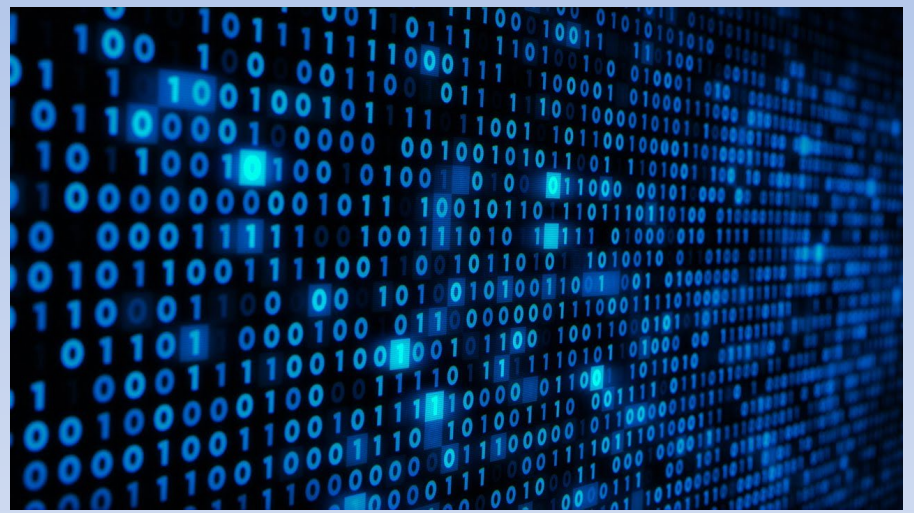
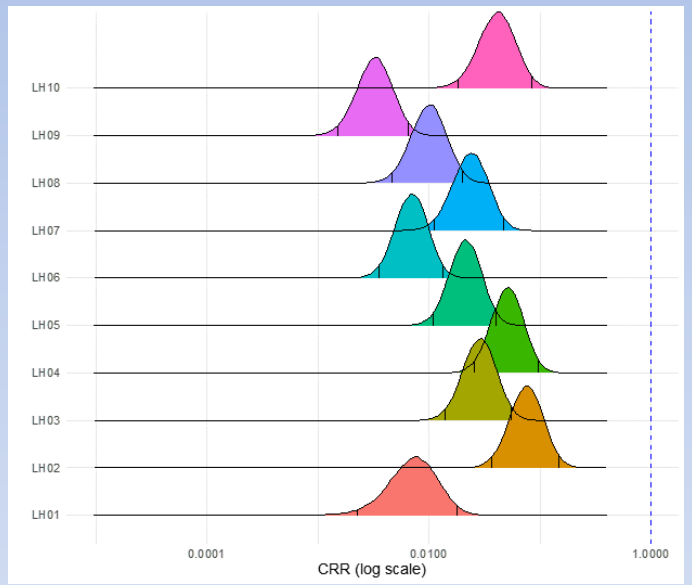
Decision support modeling for outplanting adult Chinook salmon in the Santiam River basin





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

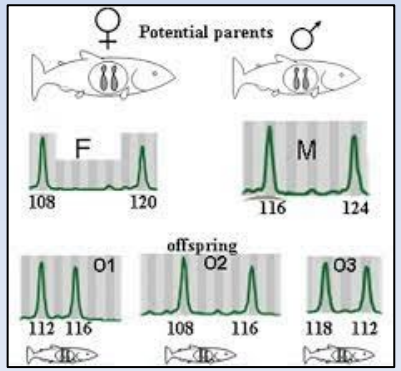
Department of Fish and Wildlife Sciences
University of Idaho

US Army Corps of Engineers®

University of Idaho
College of Natural Resources

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

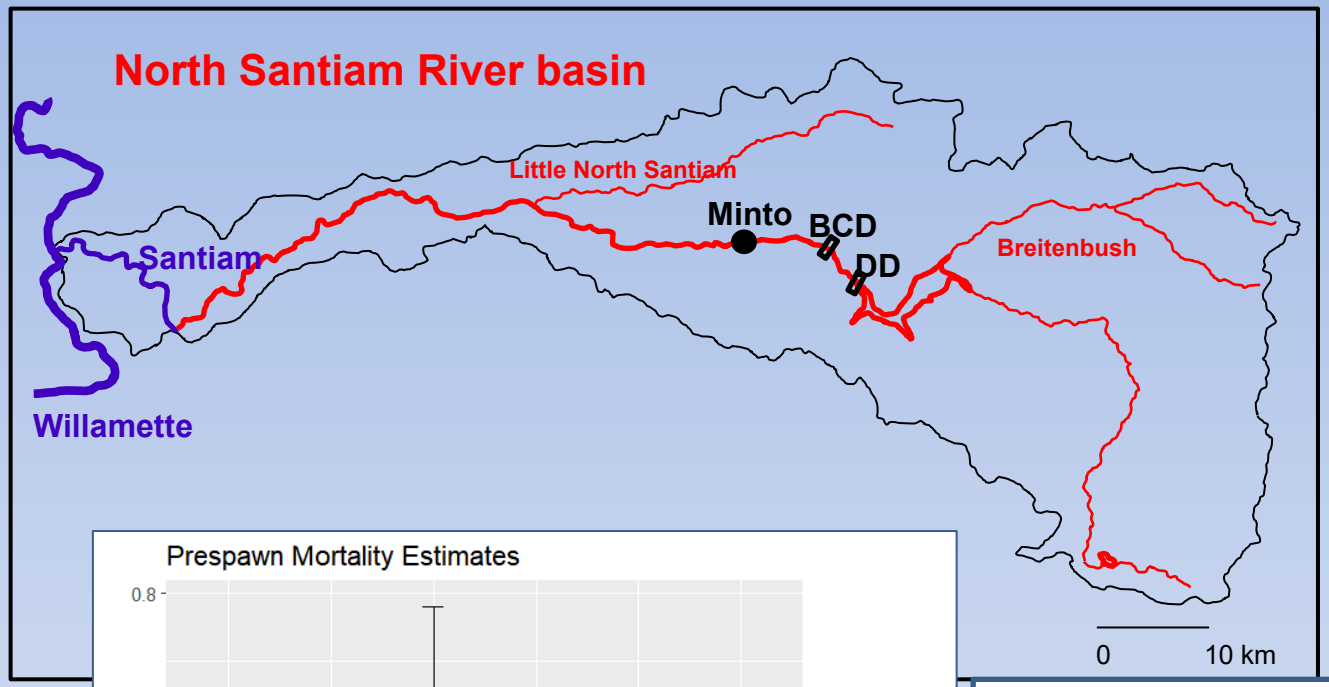


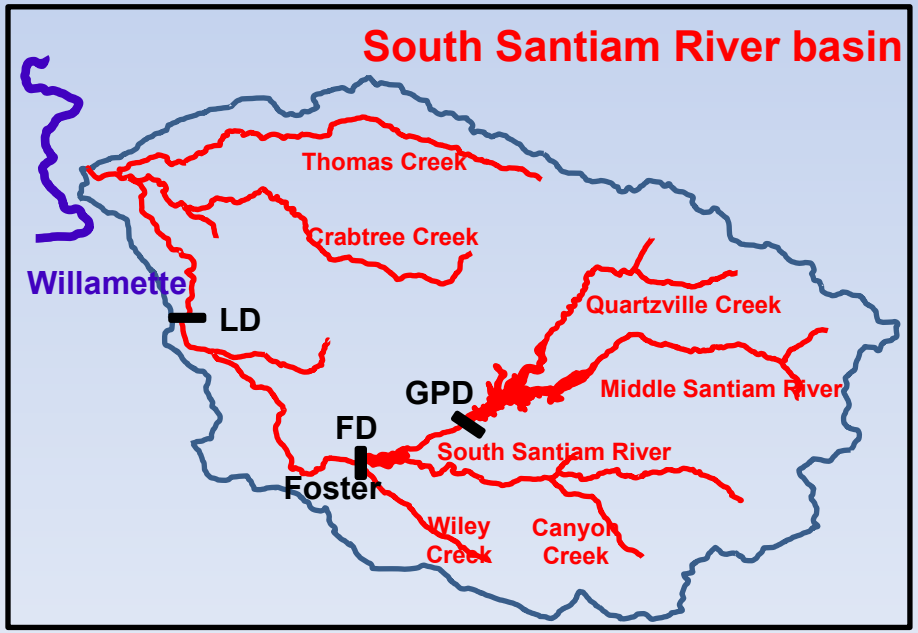
Wiley

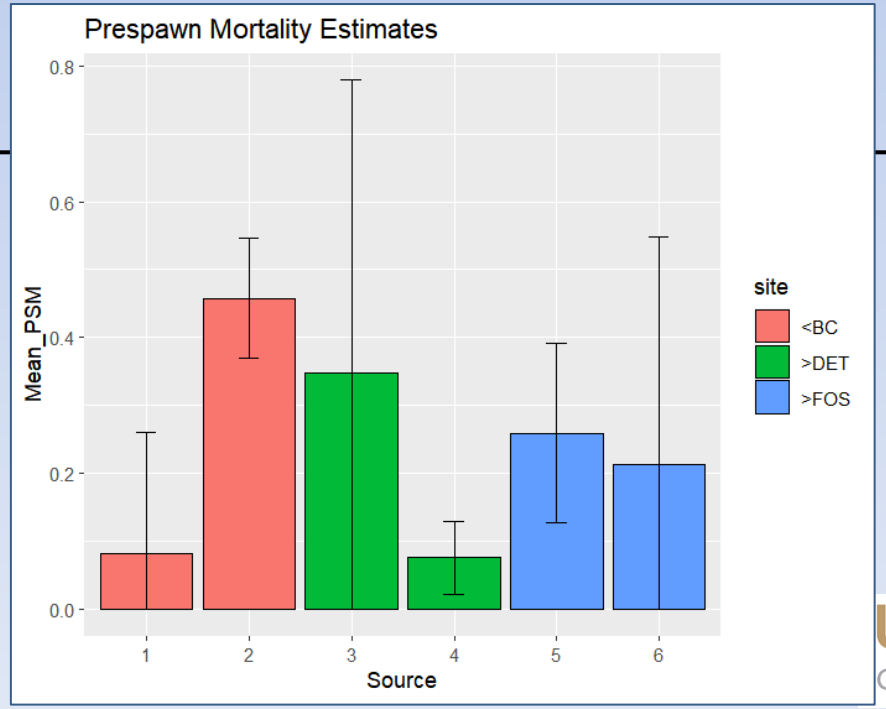
University of Idaho
College of Natural Resources

Adult Outplanting & PSM

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







1,3: ODFW_OWCS database

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

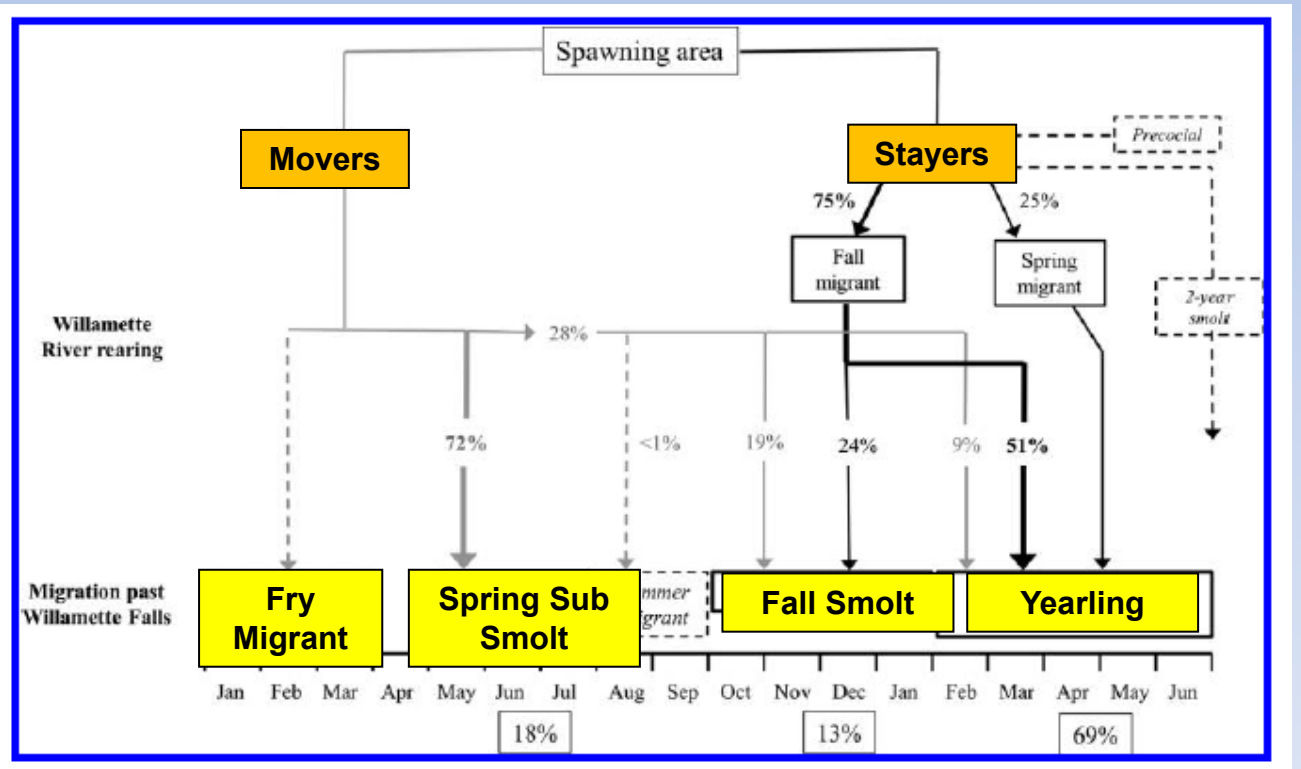
5: Naughton et al. (*2023*); NAJFM

6: DeWeber et al. (*2017*); NAJFM

Juvenile Chinook Life History Pathways

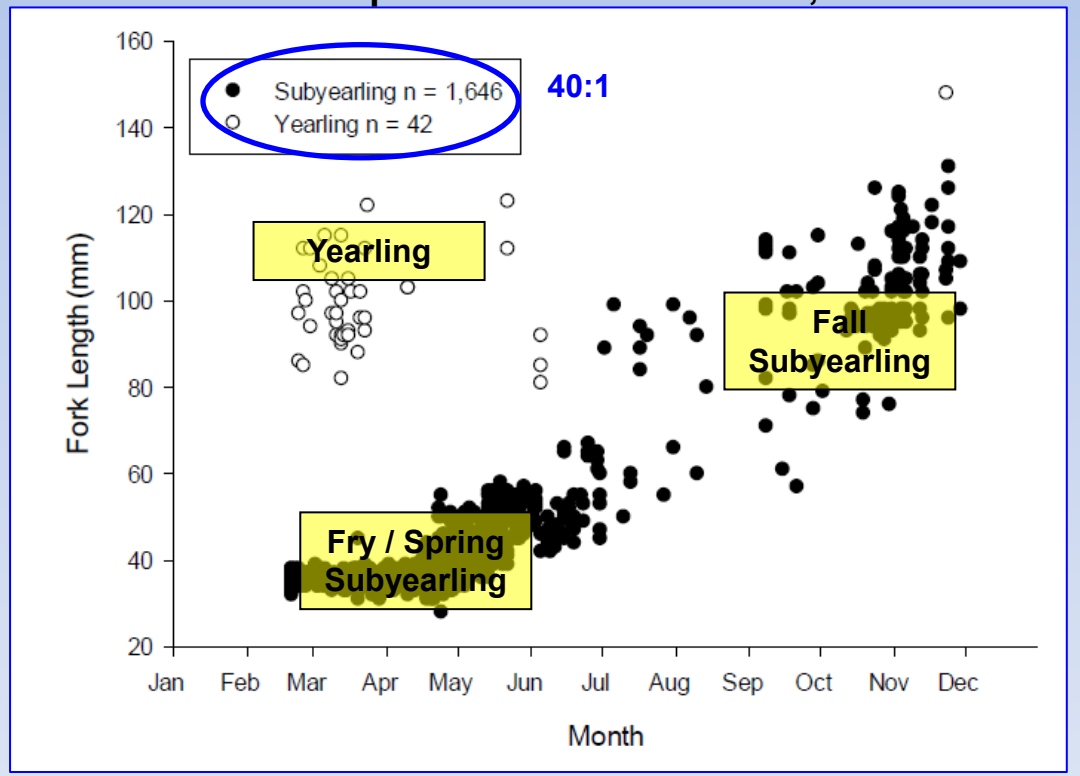
- Willamette Population Is Uniquely Diverse

McKenzie River Juvenile Chinook



Schroeder et al. (*2016*); CJFAS

Screw trap above Detroit reservoir, 2015



Romer et al. (2016); ODFW

University of Idaho
College of Natural Resources

CRR Model of North Santiam Pathways

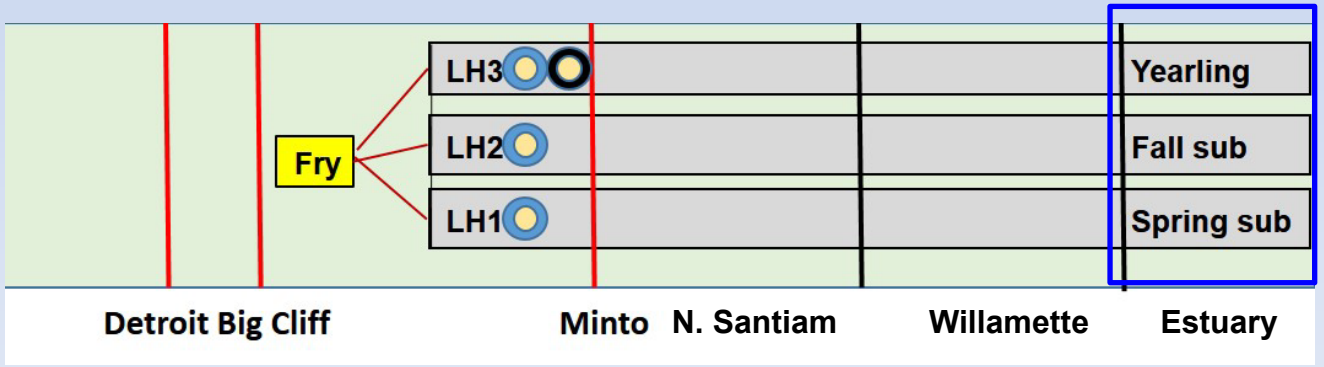
- A Continuum of LH Expression Would Be Ideal
  - Model Is A Necessary Simplification
- We Identified 13 Pathways, Primarily from SLAM
  - **S**pecies **L**ife-cycle **A**nalysis **M**odules (NOAA, 2015)

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

University of Idaho
College of Natural Resources

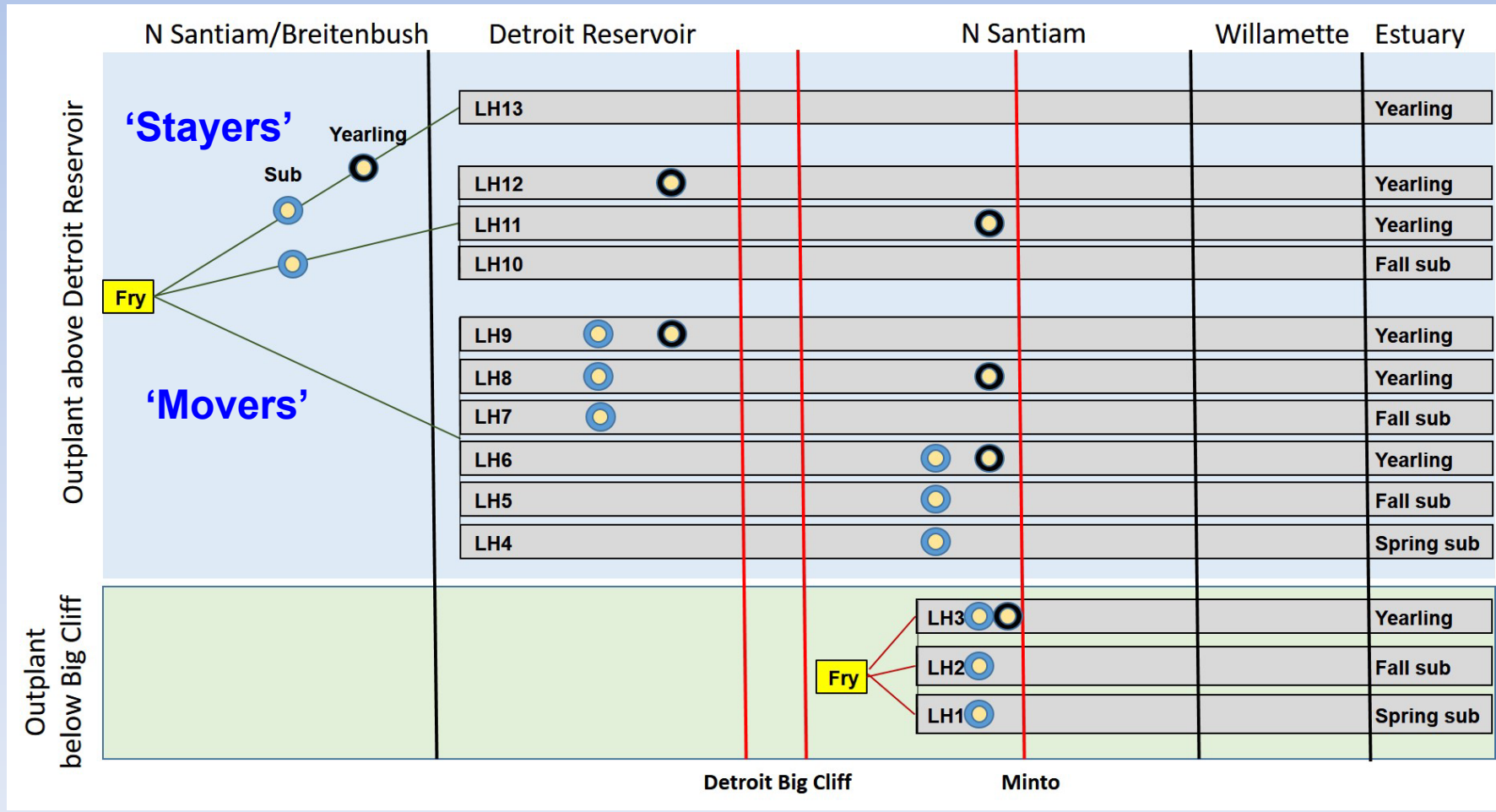
North Santiam pathways: above Detroit Dam

Breitenbush River

N Santiam River (USGS)

Detroit Dam & reservoir (OPB)

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

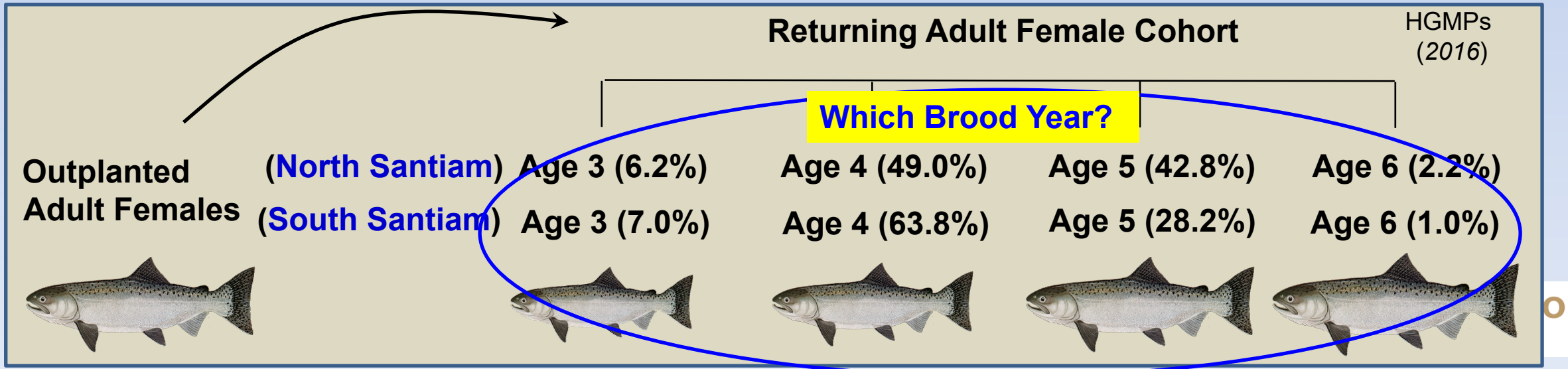


Where/When should adult Chinook be outplanted?

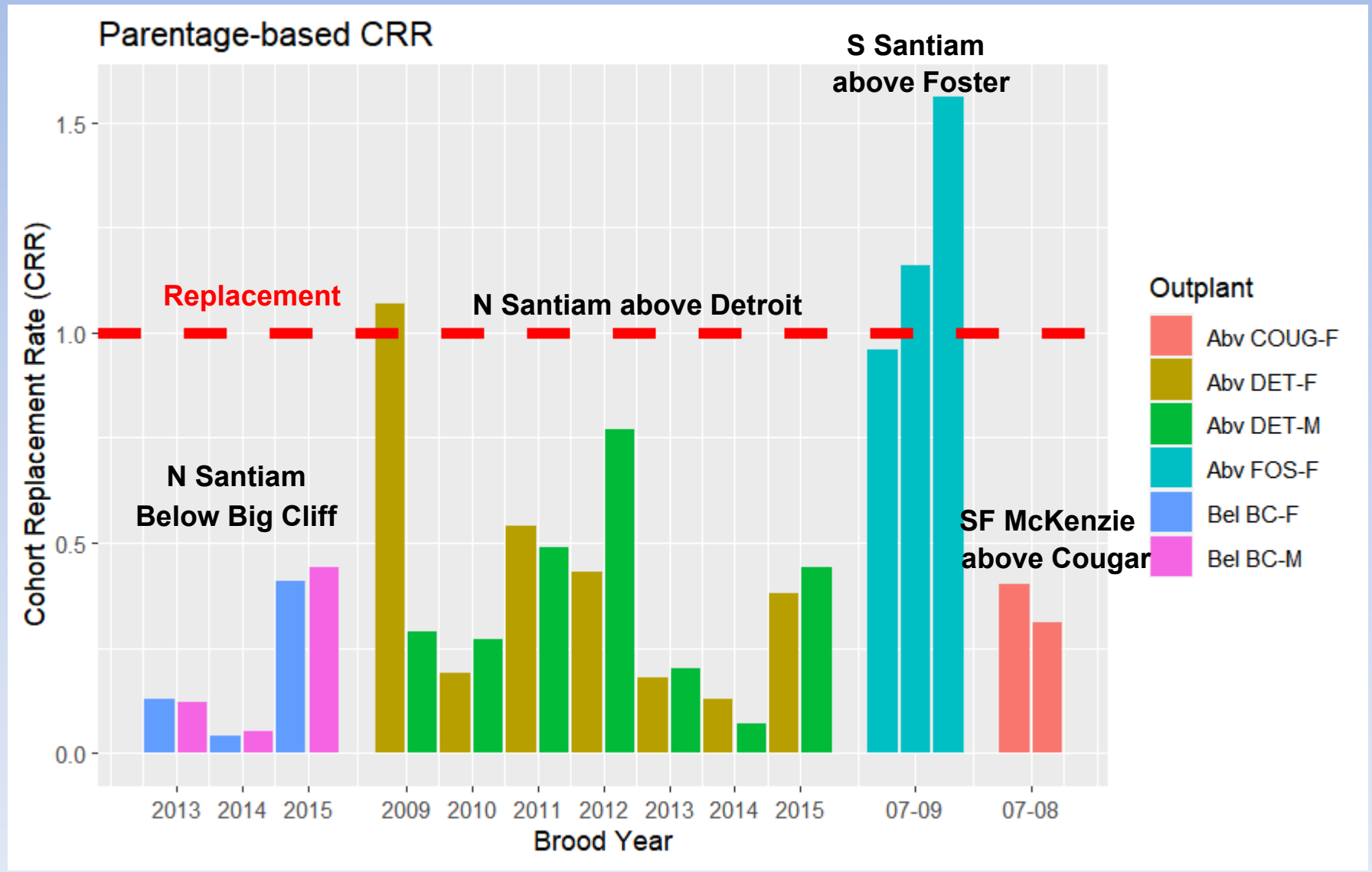
- Limited Numbers of Available Adults (+ Rules)
- PSM Is a Significant Risk Factor in Some Years / Locations
- Some Juvenile Life History Pathways More Successful
  - Large Variation in Habitat Quality
  - Reservoirs and Dams Present Substantial Risks

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

University of Idaho
College of Natural Resources

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: I**ndividual-**B**ased **M**odel (IBM)
  - Mechanistic, Spatially and Temporally Explicit (i.e., Often Daily Timestep)
- **Is Not: V**iable **S**almonid **P**opulation (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

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

'Outplanted' females

Fecundity

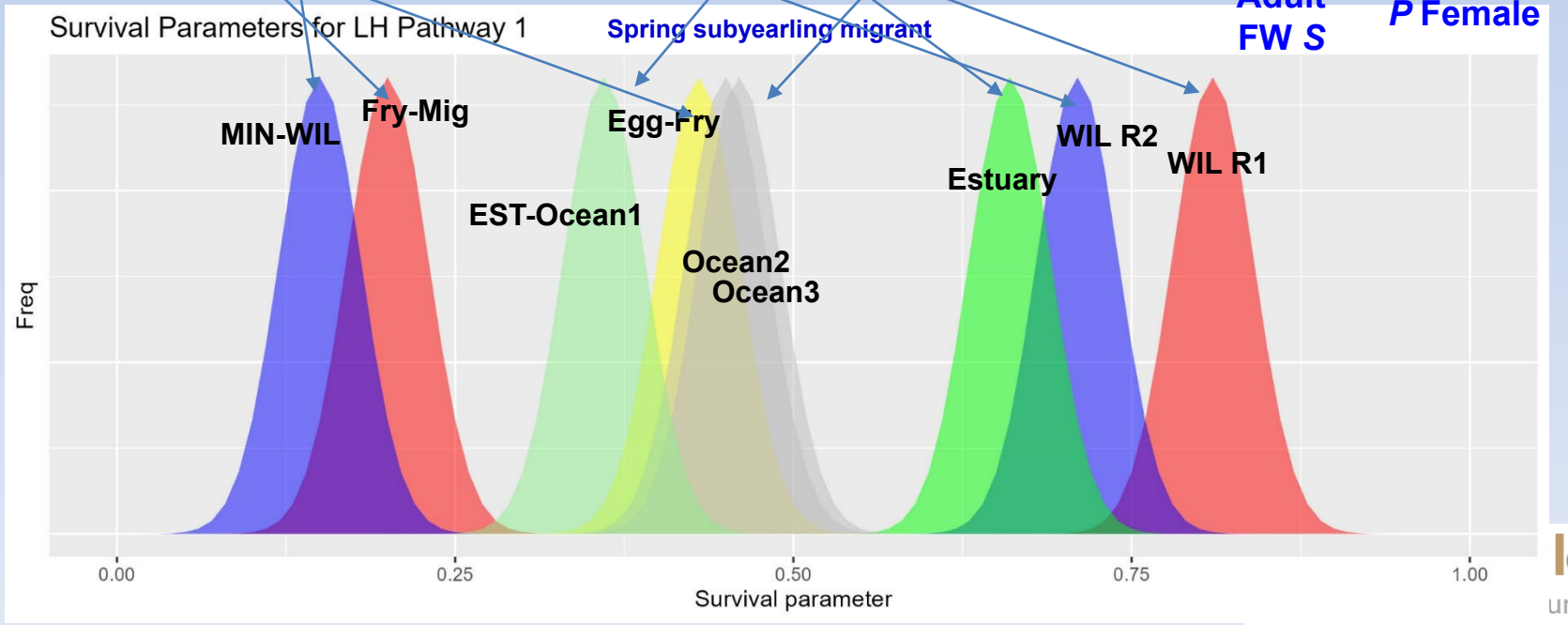
Prespawn survival (1-PSM)

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*

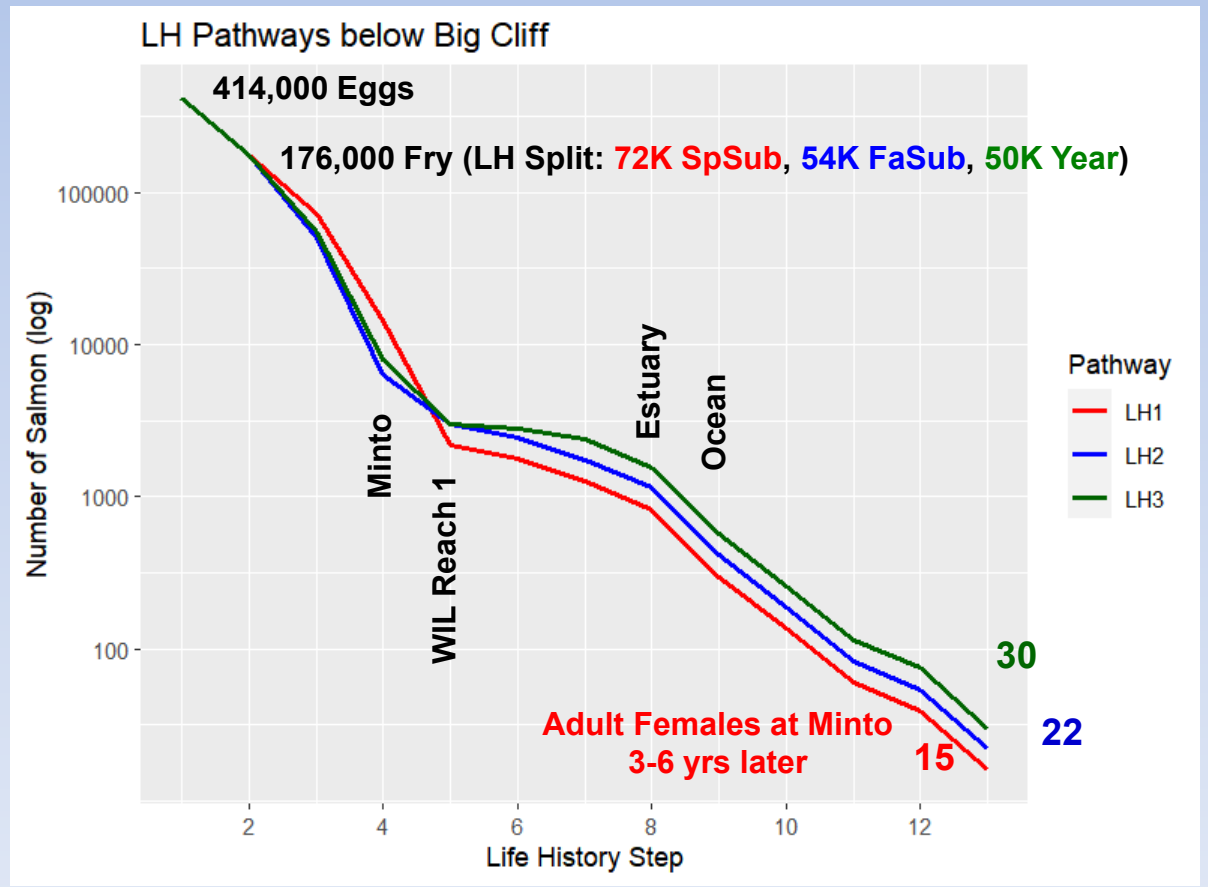
HGMP Split: 0.40 *P* Female



Idaho
urces

Math is Hard (On Salmon)

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



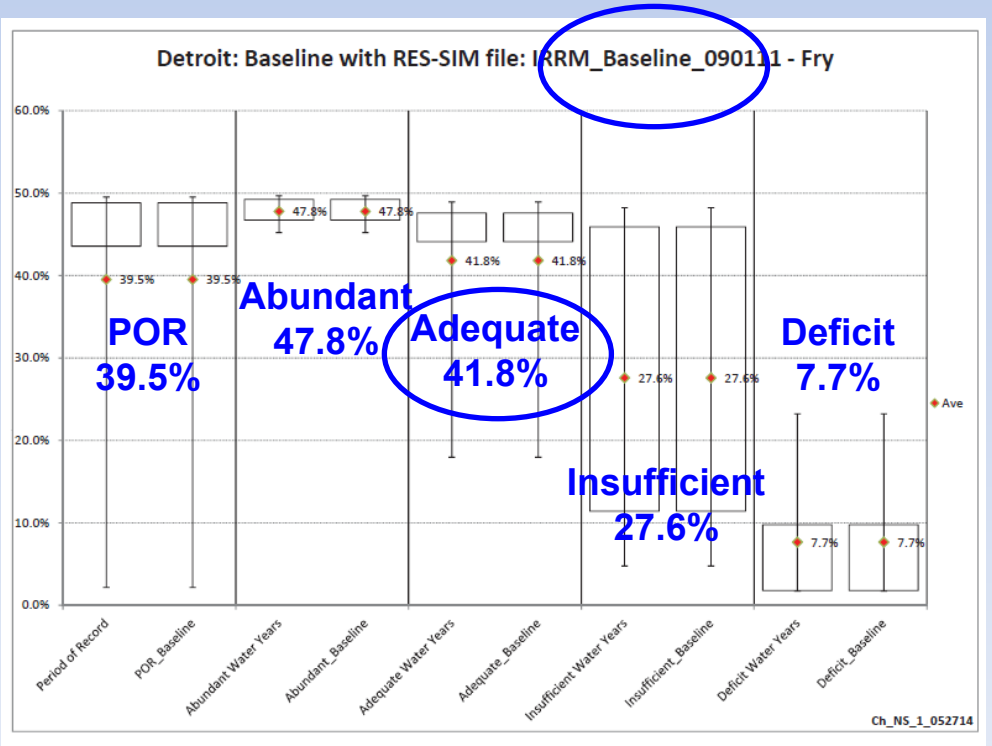
CRR = 67/100
= 0.67

University of Idaho
College of Natural Resources

Piling On: Fish Produced Above Dams

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

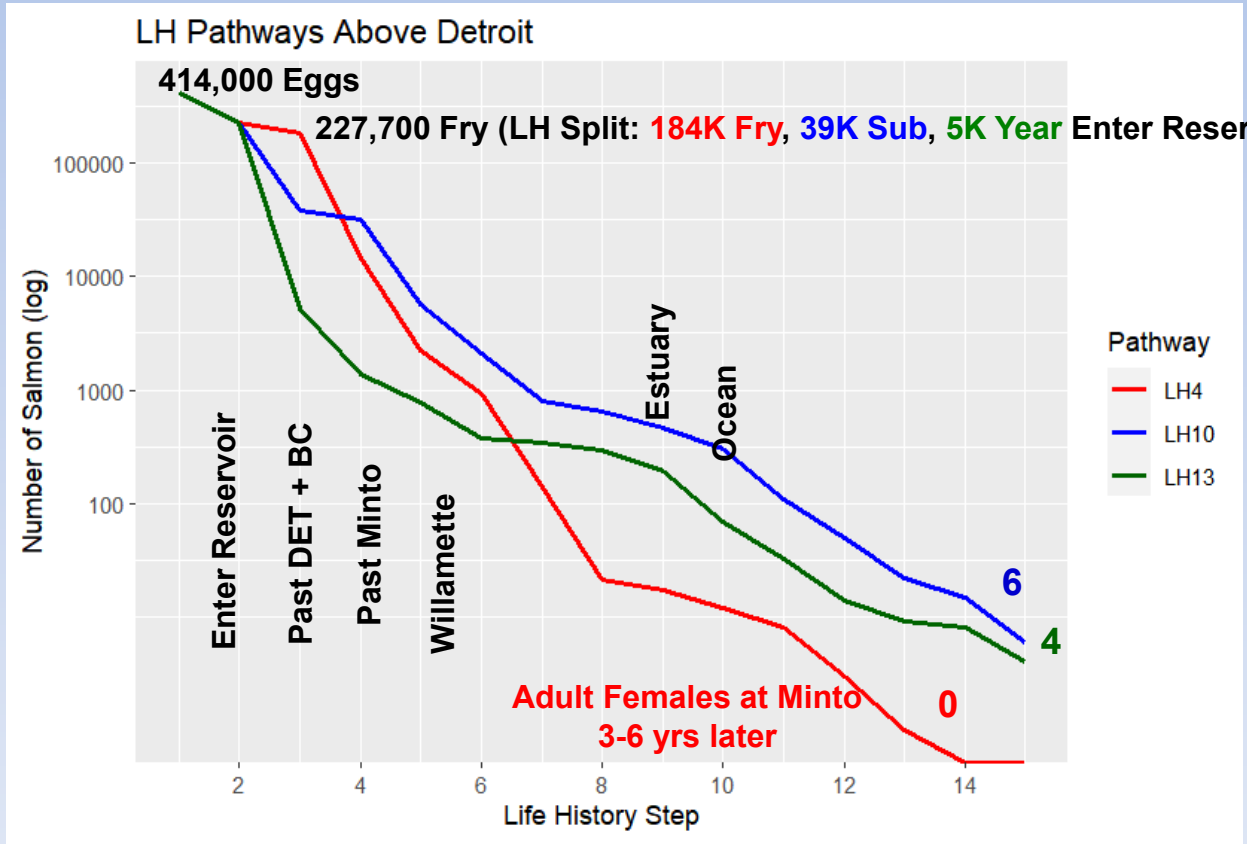
Detroit + Big Cliff Fry Passage Survival



USACE FBW Appendix K. (2015)

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



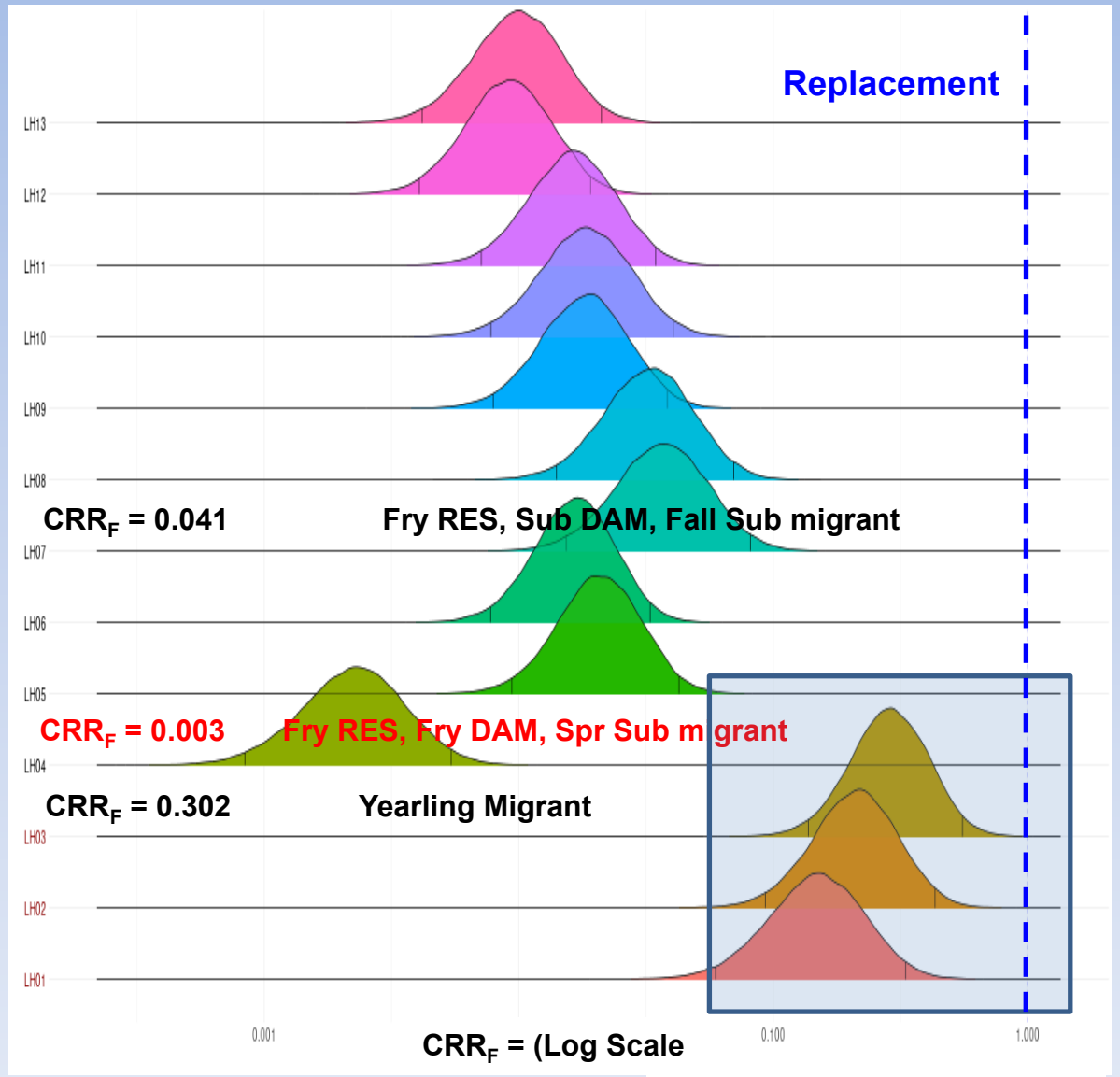
SpSub Migrant
FaSub Migrant
Yearling

3 Pathways
CRR = 10/100
= 0.10

University of Idaho
College of Natural Resources

North Santiam: Fractional CRRs

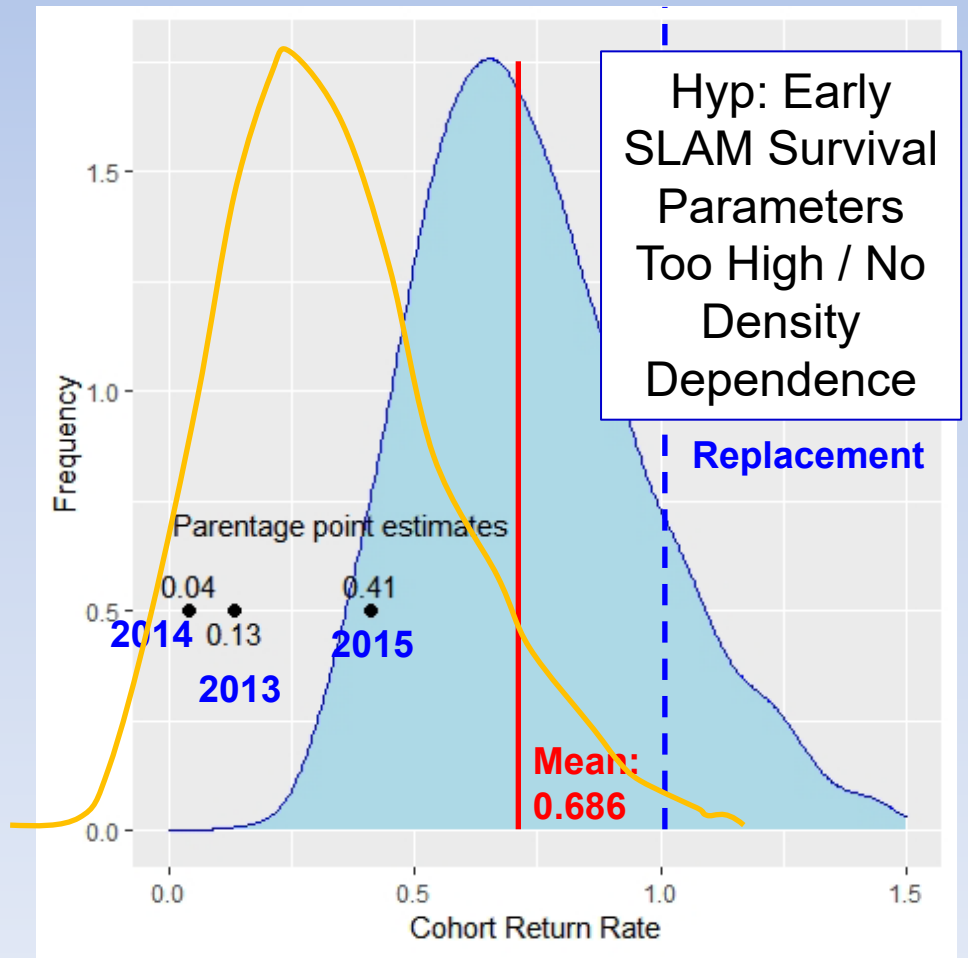
- Relative Performance Metric,
- 13 Pathways, Equal Outplanting
- Higher CRR_F:
  - 3 Below-Big Cliff Pathways
    - Fewer Survival Hits
  - Larger, Older Fish
    - Survival Advantages in most Reaches
    - Dam Passage an Exception



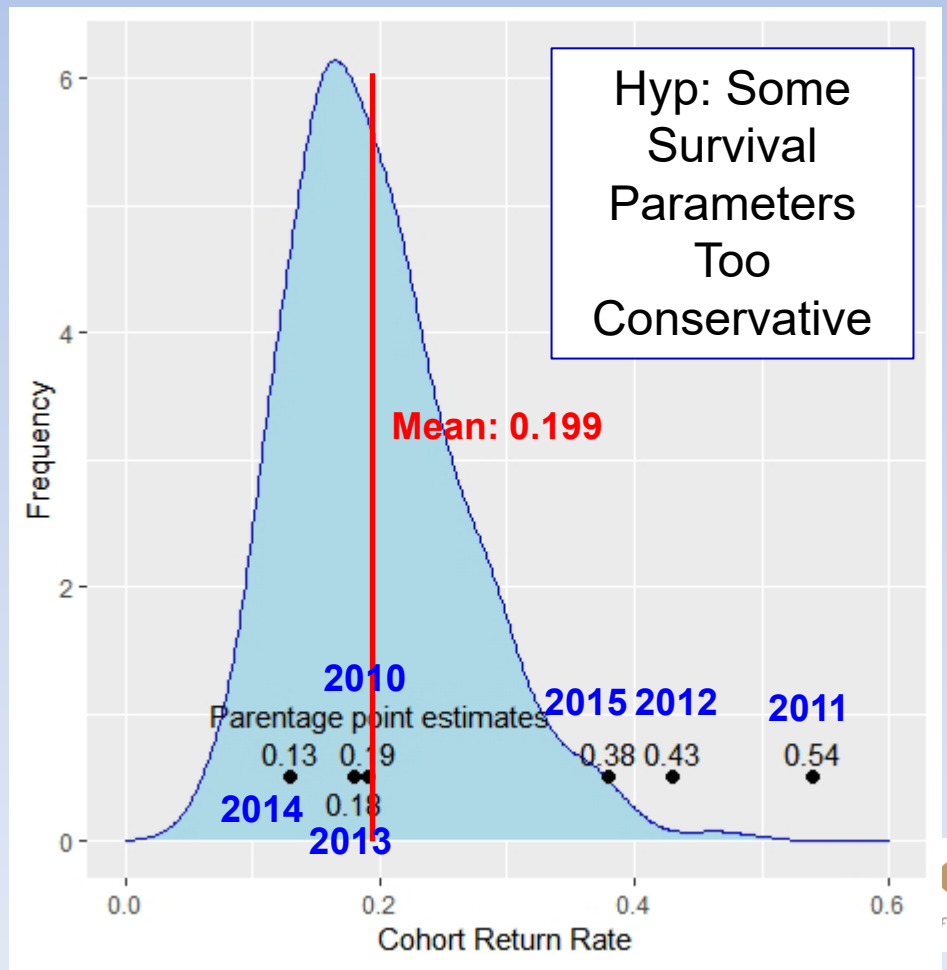
North Santiam: Combined CRR

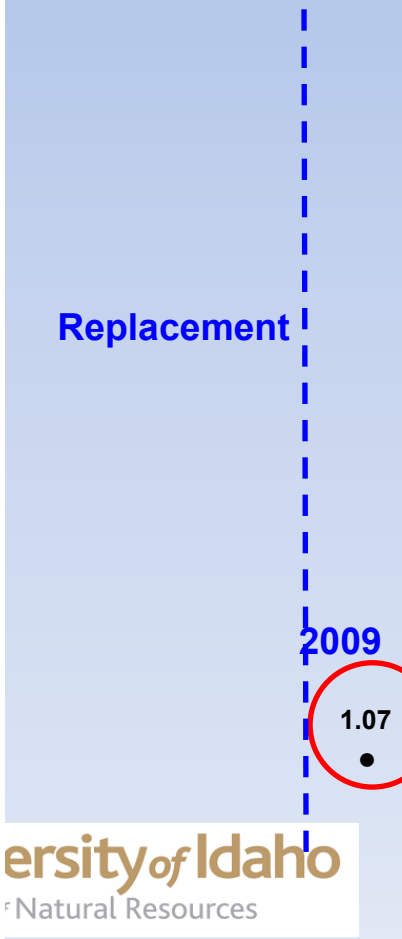
- Sum of Fractional Estimates, 2 Adult Outplant Locations

Outplant Below Big Cliff: 3 LH Pathways



Outplant Above Detroit: 10 LH Pathways

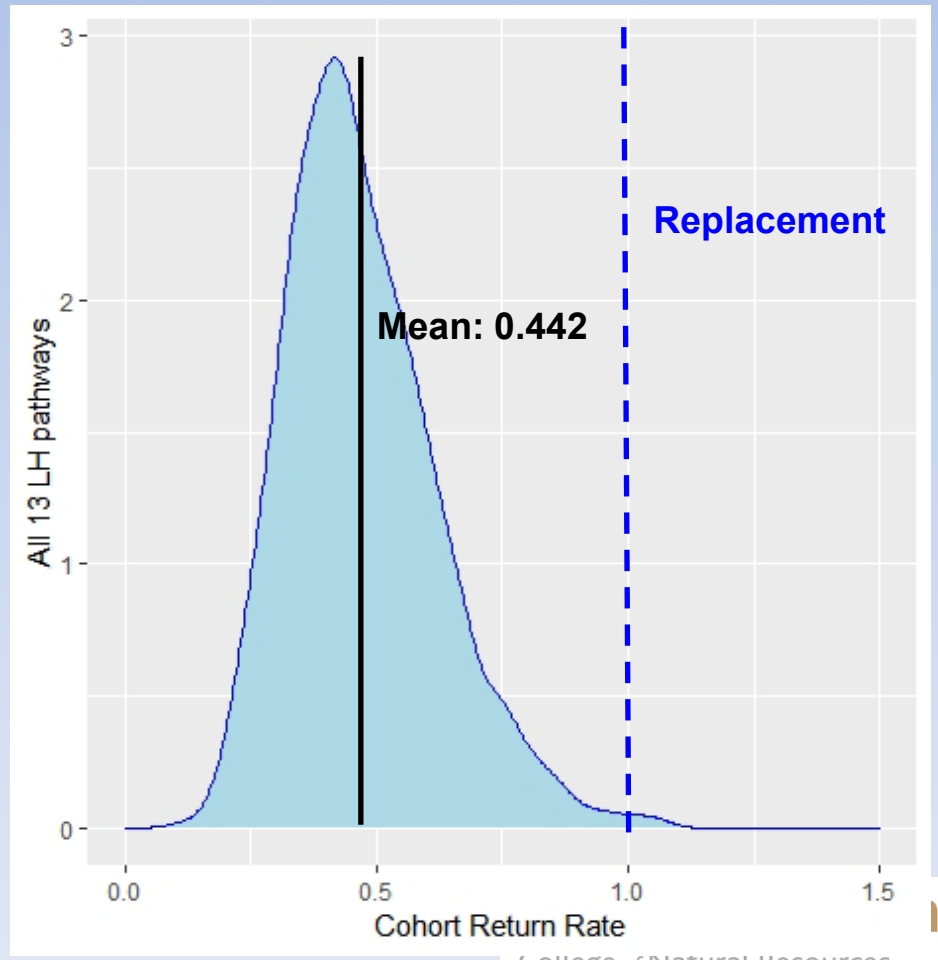




ersity of Idaho
Natural Resources

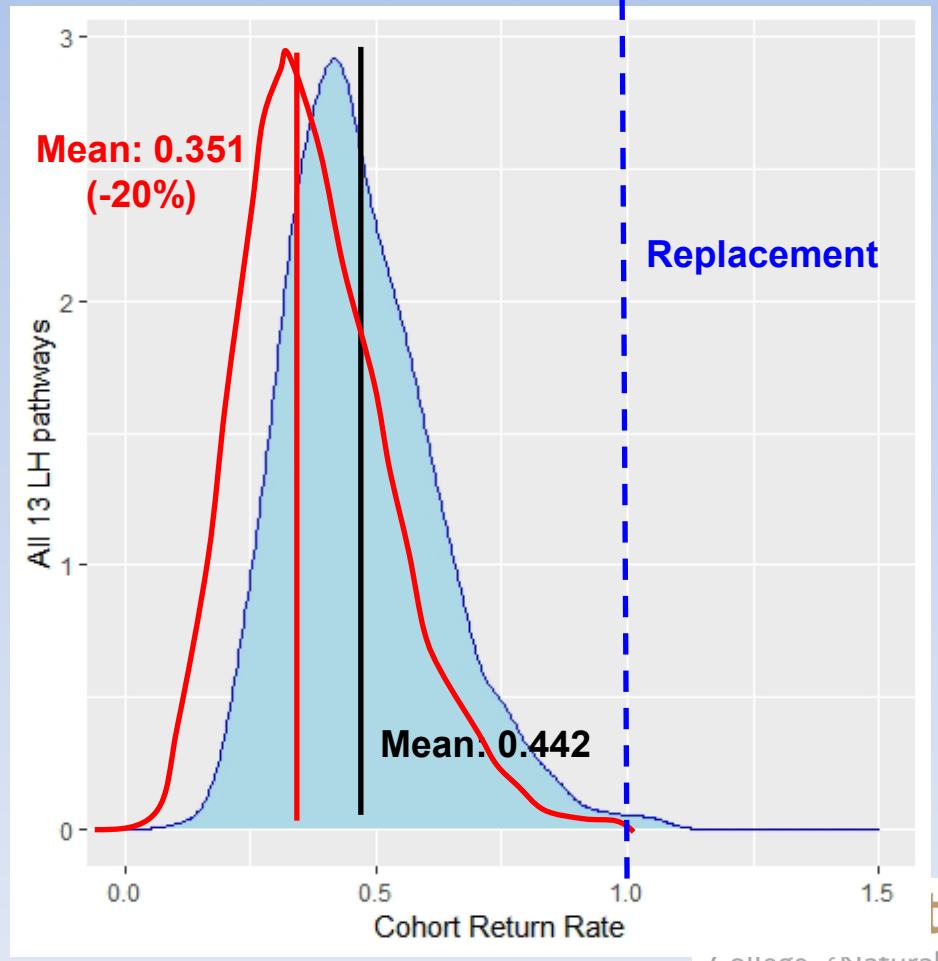
North Santiam: Total CRR

- ‘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



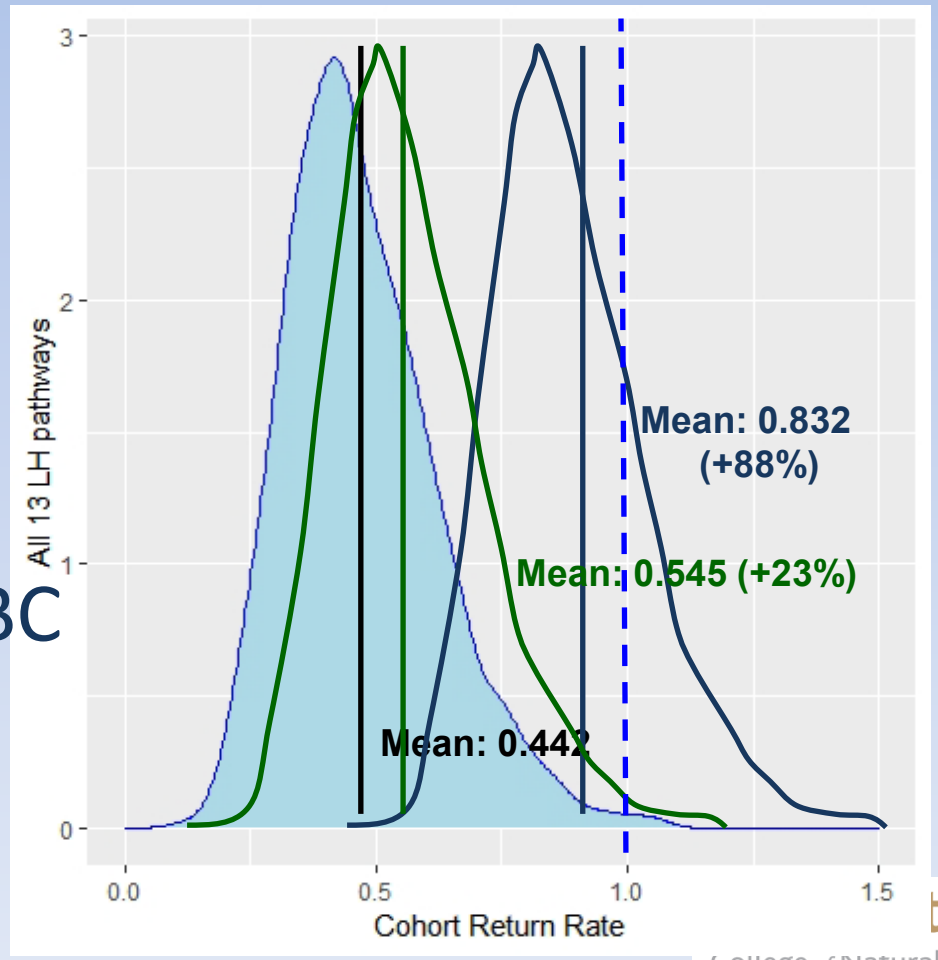
North Santiam: CRR Scenario Testing

- ‘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



University of Idaho
College of Natural Resources

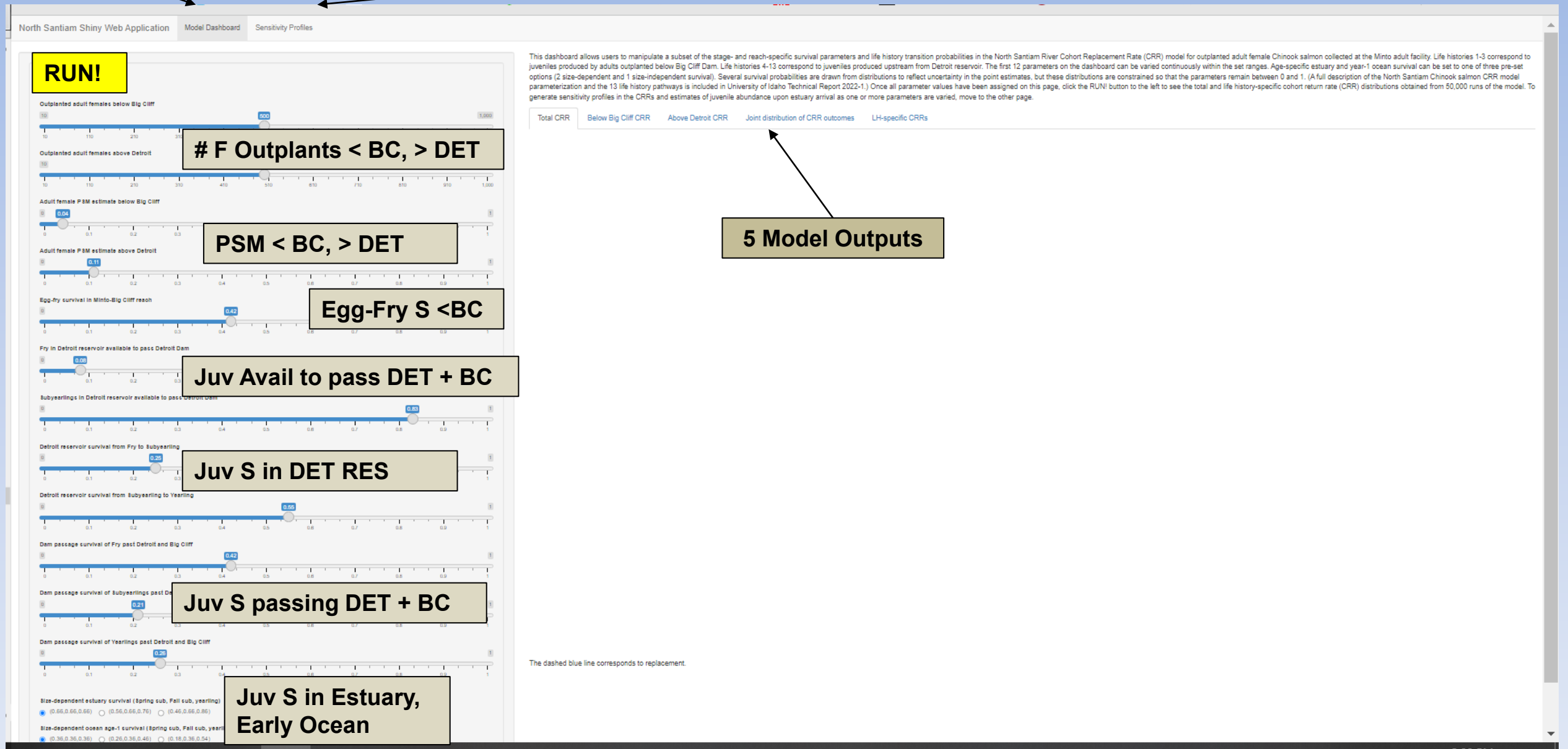
Choose Your Own Adventure: Shiny Apps

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

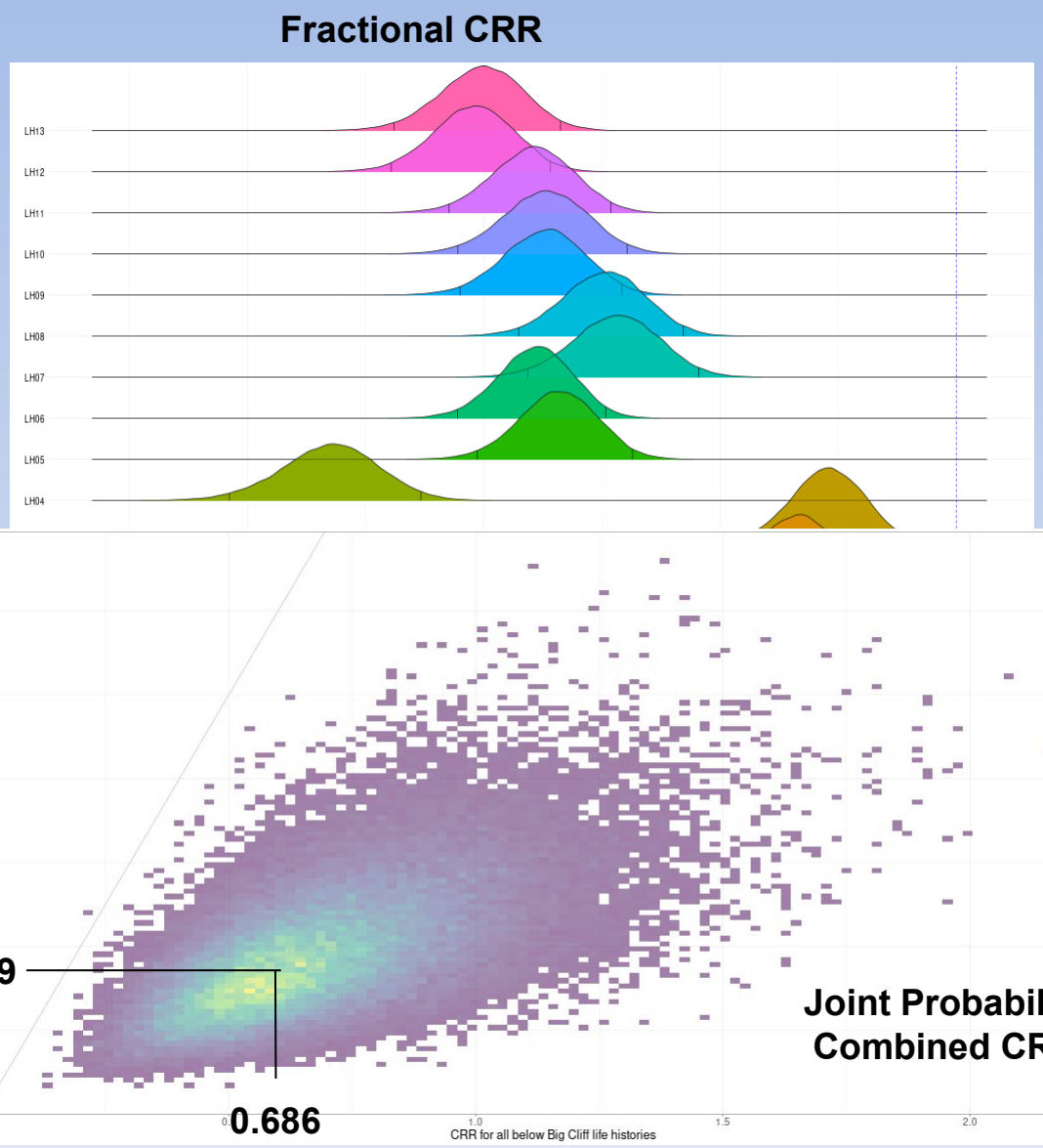
Shiny Apps

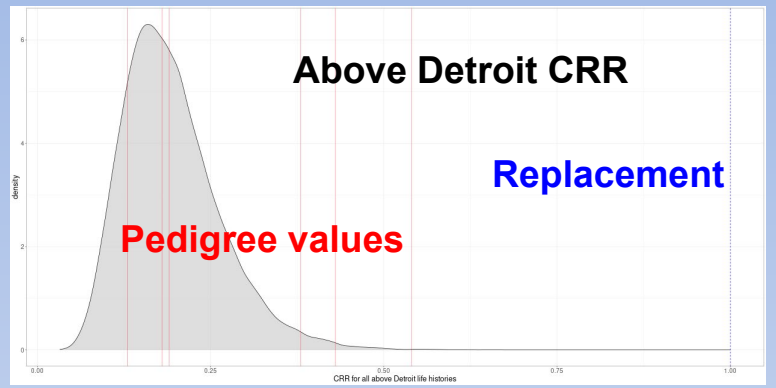
Model Dashboard
50,000 Simulations

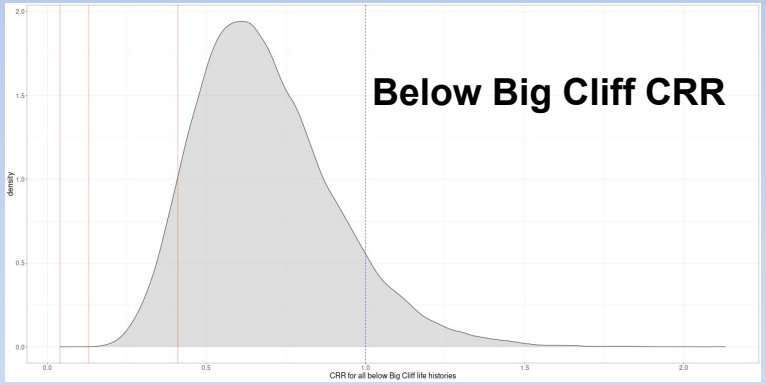
Sensitivity Profiles
500-2500 Simulations

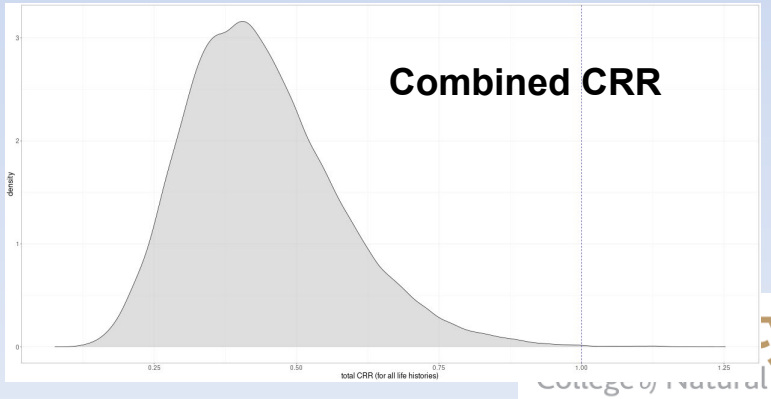


Shiny Apps: Dashboard Output



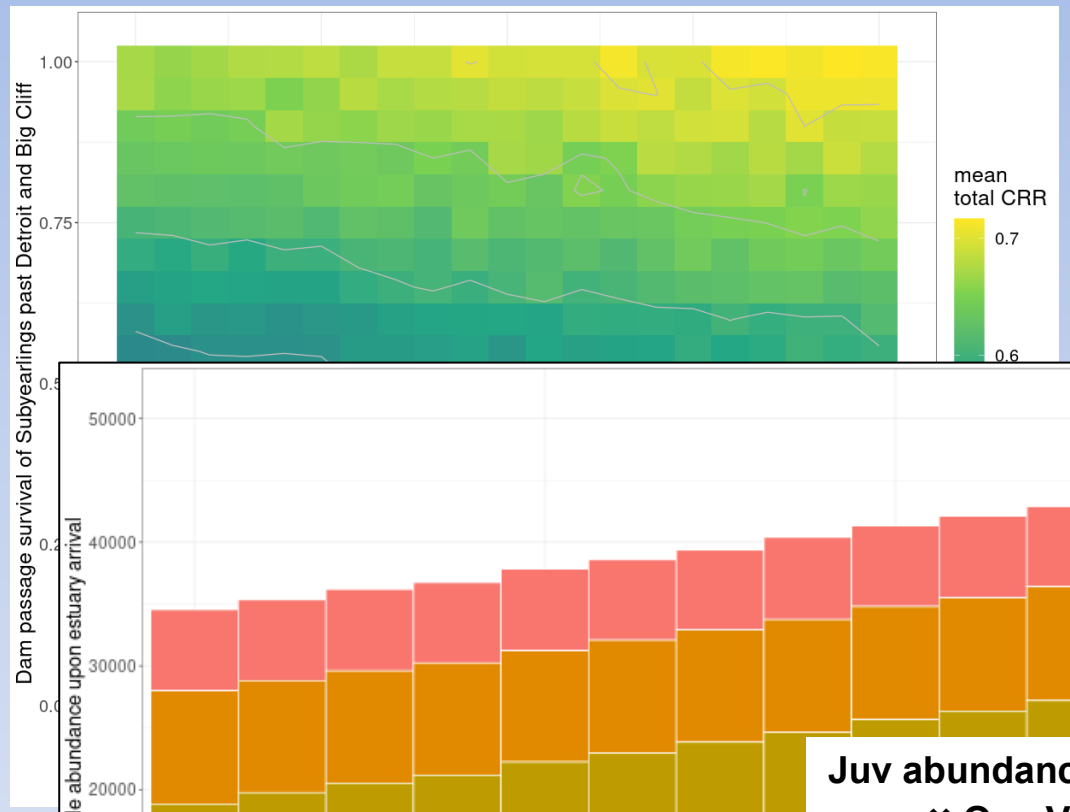




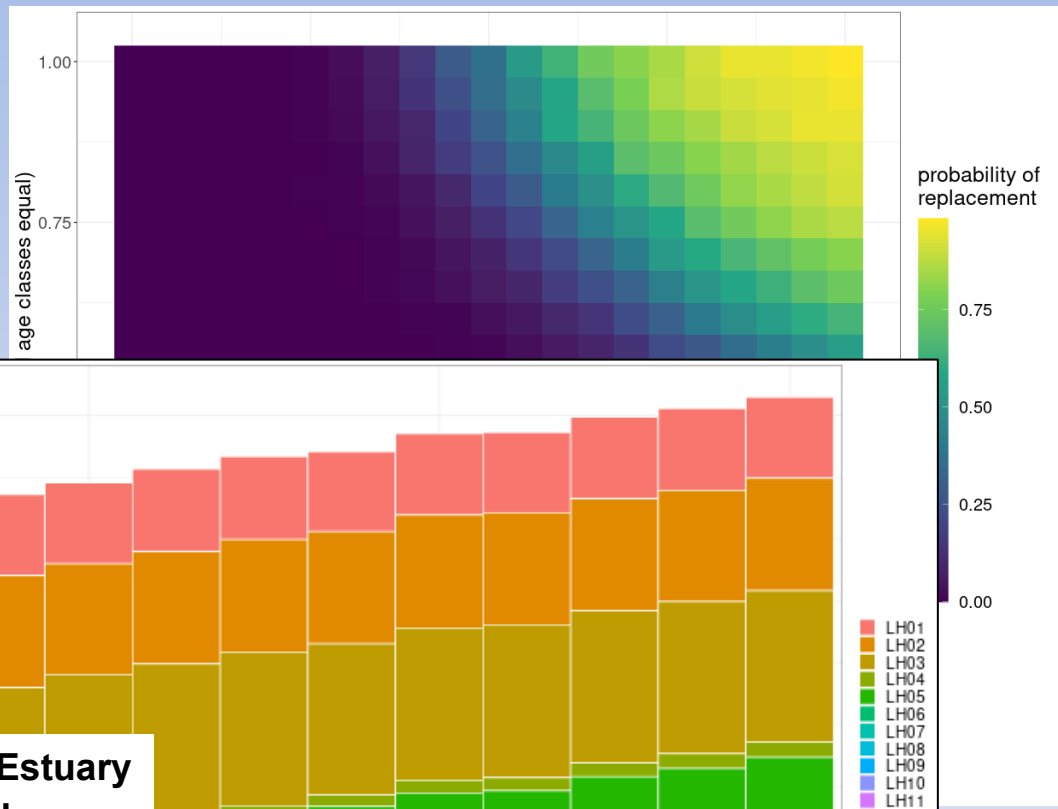


Shiny Apps: Sensitivity Profiles

Combined CRR × Two Variables



Probability of Replacement × Two Variables



Juv abundance in Estuary × One Variable

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