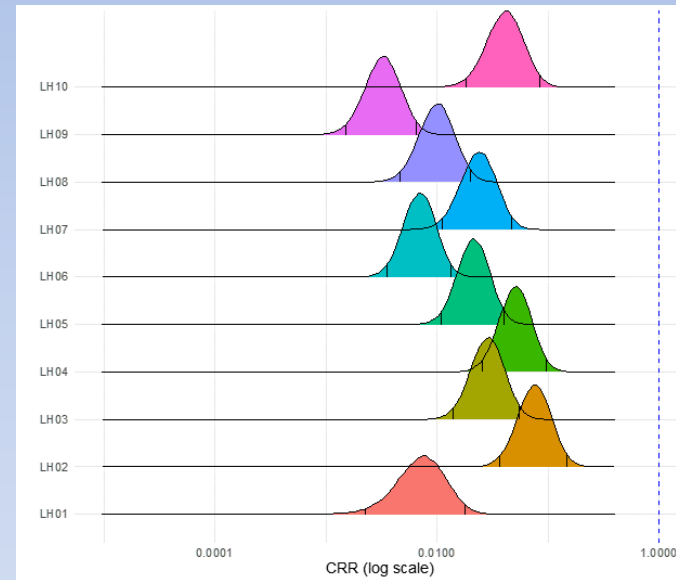
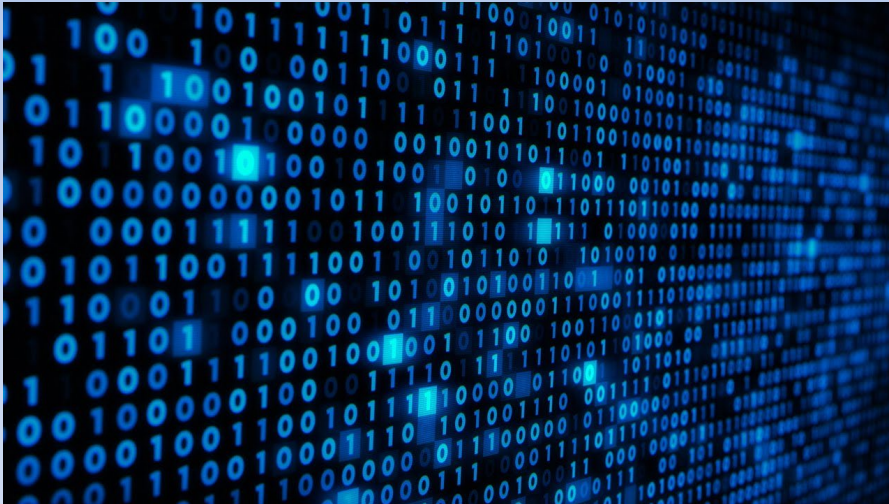


# Decision support modeling for outplanting adult Chinook salmon in the Santiam River basin



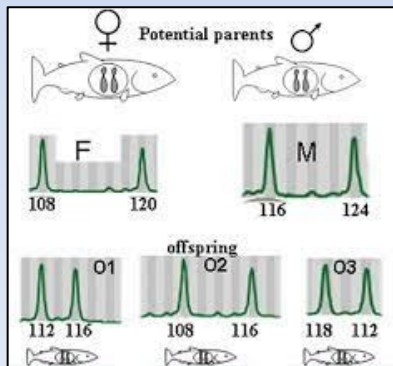
**M. Keefer, M. Yuksel, and C. Caudill**

**Department of Fish and Wildlife Sciences  
University of Idaho**



# Research Context

- 1) Adult Trap & Haul, Outplanting
- 2) Prespawn Mortality (PSM)
- 3) Juvenile Life History Pathways
- 4) Cohort Replacement Rate (CRR)
  - Genetic Pedigree / Parentage Projects
  - **Statistical Modeling of CRR**

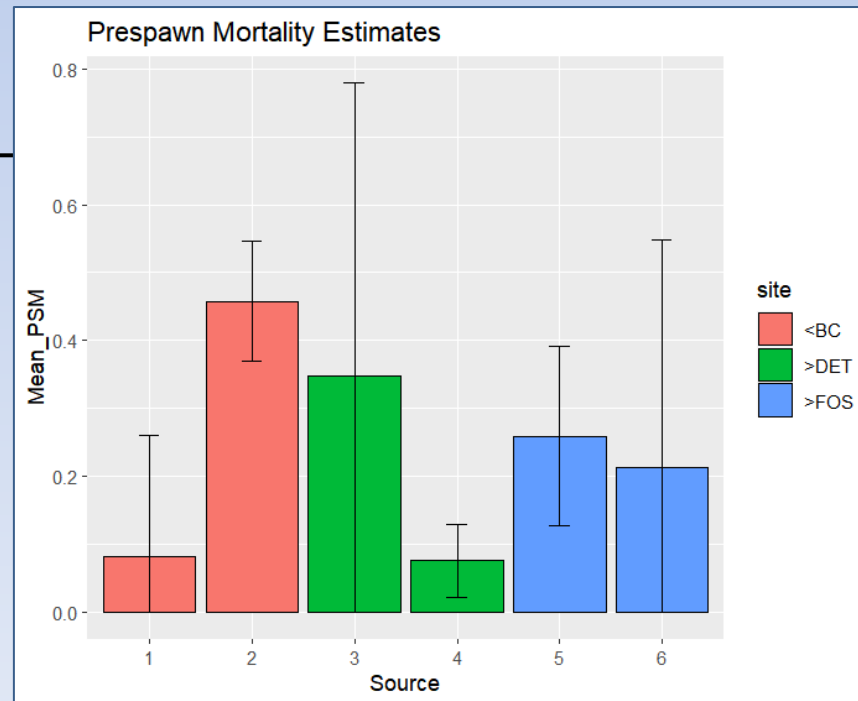
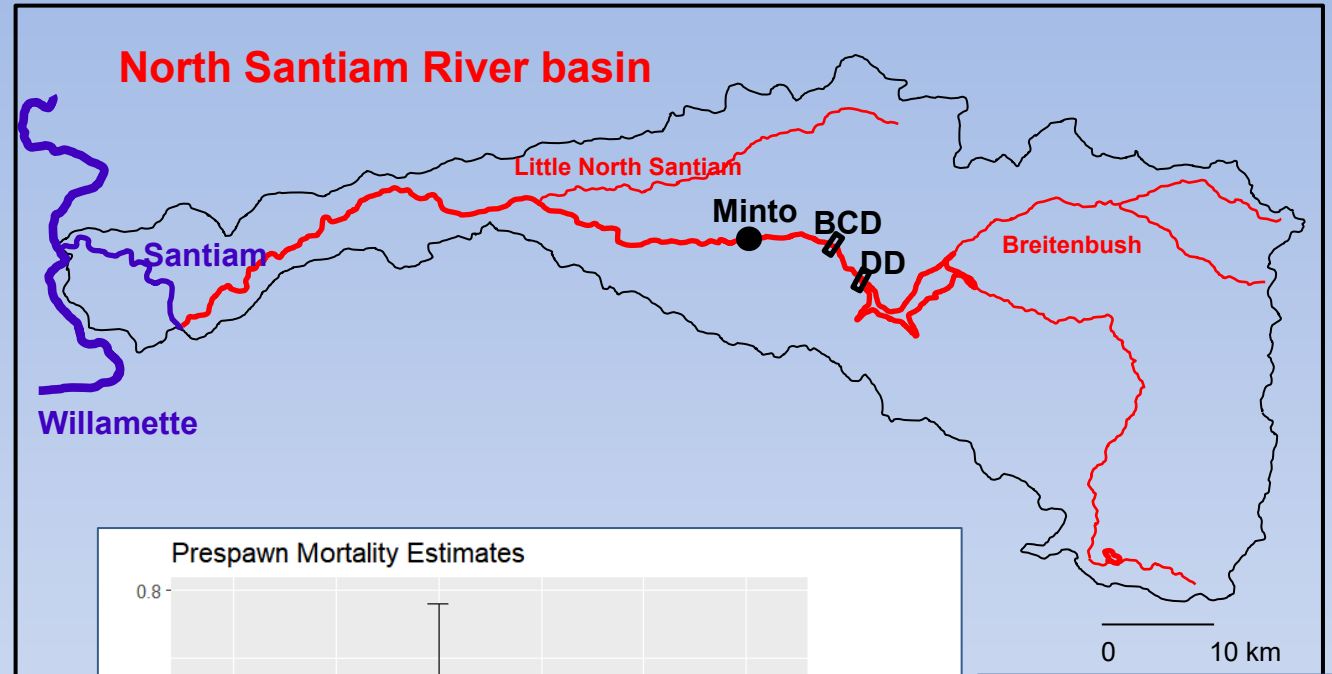


Wiley



# Adult Outplanting & PSM

- NSAN: From Minto
- SSAN: From Foster
- PSM

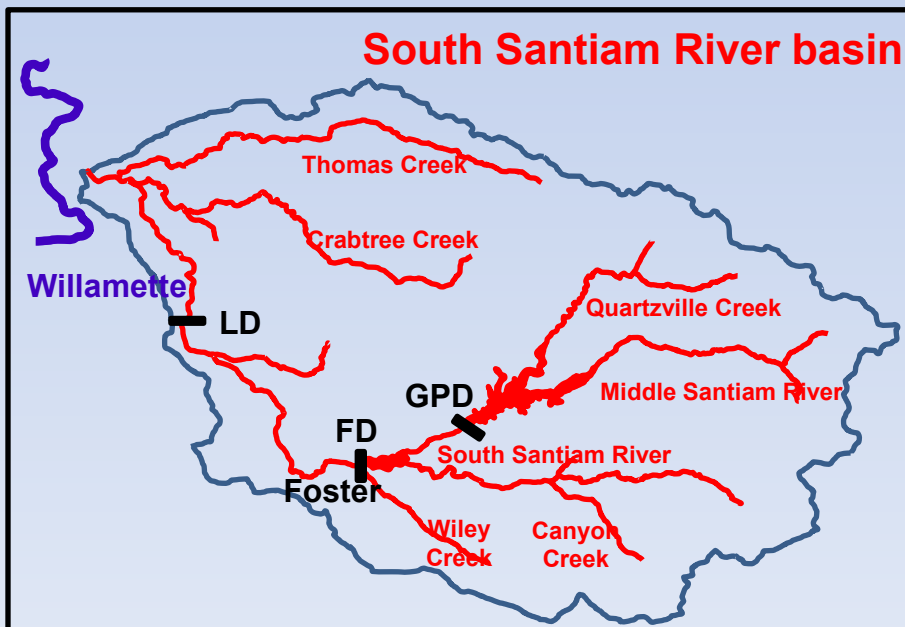


1,3: ODFW\_OWCS database

2,4: C. Sharpe, ODFW *pers comm*

5: Naughton et al. (2023); NAJFM

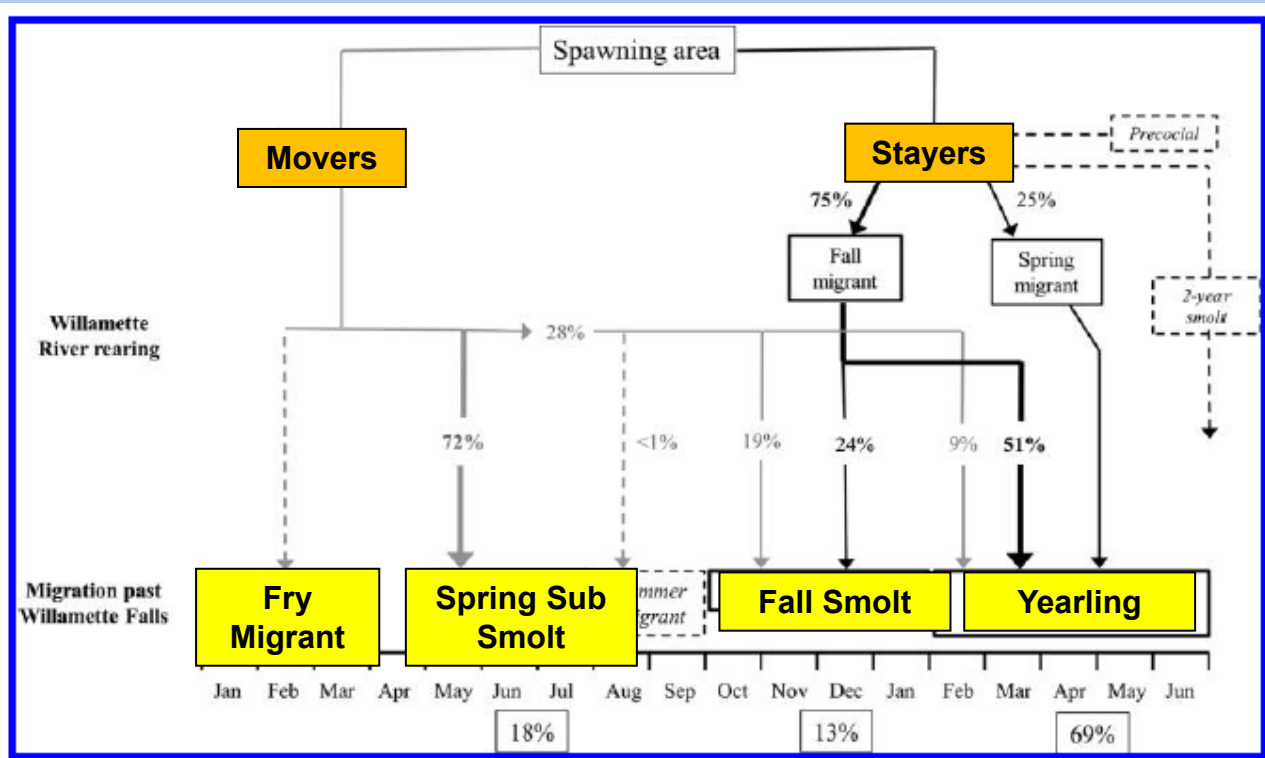
6: DeWeber et al. (2017); NAJFM



# Juvenile Chinook Life History Pathways

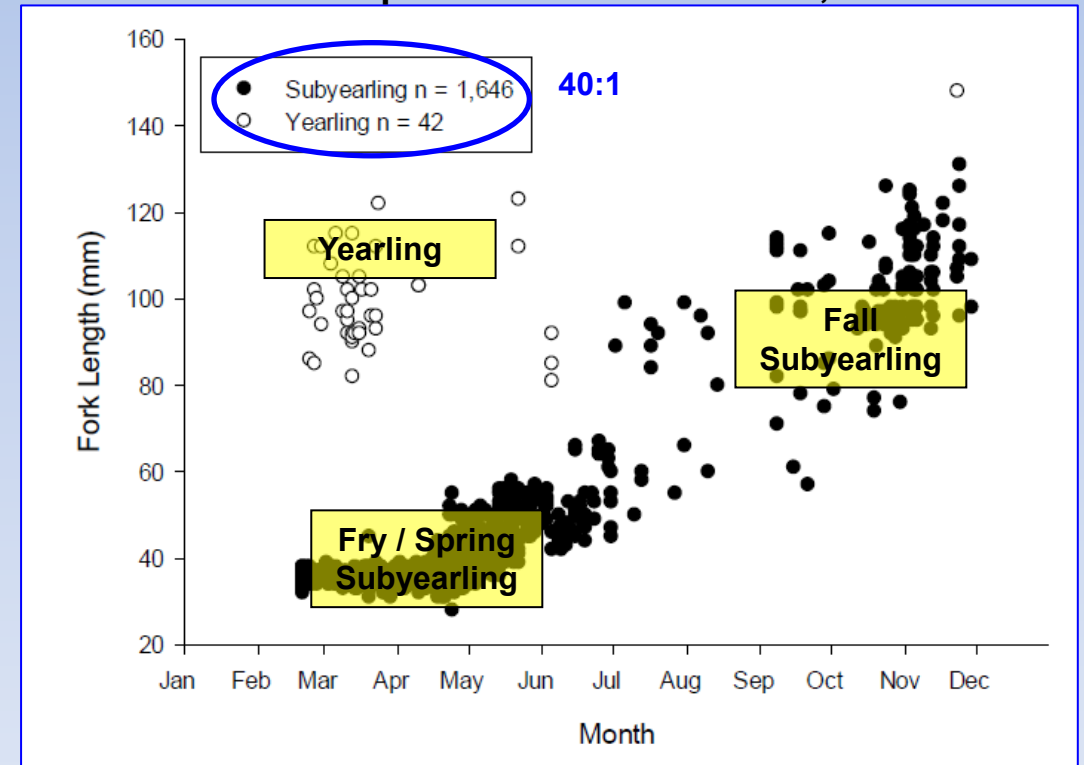
- Willamette Population Is Uniquely Diverse

McKenzie River Juvenile Chinook



Schroeder et al. (2016); CJFAS

Screw trap above Detroit reservoir, 2015



Romer et al. (2016); ODFW

# CRR Model of North Santiam Pathways

- A Continuum of LH Expression Would Be Ideal
  - Model Is A Necessary Simplification
- We Identified 13 Pathways, Primarily from SLAM
  - **Species Life-cycle Analysis Modules** (NOAA, 2015)

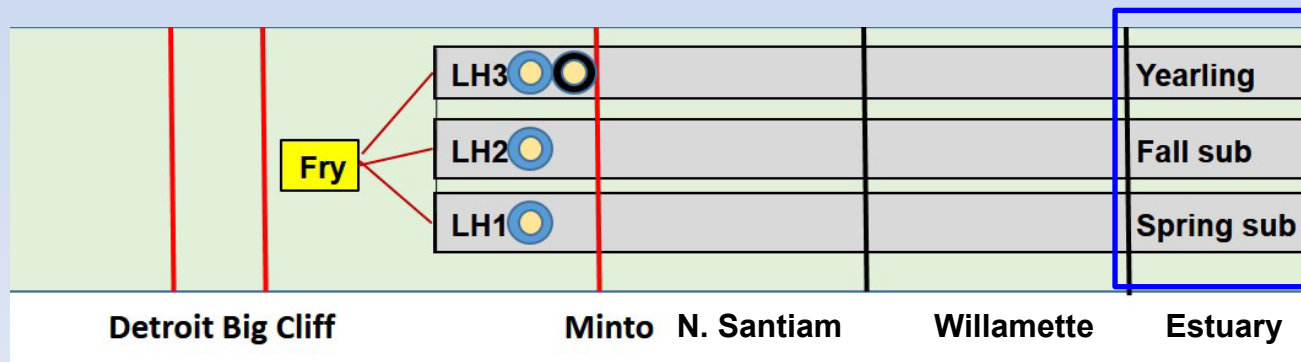
# North Santiam Pathways: Below Big Cliff Dam

- 3 juvenile Life History Pathways
  - LH1: Spring Subyearling Migrant
  - LH2: Fall Subyearling Migrant
  - LH3: Yearling Migrant



Native Fish Society

Simplification: 'Stayers'



Migrant Ages

# North Santiam pathways: above Detroit Dam

- 10 juvenile Life History Pathways
  - 6 Yearling, 3 Fall Subyearling, 1 Spring Subyearling



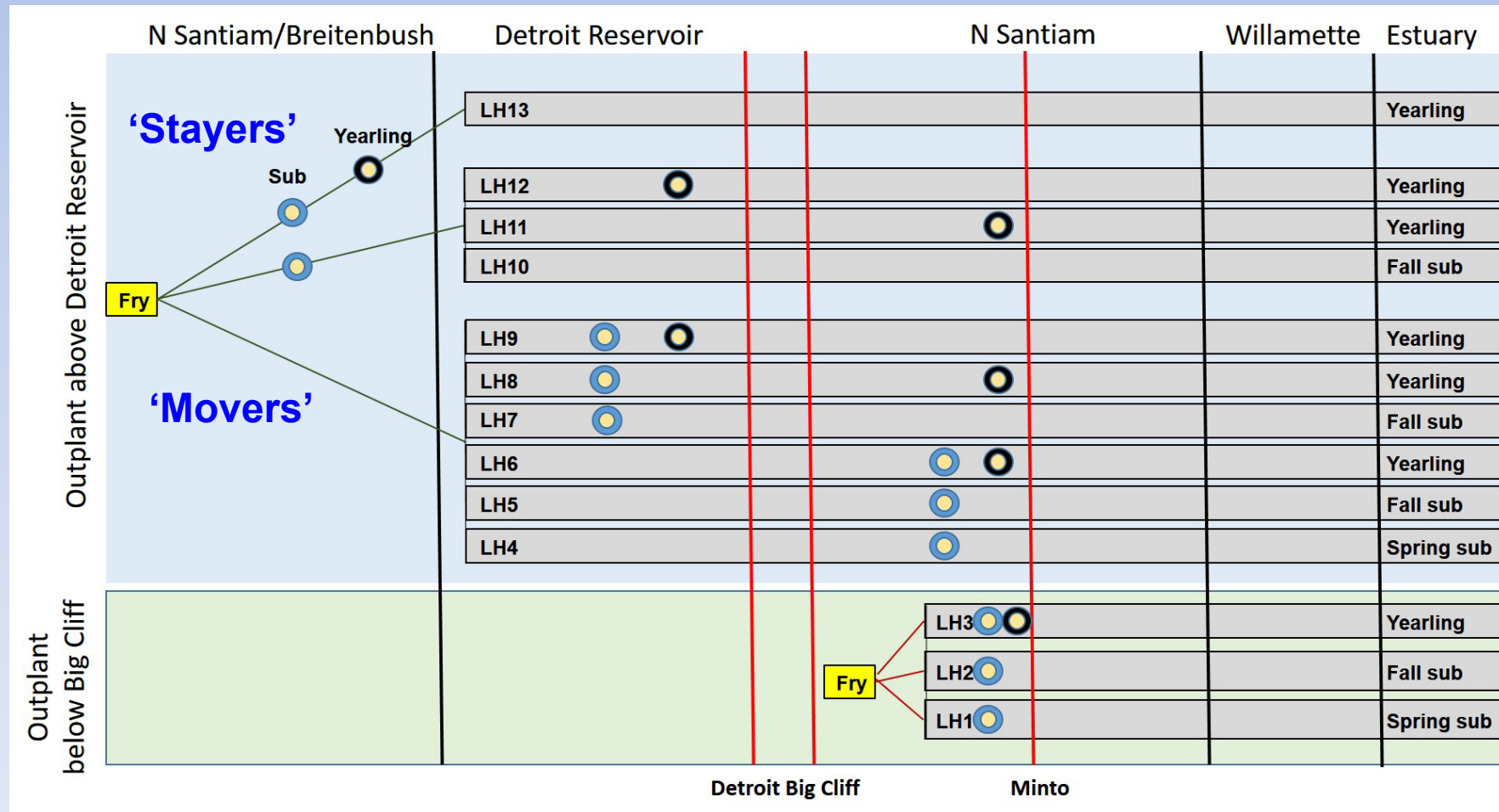
Breitenbush River



N Santiam River (USGS)



Detroit Dam & reservoir (OPB)



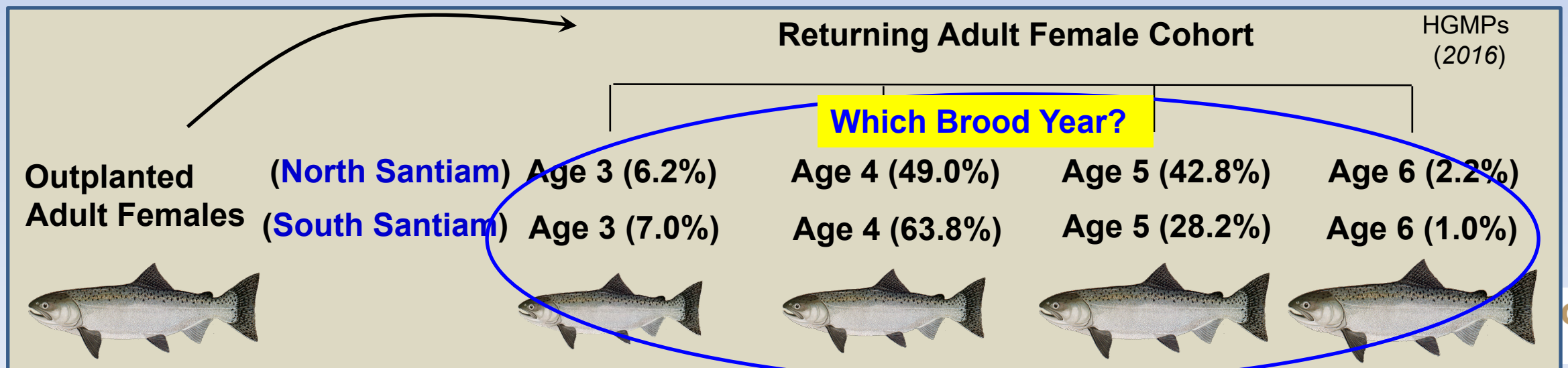
# Where/When should adult Chinook be outplanted?

- Limited Numbers of Available Adults (+ Rules)
- PSM Is a Significant Risk Factor in Some Years / Locations
- Some Juvenile Life History Pathways More Successful
  - Large Variation in Habitat Quality
  - Reservoirs and Dams Present Substantial Risks

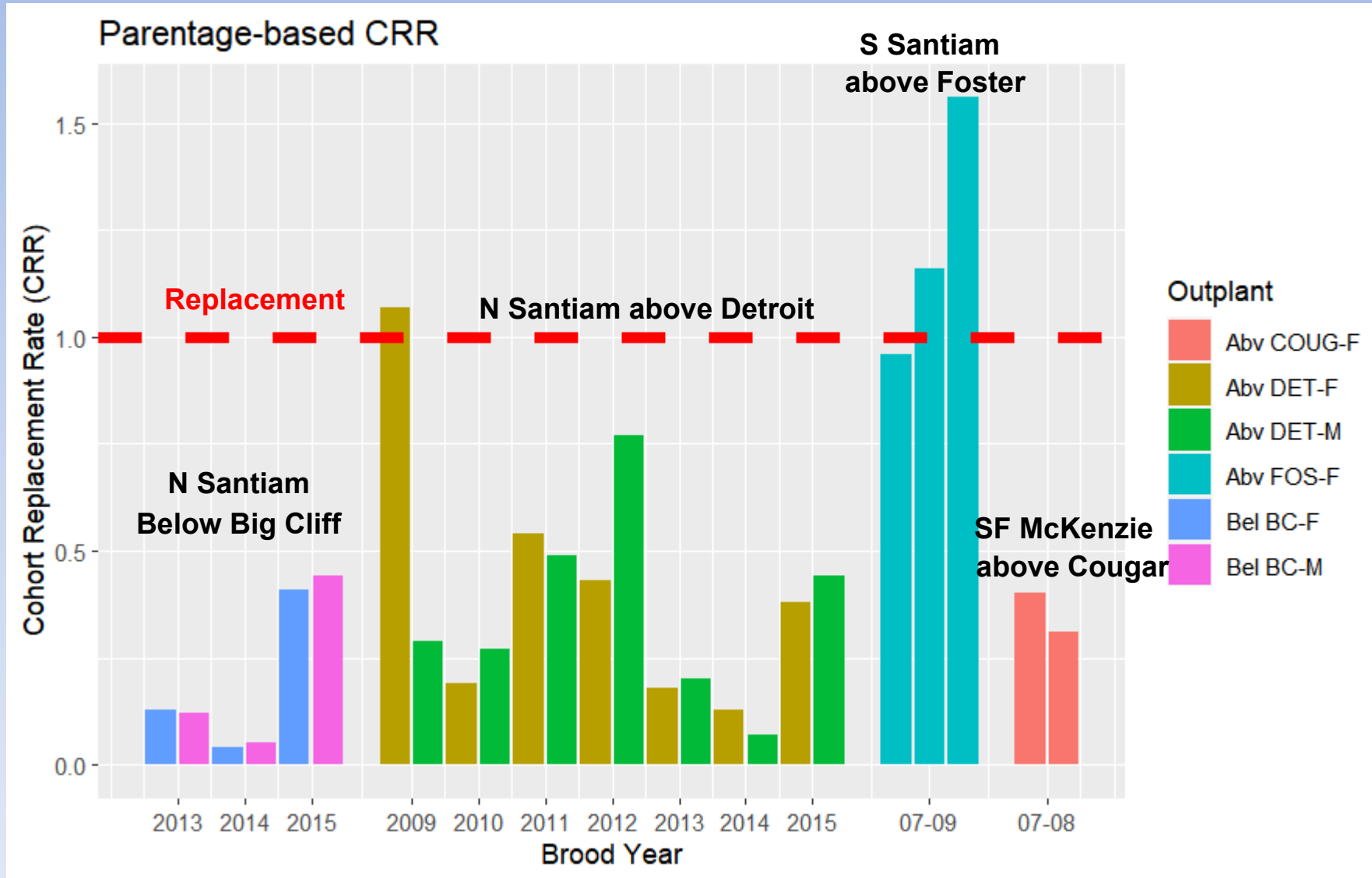


# How to Assess 'Performance of a Cohort?

- Cohort Replacement Rate (CRR)
  - How Many Future Adults Are Produced by a Brood?
  - Difficult to Estimate CRR from Routine Monitoring Data
- Genetic Pedigree Studies Are the Gold Standard
  - Dayan and O'Malley Pedigree Talks After Lunch



# CRR Estimates from Pedigree Studies



N Santiam: O'Malley et al. (2015, 2017, 2023); OSU/ODFW

S Santiam: Evans et al. (2016); CJFAS

McKenzie: Sard et al. (2016); CJFAS

# Pedigree Alternative: *In Silico* Simulations

- A Potential Shortcut to Pedigree: CRR Model
- Use Inputs from a Variety of Research & Monitoring Projects
- 1) Adult outplant N, PSM, fecundity
- 2) Juvenile Life History Splits
  - Likelihood of Taking a Specific Pathway
- 3) Juvenile Survival Probabilities
  - Reach-Specific (Rearing Site, Reservoir, Dam Passage, Main Stems, Estuary, Ocean)
  - Life Stage-Specific (Egg, Fry, Subyearling, Yearling, Sub-Adult, Etc.)

# What the CRR Model Is And Is Not:

- **Is Not:** Individual-Based Model (IBM)
  - Mechanistic, Spatially and Temporally Explicit (i.e., Often Daily Timestep)
- **Is Not:** Viable Salmonid Population (VSP) or Life Cycle Model
  - Long Time Horizons (i.e., Extinction Risk, Genetic Changes)
  - Multiple Cohorts / Generations / Environmental Cycles
- **Is:** Simple Tool to Estimate CRR of a Single Adult Cohort
  - Model groups (i.e., Pathways), Not Individuals
  - Explore Basic Hypotheses / Compare Scenarios

# Math is Hard (On Salmon)

- CRR Example for adults that spawn below Big Cliff

$$N_{RET F} = N_{e1} \times S_{e1} \times F \times [LH \text{ Splits} \times \text{Survival Parameters}]$$

'Outplanted' females  
Fecundity

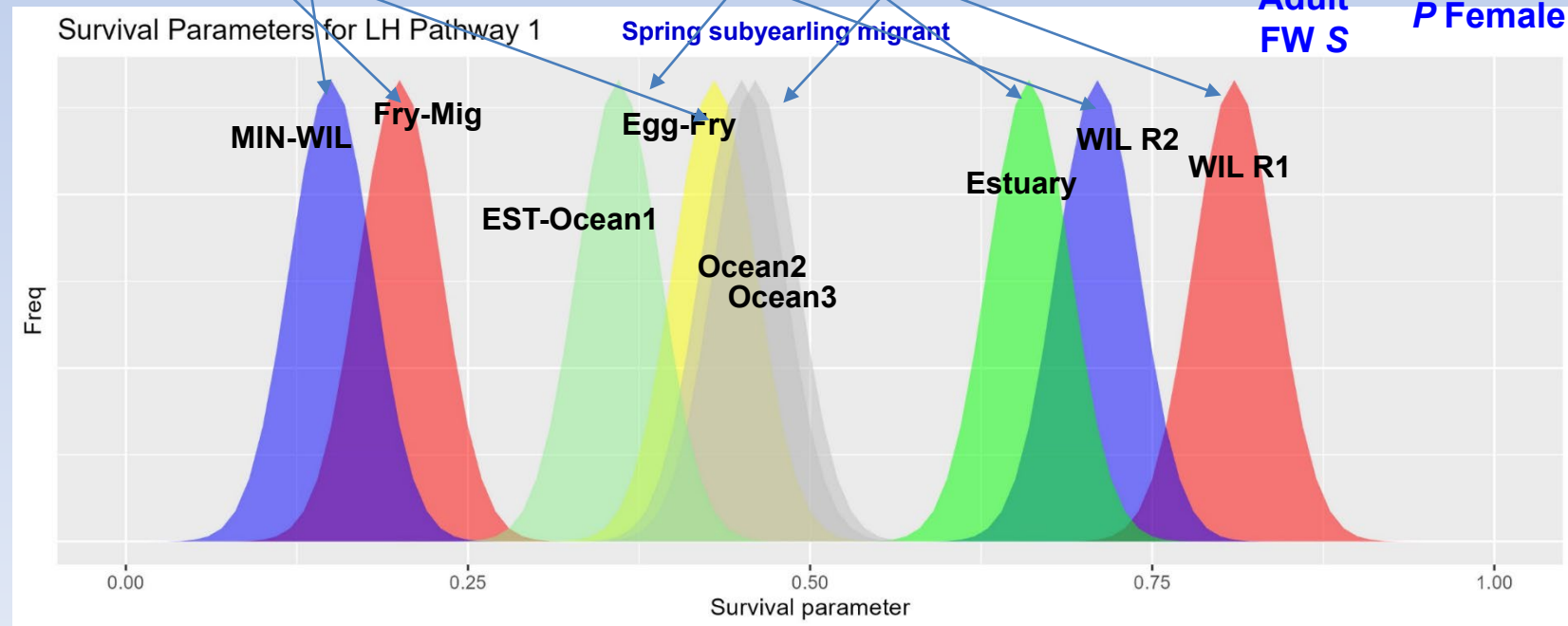
Prespawn survival (1-PSM)

SLAM Split: 0.41  
Pathway 1 SpSub Migrant

$$[P_{e1} \times S_{e1} \times S_{e4} \times S_{f1} \times S_{g1} \times S_{h1} \times S_{i1} \times S_{j1} \times [Ocean S] \times S_{l1} \times P_f]$$

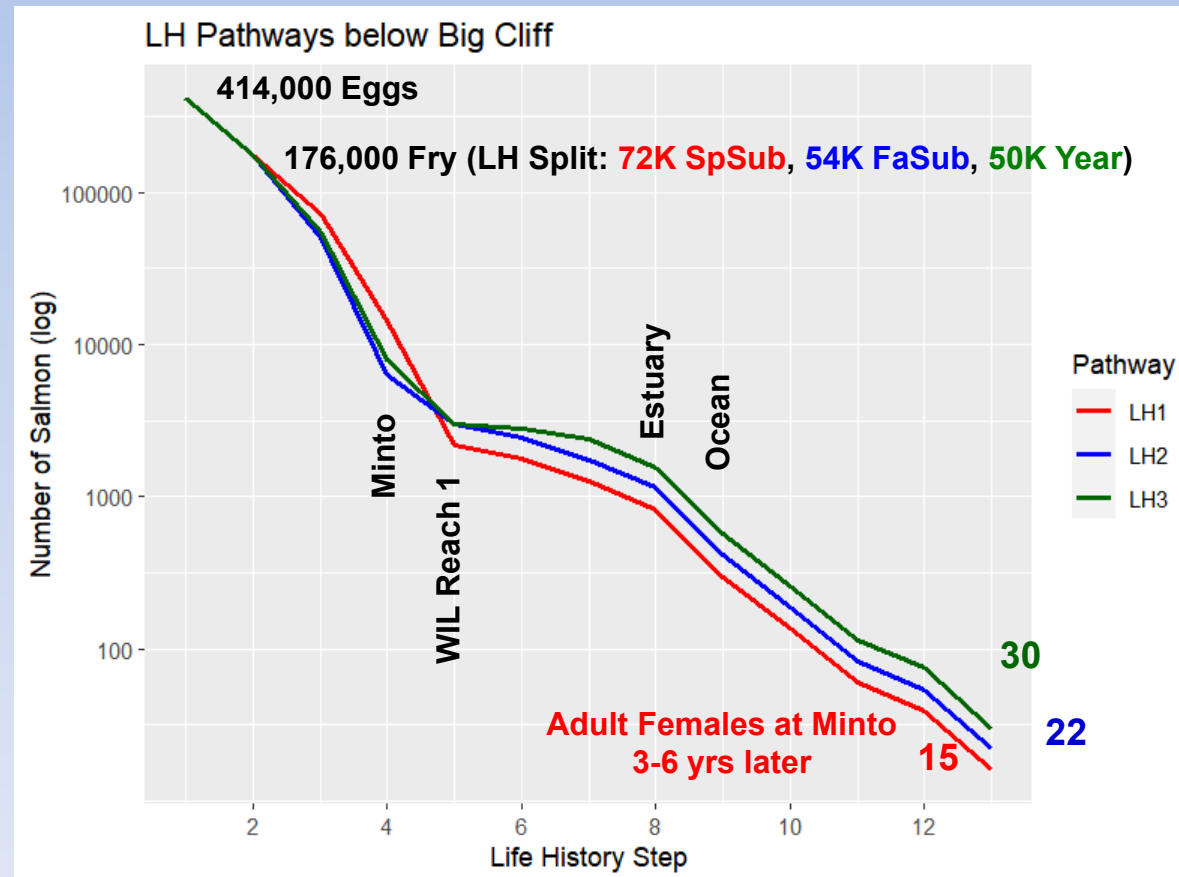
0.65 SLAM Adult FW S

HGMP Split: 0.40 P Female



# Math is Hard (On Salmon)

- 100 'Outplanted' Adult Females, PSM = 8%, Fec = 4,500 eggs/F
- 3 Juvenile Life History Pathways



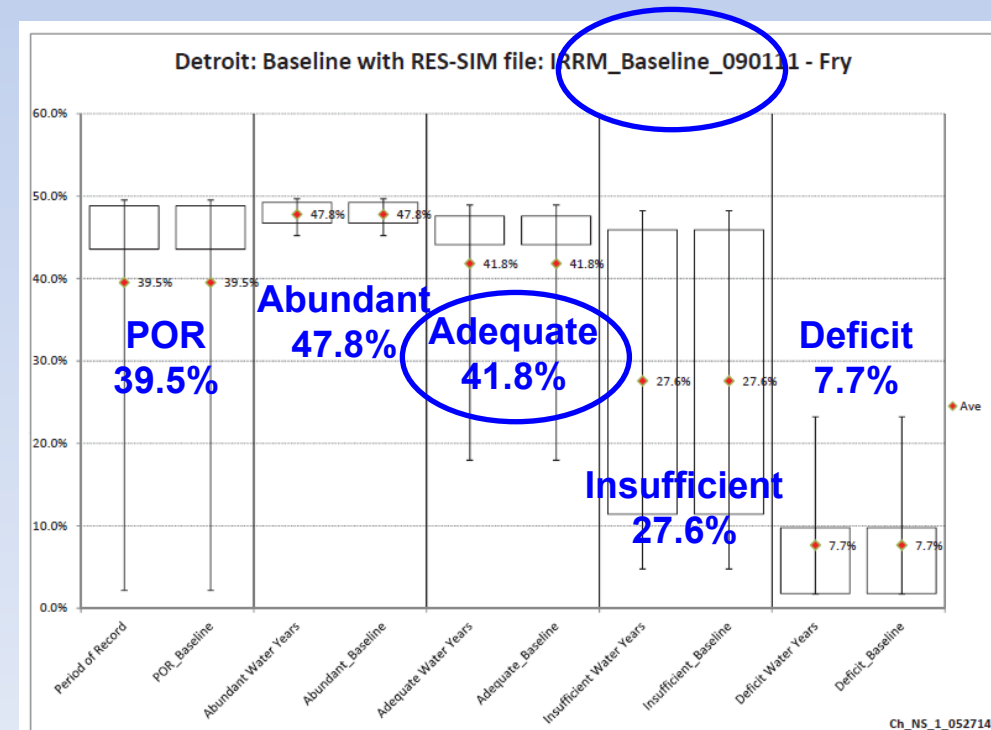
$$\text{CRR} = 67/100 = 0.67$$

# Piling On: Fish Produced Above Dams

- Natal Stream Survival
- Reservoir Survival
- Dam Passage Survival
  - Fish Benefits Workbook (FBW)
    - Baseline Operations
    - ‘Adequate Water Years’

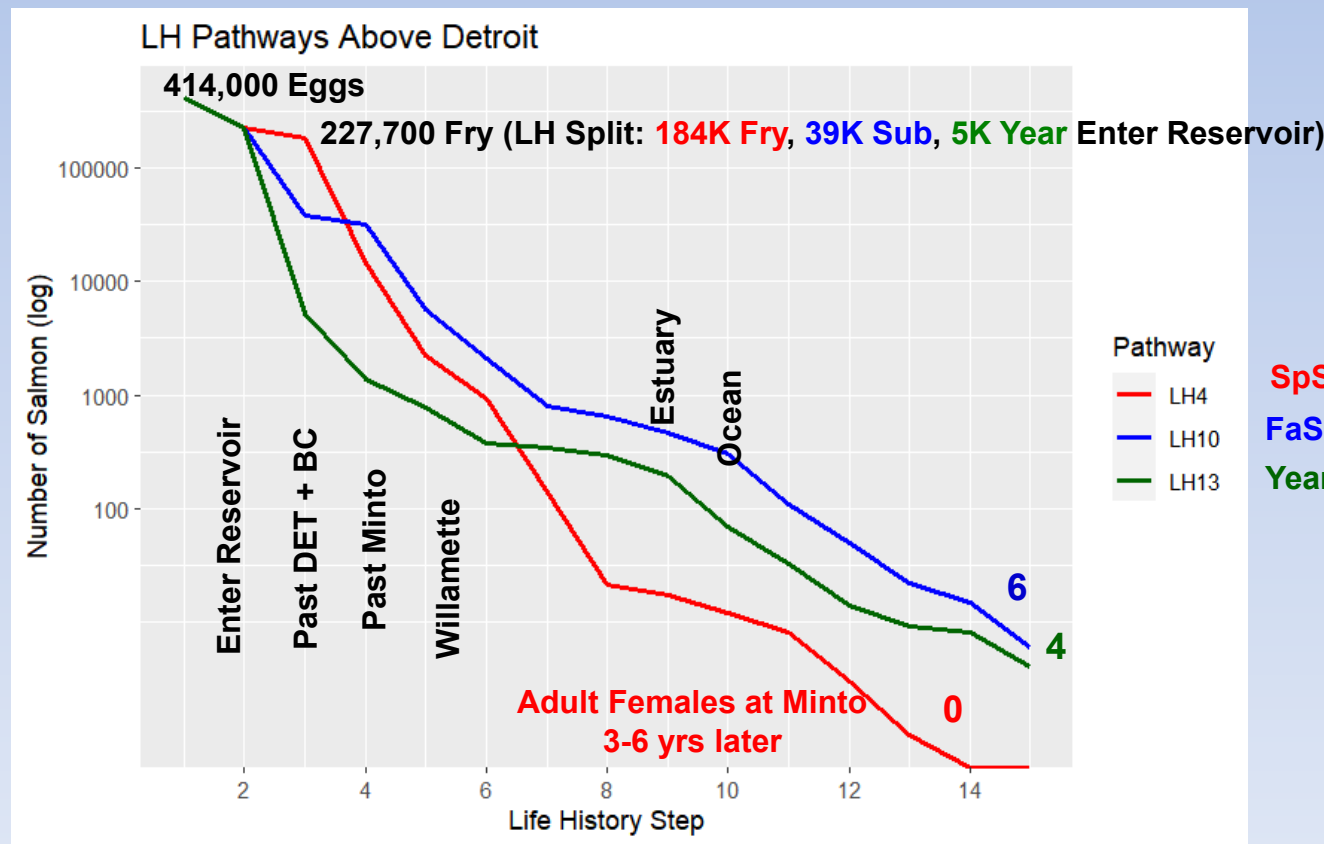
USACE FBW  
Appendix K.  
(2015)

Detroit + Big Cliff Fry Passage Survival



# Piling On: Fish Produced Above Detroit

- 100 'Outplanted' Adult Females, PSM = 8%, Fec = 4,500 eggs/F
- 3 of the 10 Juvenile Life History Pathways



3 Pathways  
CRR = 10/100  
= 0.10

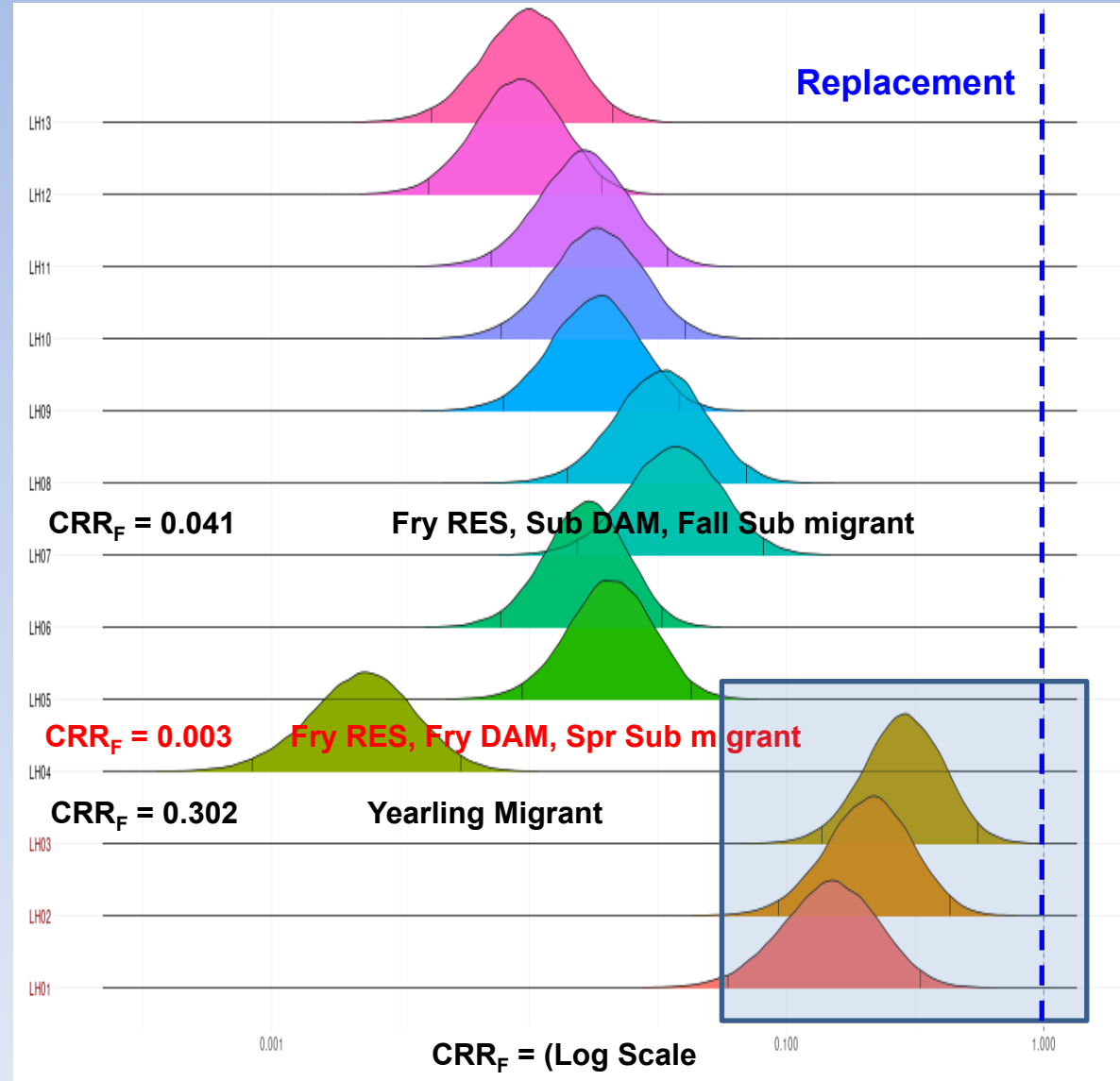


# North Santiam: Fractional CRRs

- Relative Performance Metric,
- 13 Pathways, Equal Outplanting
- Higher  $CRR_F$ :
  - 3 Below-Big Cliff Pathways
    - Fewer Survival Hits
  - Larger, Older Fish
    - Survival Advantages in most Reaches
    - Dam Passage an Exception

Above Detroit

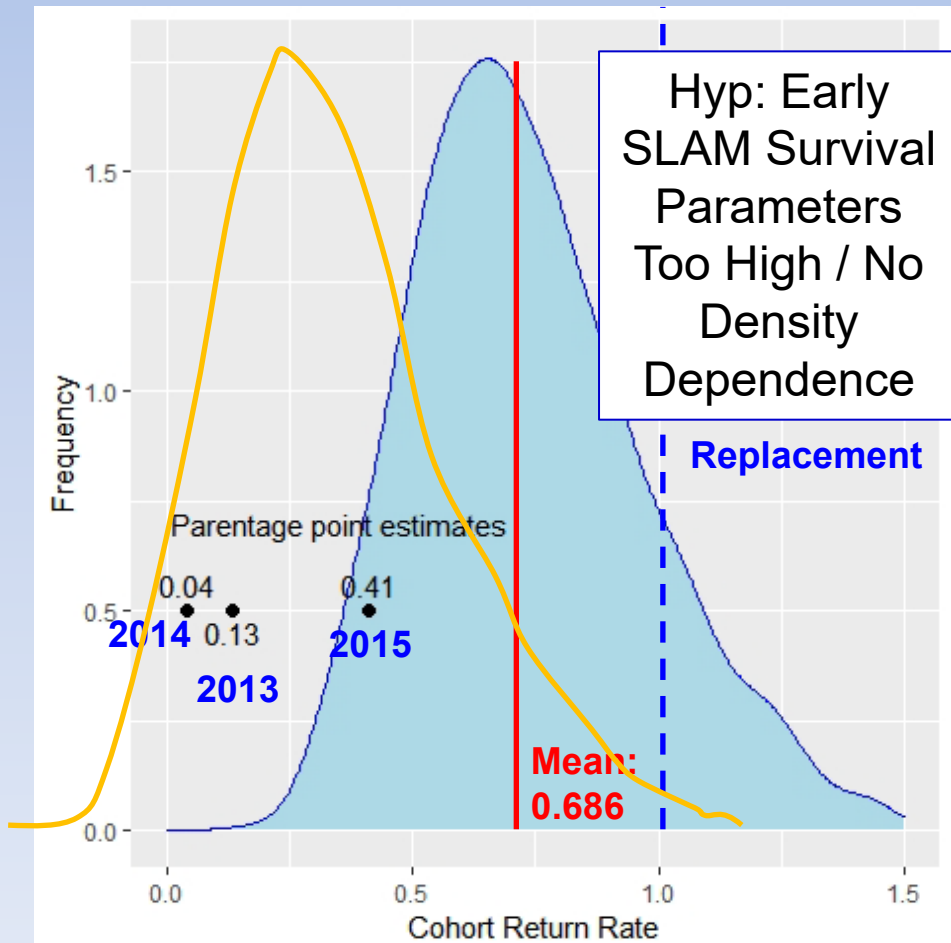
Below Big Cliff



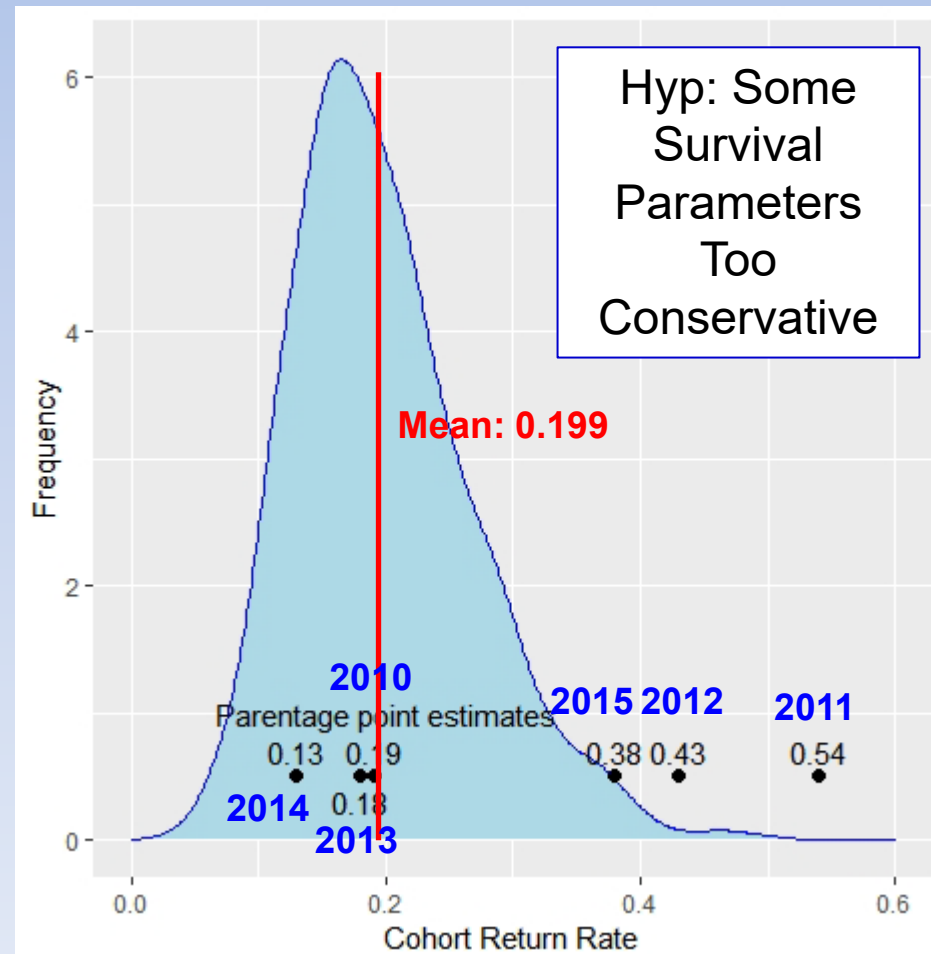
# North Santiam: Combined CRR

- Sum of Fractional Estimates, 2 Adult Outplant Locations

Outplant Below Big Cliff: 3 LH Pathways



Outplant Above Detroit: 10 LH Pathways

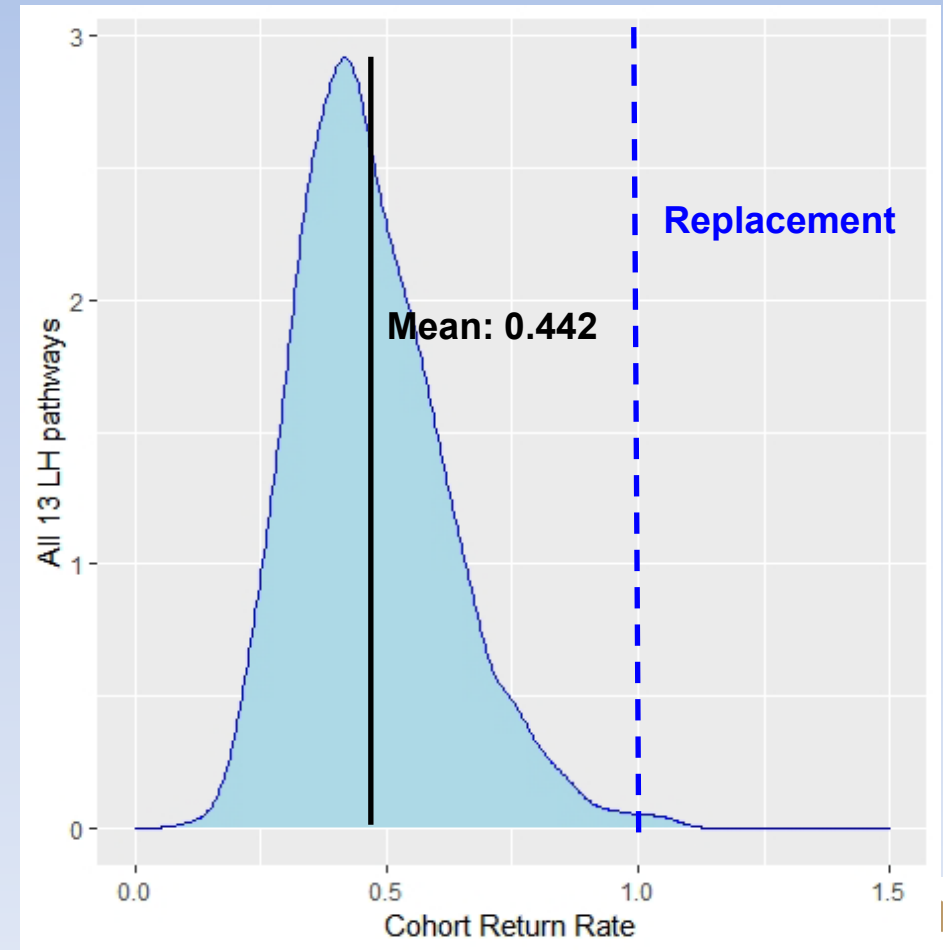


Replacement

2009  
1.07

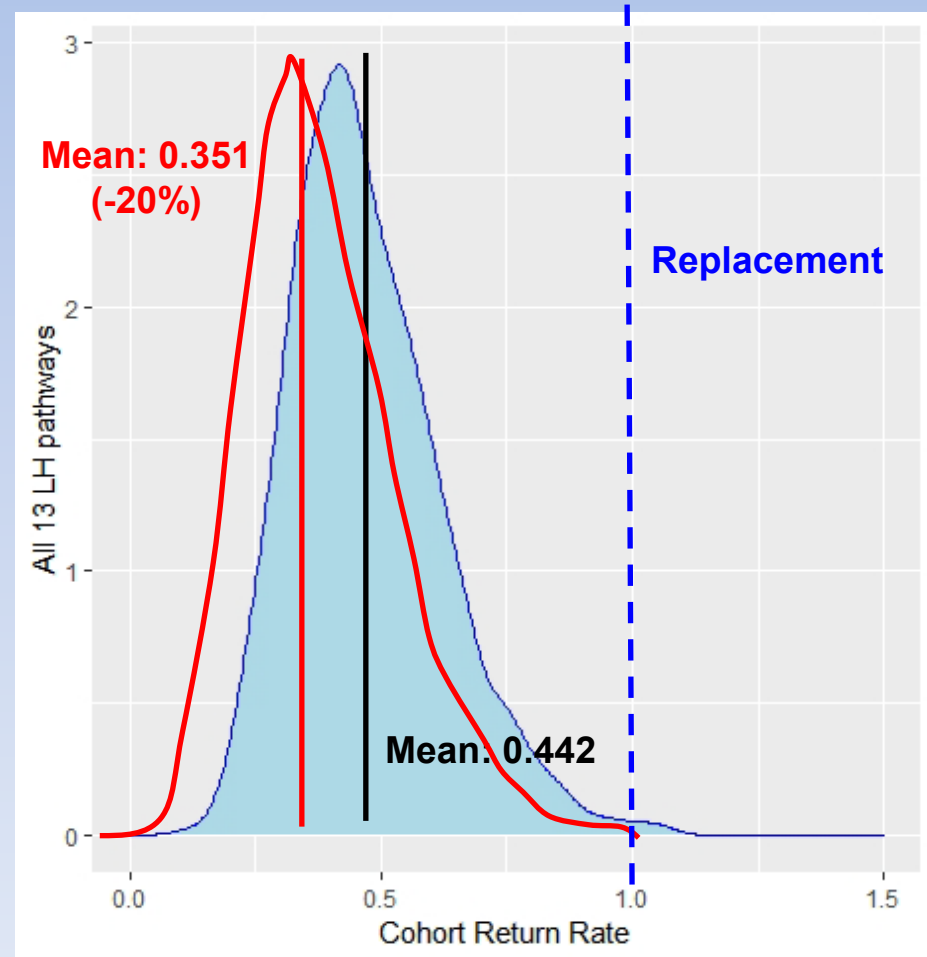
# North Santiam: Total CRR

- 'Baseline' Model: Equal Outplanting, 13 Pathways
  - Below Big Cliff Model Mean = 0.686
  - Above Detroit Model Mean = 0.199
  - No Parentage Equivalent for Blended Outplant Group



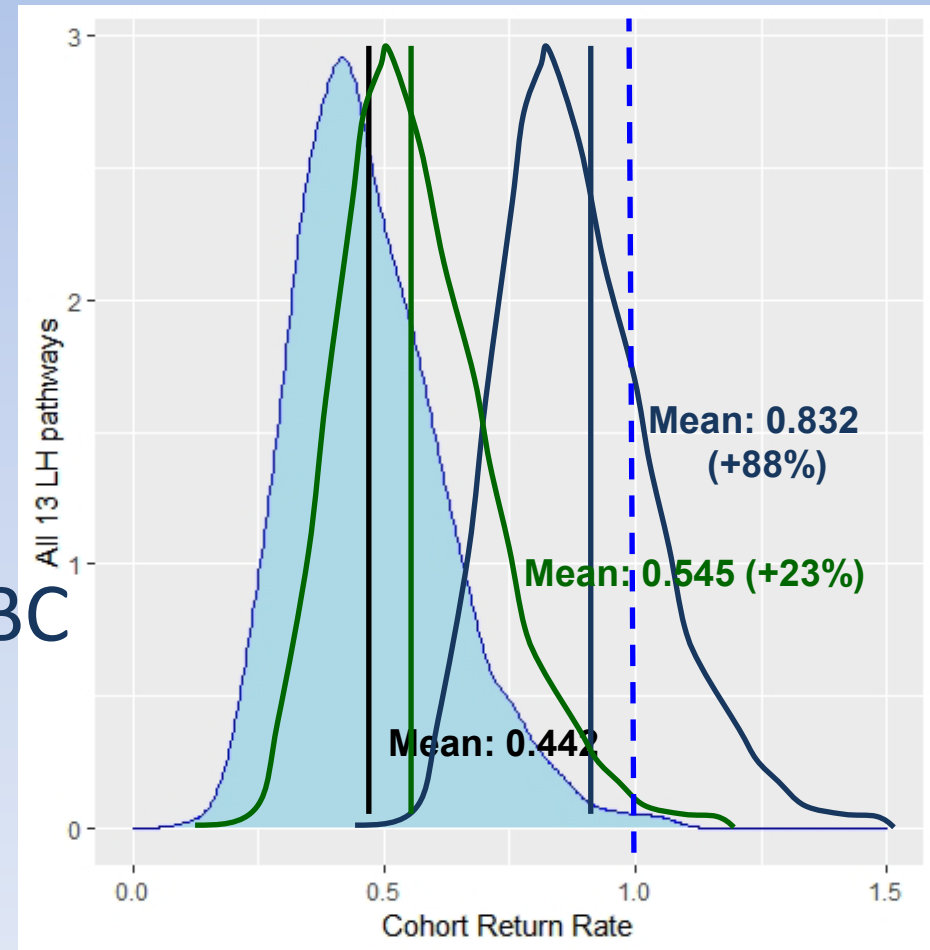
# North Santiam: CRR Scenario Testing

- 'Baseline' Model: Equal Outplanting
- Sc: Increase PSM to 25%
  - Above DET & Below BC
  - Affects all Pathways



# North Santiam: CRR Scenario Testing

- 'Baseline' Model: Equal Outplanting
- Sc: Increase PSM to 25%
  - Affects all Pathways
- Sc: Double Dam Passage Survival
  - Affects 10 Pathways
  - Fry = 84%, Sub = 42%, Year = 52%
- Sc: 90% Egg-Fry Survival below BC
  - Affects 3 Pathways
  - Baseline = 43% Survival



# Choose Your Own Adventure: Shiny Apps

- [https://mete-yuksel.shinyapps.io/NSAN\\_model](https://mete-yuksel.shinyapps.io/NSAN_model)
- [https://mete-yuksel.shinyapps.io/SSAN\\_model](https://mete-yuksel.shinyapps.io/SSAN_model)
  - Remote, web-based option (Convenient)
  - Run Apps on any Computer with R, R Studio (Faster)

# Shiny Apps

Model Dashboard  
50,000 Simulations

Sensitivity Profiles  
500-2500 Simulations

North Santiam Shiny Web Application

Model Dashboard

Sensitivity Profiles

**RUN!**

Outplanted adult females below Big Cliff

# F Outplants < BC, > DET

Outplanted adult females above Detroit

PSM < BC, > DET

Adult female P SM estimate below Big Cliff

Adult female P SM estimate above Detroit

Egg-Fry S < BC

Egg-fry survival in Minto-Big Cliff reach

Juv Avail to pass DET + BC

Fry in Detroit reservoir available to pass Detroit Dam

Juv S in DET RES

Detroit reservoir survival from Fry to Subyearling

Juv S passing DET + BC

Detroit reservoir survival from Subyearling to Yearling

Juv S in Estuary,  
Early Ocean

Dam passage survival of Fry past Detroit and Big Cliff

Dam passage survival of subyearlings past Detroit

Dam passage survival of Yearlings past Detroit and Big Cliff

Size-dependent estuary survival (Spring sub, Fall sub, yearling)

Size-dependent ocean age-1 survival (Spring sub, Fall sub, yearling)

This dashboard allows users to manipulate a subset of the stage- and reach-specific survival parameters and life history transition probabilities in the North Santiam River Cohort Replacement Rate (CRR) model for outplanted adult female Chinook salmon collected at the Minto adult facility. Life histories 1-3 correspond to juveniles produced by adults outplanted below Big Cliff Dam. Life histories 4-13 correspond to juveniles produced upstream from Detroit reservoir. The first 12 parameters on the dashboard can be varied continuously within the set ranges. Age-specific estuary and year-1 ocean survival can be set to one of three pre-set options (2 size-dependent and 1 size-independent survival). Several survival probabilities are drawn from distributions to reflect uncertainty in the point estimates, but these distributions are constrained so that the parameters remain between 0 and 1. (A full description of the North Santiam Chinook salmon CRR model parameterization and the 13 life history pathways is included in University of Idaho Technical Report 2022-1.) Once all parameter values have been assigned on this page, click the RUN! button to the left to see the total and life history-specific cohort return rate (CRR) distributions obtained from 50,000 runs of the model. To generate sensitivity profiles in the CRRs and estimates of juvenile abundance upon estuary arrival as one or more parameters are varied, move to the other page.

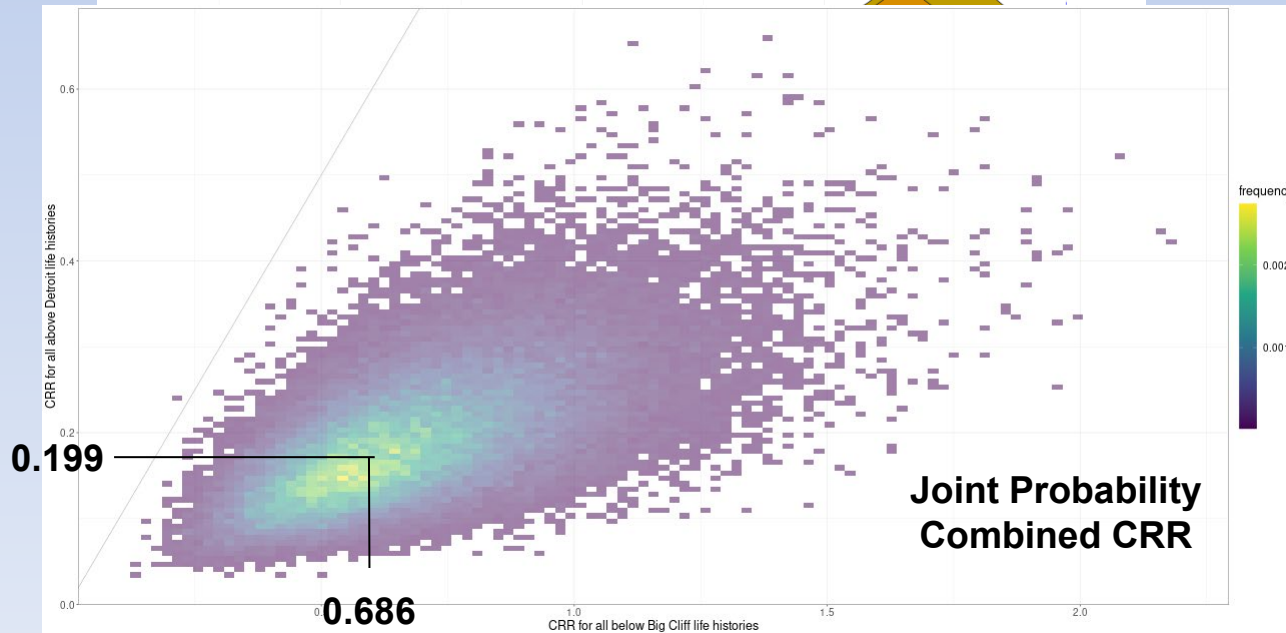
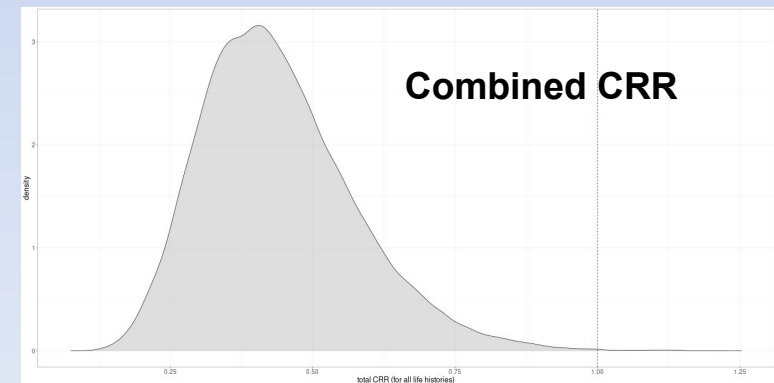
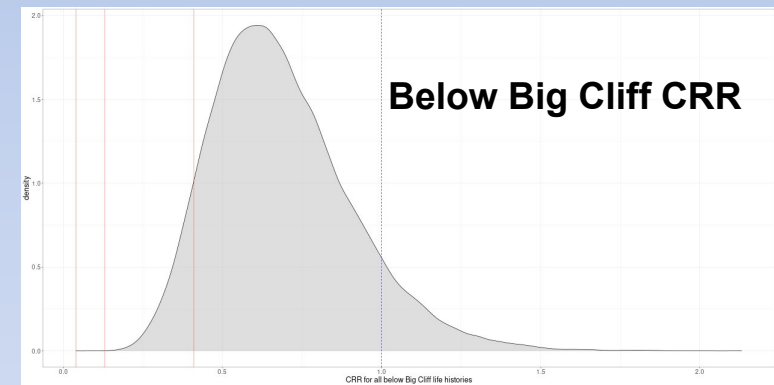
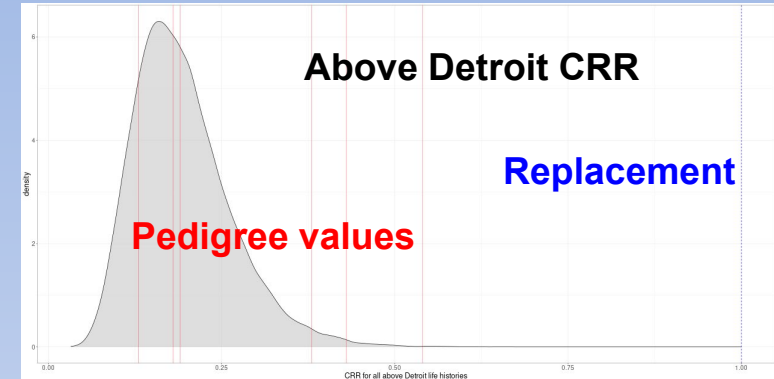
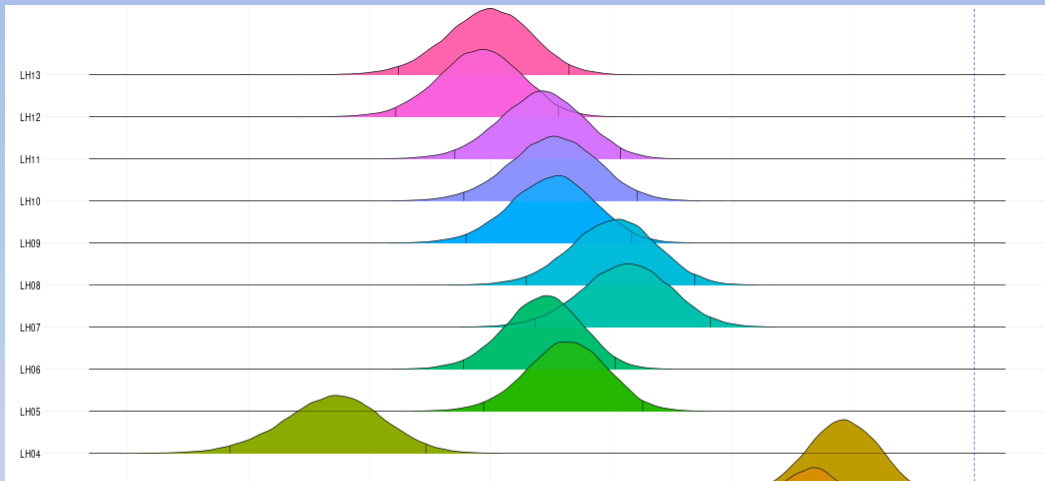
Total CRR Below Big Cliff CRR Above Detroit CRR Joint distribution of CRR outcomes LH-specific CRRs

5 Model Outputs

The dashed blue line corresponds to replacement.

# Shiny Apps: Dashboard Output

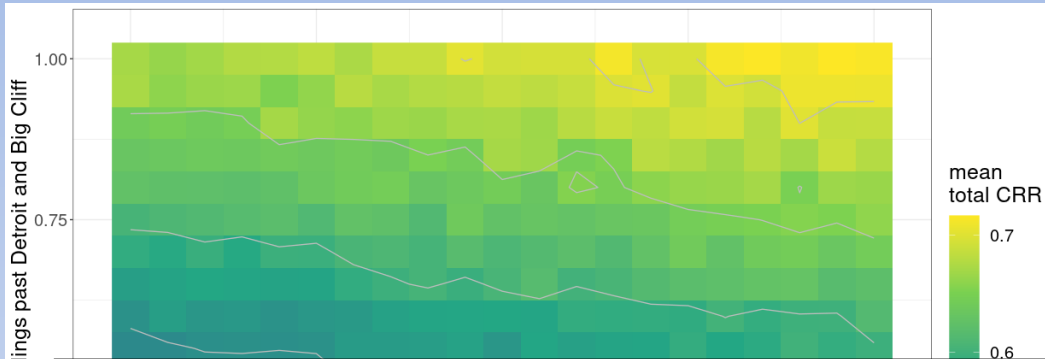
### Fractional CRR



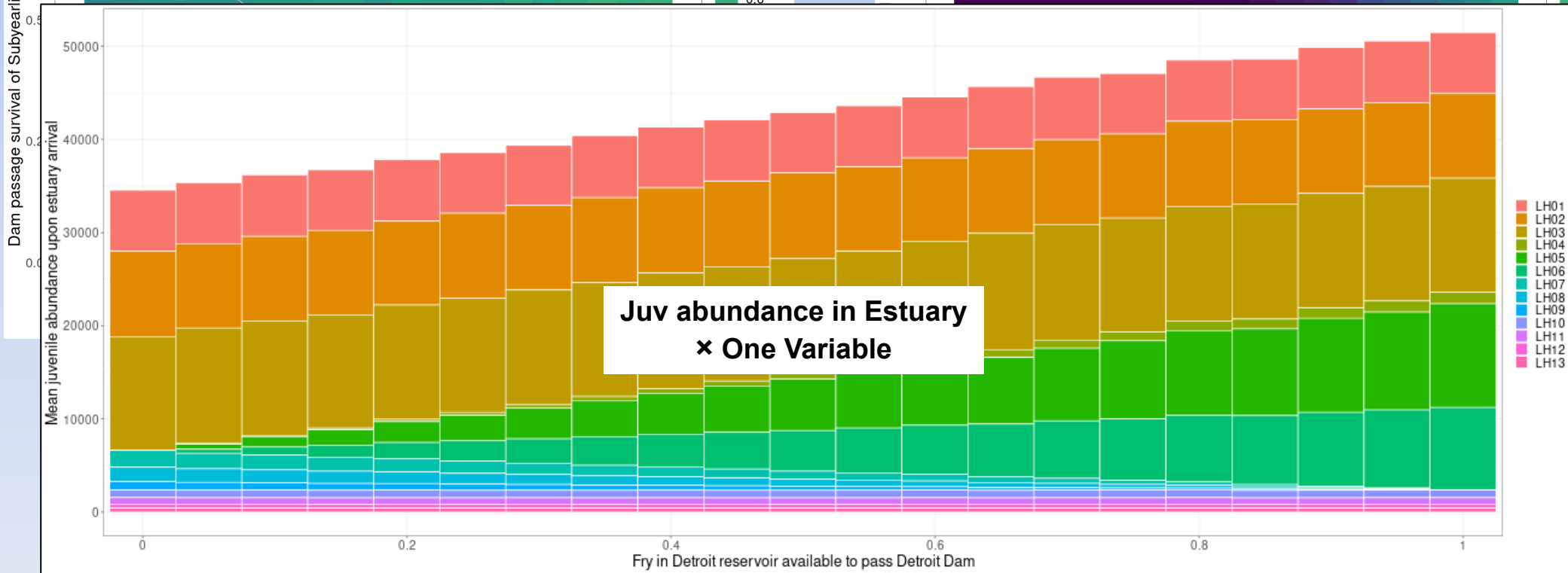
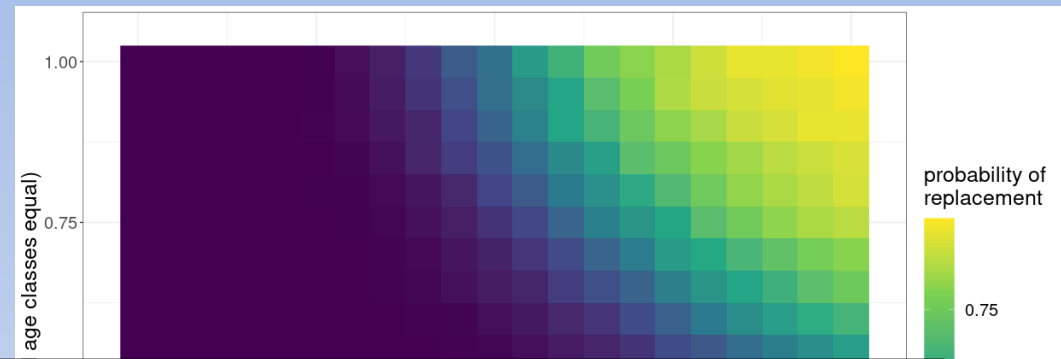


# Shiny Apps: Sensitivity Profiles

Combined CRR × Two Variables



Probability of Replacement × Two Variables



# Summary

- CRR Model: A (Hopefully!) Useful Tool
  - Demonstrate the Contribution Differences Among LH Pathways
- Apps Allow User-Driven Exploration of Scenarios / Parameters
- Next Steps: Many Parameter Values Can Be Refined
  - Lowest Confidence is for Early Juvenile Survival Parameters
    - Egg-Fry Survival
    - Fry and Subyearling Survival in Multiple Habitats
- Pedigree Studies Are Invaluable

