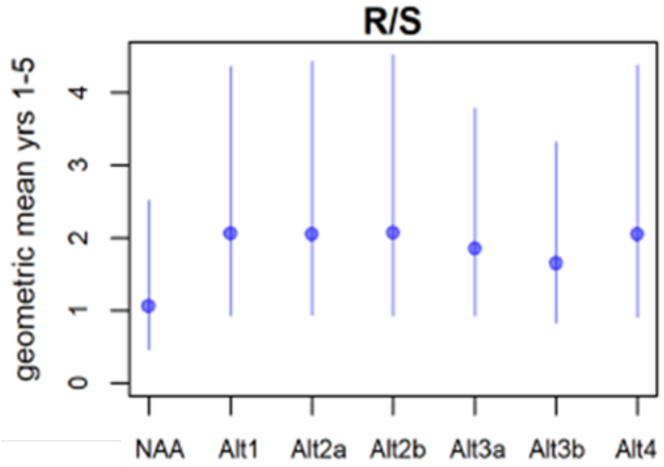
R/S = Recruits per spawner SAR = Smolt-Adult Return Rate

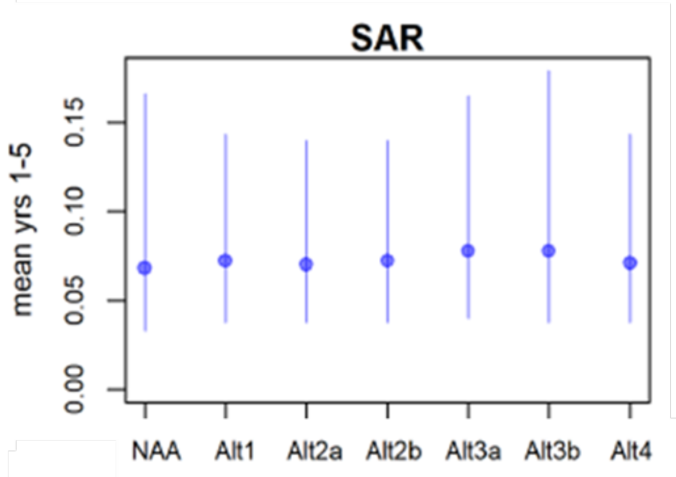
Results obtained from LCM simulations in 2022 EIS, USACE

Measures of CRR_p and $CRR_{R/S}$

- **Both contain full life-cycle responses**
- **Take a minimum of 5 years to compile before they could be used**
- **Interannual variability in both CRR metrics can be very high**
- **Major source of variance is in marine survival rates**
- **May not be possible to detect long-term average responses after many years of monitoring**
- **Too much error variability to allow reliable assessment of responses to DPMs**







Alternative composite performance metrics

Fry-smolt survival rate

- ***Composite measure of juvenile freshwater response to a DPM***
- ***Mean value from 5 years from LCM modeling moderately informative***
- ***Plots ignore measurement error***
- ***Radio telemetry possible, N >50 fish***

  where N is number of fish passing dam

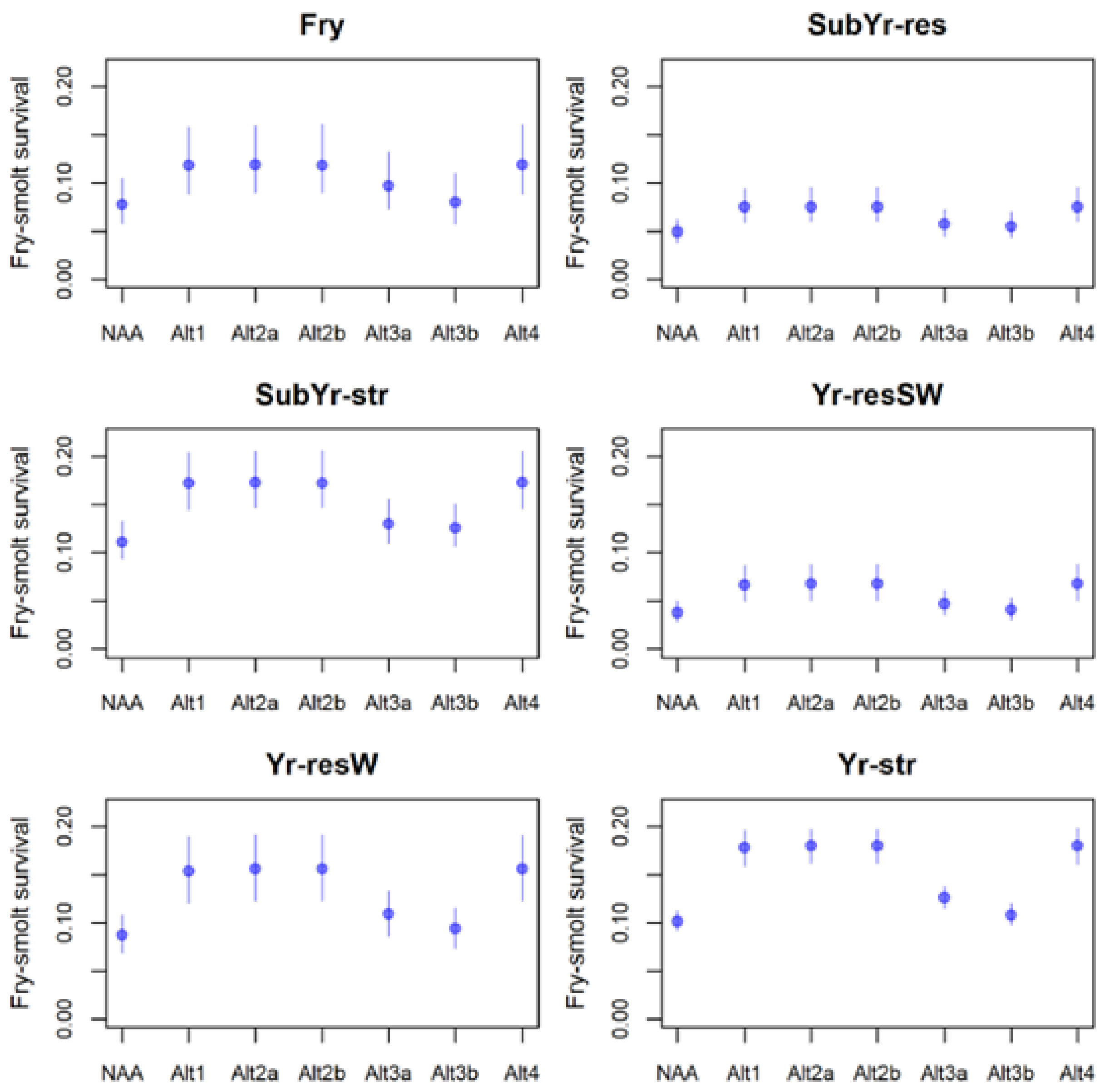


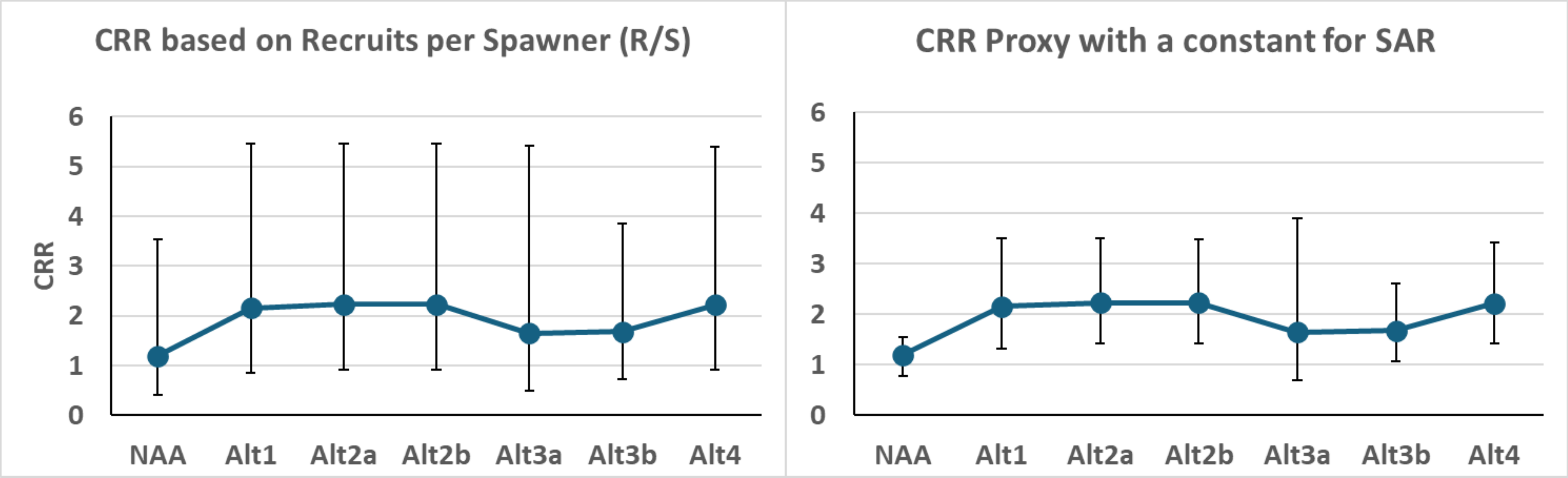
Figure 2.7.6. Fry to smolt survival for each juvenile migrant type under each EIS alternative. Calculated as the mean over years 1-5 of each simulation run. Median (circles) and 95% confidence intervals (lines) are from 10,000 simulation runs.

CRR Proxy, CRR_x

- **Excludes the variable marine survival rate component**

  CRR_x = LTA Fry Production * Fry-smolt survival * LTA marine survival * (1-PSM)

- **Uses**
  - ***A long-term average (LTA) fry production estimate (fixed value)***
  - ***Fry-smolt survival and PSM estimated from annual monitoring***
  - ***LTA marine survival rate estimate (fixed value)***
- **Could be assembled**
  - ***For all life history types or ones of particular interest***
  - ***From within year data, to give an immediate CRR_x by year***
    - ***Mean from 5 years could be moderately informative***



Summary

- **Need to consider both sampling error and interannual variability in monitoring metrics in evaluating usefulness of candidate monitoring metrics**
  - ***Active tags, acceptable precision with N≥50 fish passing / route***
  - ***Field studies using active tags and FBW modeling show moderate-large amounts of interannual variability in DPE and DPS particularly under operational DPMs***
- **Time frames of a few years may be required to establish effectiveness at anticipated levels of variability**

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Summary

- **Can be trade-offs in responses between different life history stages**
- **It may be appropriate to monitor and assess composite population responses to dam passage measures**
- **Cohort replacement rate metrics for spring Chinook salmon in the UWR will include high interannual variability**
  - **Would make it difficult to use CRRs to evaluate responses to DPMs**

Summary

- **Identified composite performance metrics that could inform about the overall effectiveness of dam passage measures**
  - ***Fry-to-smolt survival rates***
  - ***CRR proxies that use a long-term average value for marine survival rate***
- **These offer to provide informative and timely measures of population responses**
- **Further research is needed to identify**
  - ***Additional performance metrics***
  - ***Suitable field sampling methods for them***
  - ***Statistical methods to appropriately estimate different performance metrics***

Acknowledgments

- **Oregon State Fish and Wildlife Department for its implementation of the paired release experiments and Beach Seine study 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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- **Rich Piaskowski and Rachel Liard**

Dam passage measures in the Upper Willamette River

- **Improvements to dam passage have been required to facilitate recovery of ESA listed spring Chinook salmon (*Oncorhynchus tshawytscha*) and winter steelhead (*O. mykiss*) populations in the UWR**

		Alternative Sets of Dam Passage Measures						
Sub-basin	Dam	NAA	Alt 1	Alt2a	Alt2b	Alt3a	Alt3b	Alt4
North Santiam	DET		FSS	FSS	FSS	SD FD	SS FD	FSS
	BCL		Collect at DET	Collect at DET	Collect at DET	SS	SS	Collect at DET
South Santiam	FOS		MW	MW	MW			MW
	GPR		FSS	SS FD	SS FD	SS FD	SD FD	
McKenzie	CGR			FSS	SD (DT) FD (DT)	SD FD	SD (DT) FD (DT)	FSS
Middle Fork	LOP		FSS	FSC	FSC	SD FD	SS FD	FSS
	DEX					SS	SS	
	HCR					SS FD	SD FD	FSC

NAA=no action alternative, Alt=alternative, FSS=Floating Screen Structure, FSC=Floating Surface Collector, MW=Modified Fish Weir, SS=Spring Spill, SD=Spring Drawdown, FD=Fall Drawdown. Drawdowns to regulating outlets (RO) unless diversion tunnel (DT) specified. DET = Detroit, BCL = Big Cliff, FOS = Foster, GPR = Green Peter, CGR = Cougar, LOP = Lookout Point, DEX = Dexter, HCR = Hills Creek