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# Nooksack early Chinook Life Cycle Model

WRIA1 SRST

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# Outline

- Background and objectives
- Overview of the Nooksack LCM framework
  - Parameterization and inputs
  - Graphical User Interface
  - Sandbox and scenario utilities
  - Live Demo
- Next steps and Future Refinements
- Questions

# Background

- Nooksack supports two early Chinook populations
  - *NF/MF early Chinook*
  - *SF early Chinook*
- Important to recovery of Puget Sound Chinook ESU
- Current escapement well below recovery goals
- Developing LCM to support recovery planning

***Regional Population Trends***

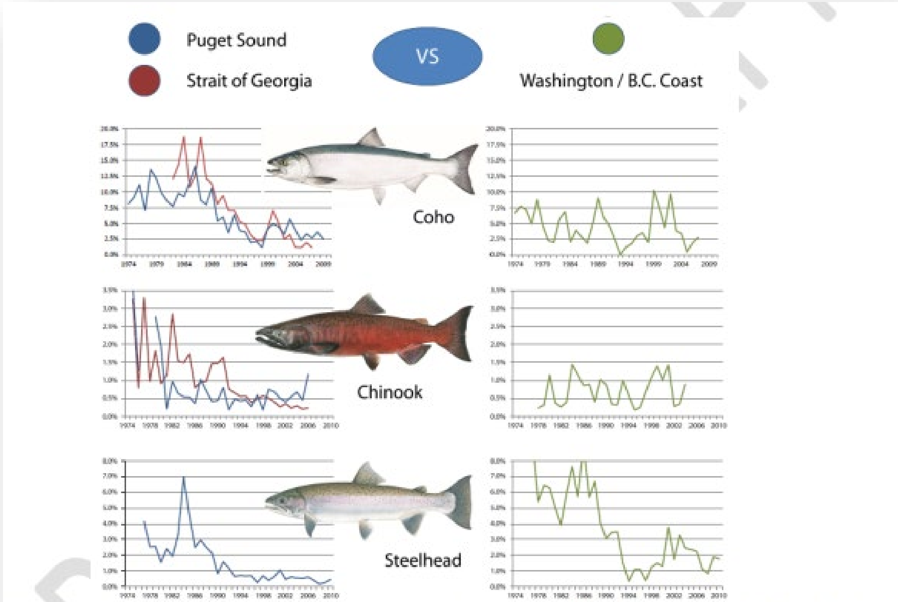
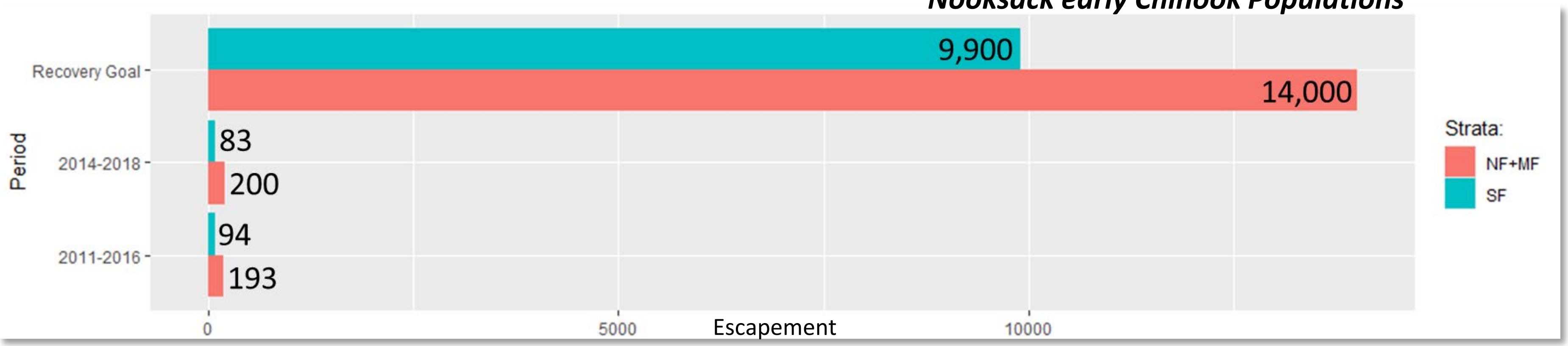



*Figure 24. Marine survival rates over recent decades for Coho salmon, Chinook salmon, and steelhead from Puget Sound and Strait of Georgia and the Washington/British Columbia coast.* Source: (LLTK & PSF, 2019)

***Nooksack early Chinook Populations***



# Nooksack early Chinook LCM Objectives

(1) Incorporates existing habitat status and trends data/metrics, prioritizes local data where available
(2) Encompasses the entire Chinook life cycle
(3) Outputs for adult and smolt abundance and productivity, at a minimum, and diversity and spatial structure metrics, if possible;
(4) Supports identification of limiting factors and prioritization of restoration strategies;
(5) Provides estimates of population effects of watershed-scale or broad management and climate change scenarios, while having sufficient spatial resolution to support restoration planning,
(6) Is easily used, maintained, and updated by appropriately trained or qualified staff; and
(7) Provides transparency with model inputs and calculations being easily tracked and examined by qualified staff.

# Nooksack early Chinook LCM

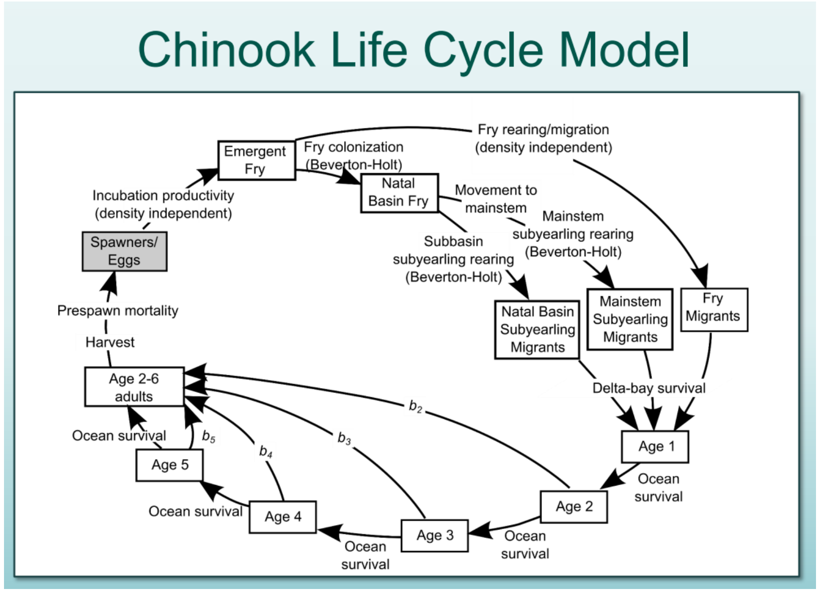
Framework

# LCM Framework: Overall structure

***Multistage Beverton-Holt Model***

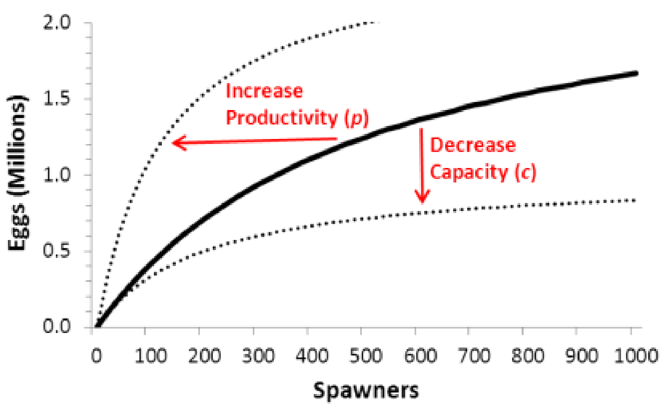
- *Models transitions between life stages*
- *Includes capacity and productivity functions*
- *Can be linked to multiple inputs*
- *Integrates full life cycle*

***NOAA HARP Model Example***




*Nooksack early Chinook LCM based primarily on NOAA HARP approach*

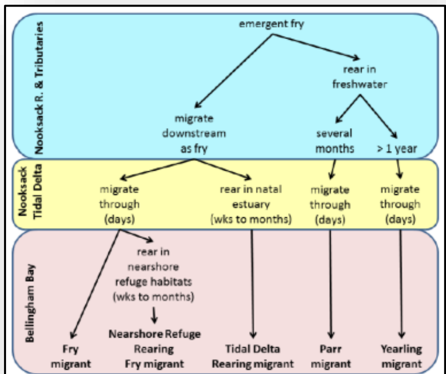
***Beverton-Holt Stock-recruitment model example***



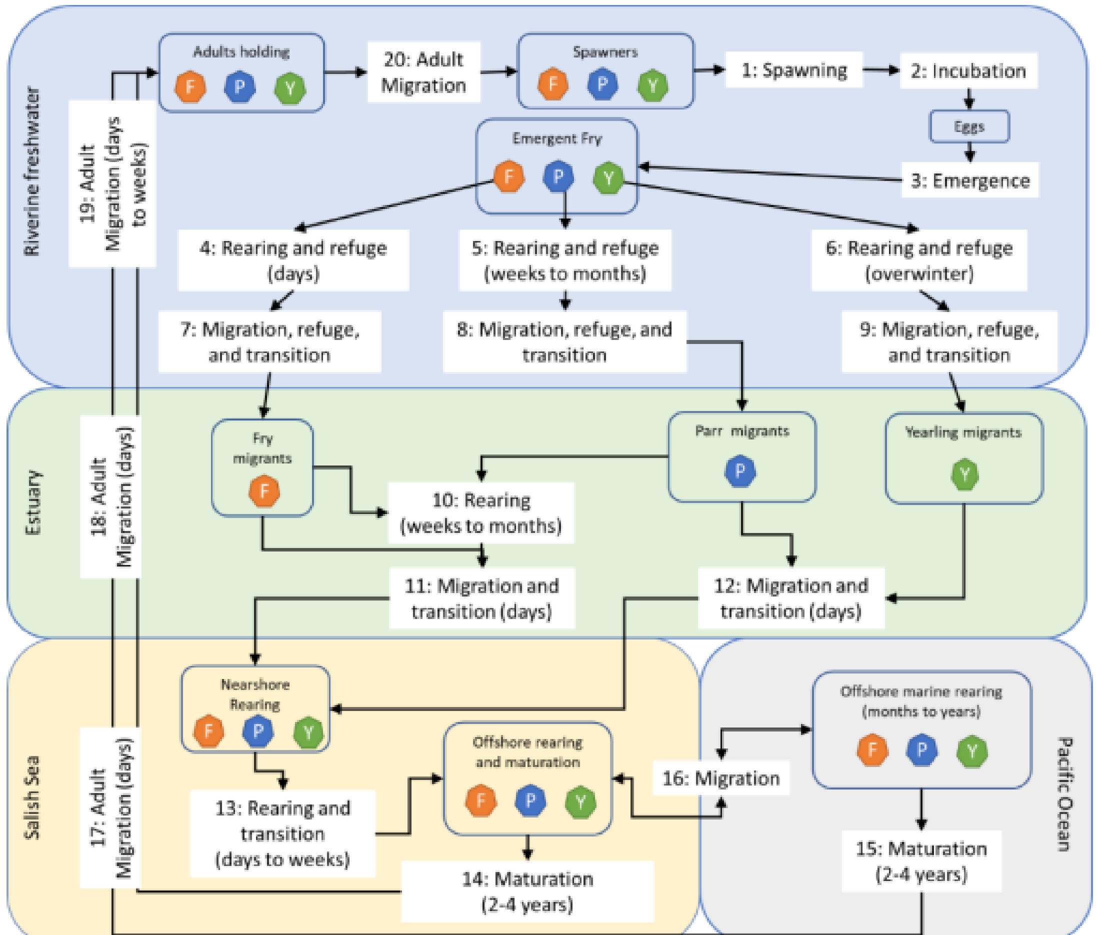

$$N_{s+1} = \frac{N_s}{\frac{1}{p_{s\rightarrow s+1}} + \frac{1}{c_{s+1}} N_s}$$

# LCM Framework: Full life cycle and diversity

***Conceptual models from Beamer and Greene***




***Spatially and temporally explicit life cycle diagram for Nooksack early Chinook LCM***




***Juvenile Life History Diversity***

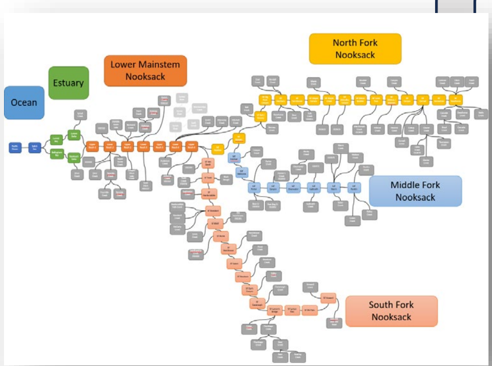
- F *Fry migrants*
- P *Parr migrants*
- Y *Yearling migrants*

# LCM Framework: Spatially Explicit

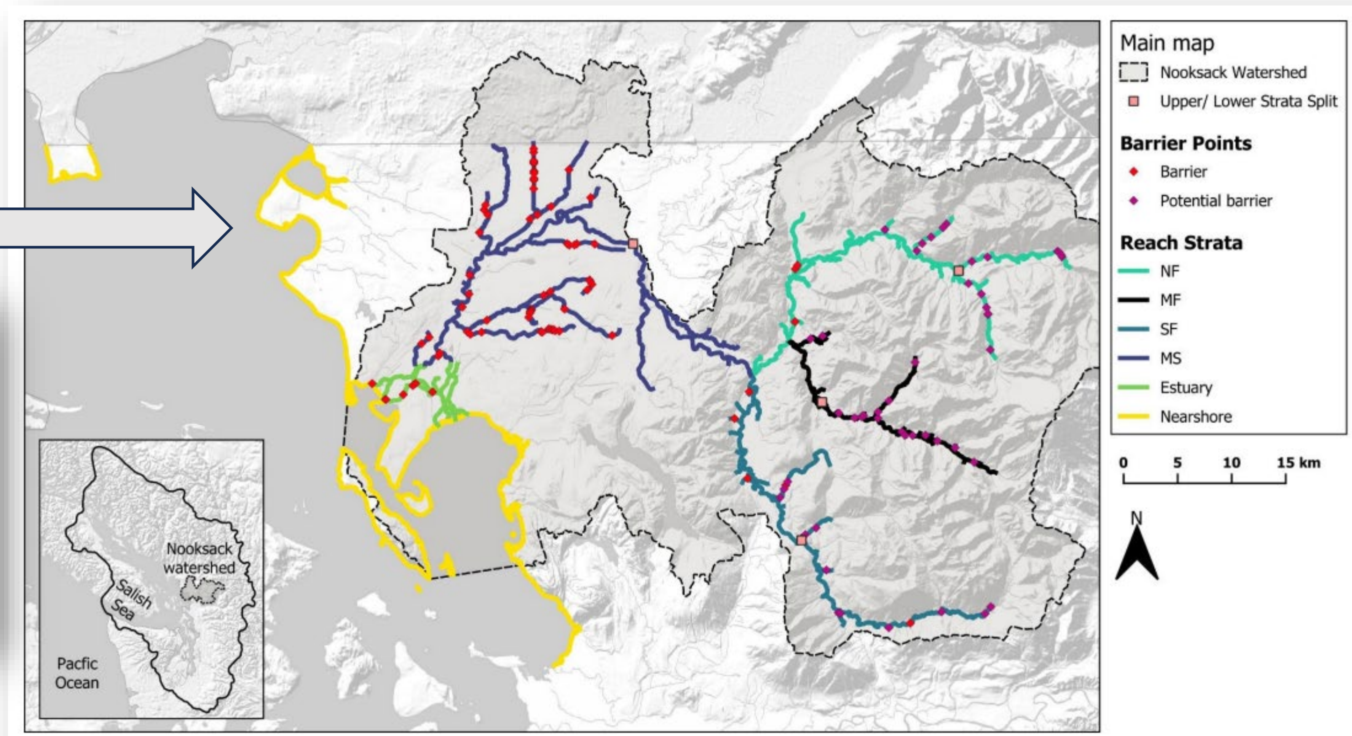
***Reach-scale network:***

- *Consistent with recovery and restoration reaches*
- *Functions as routed network*
- *Works with fry cascade model*

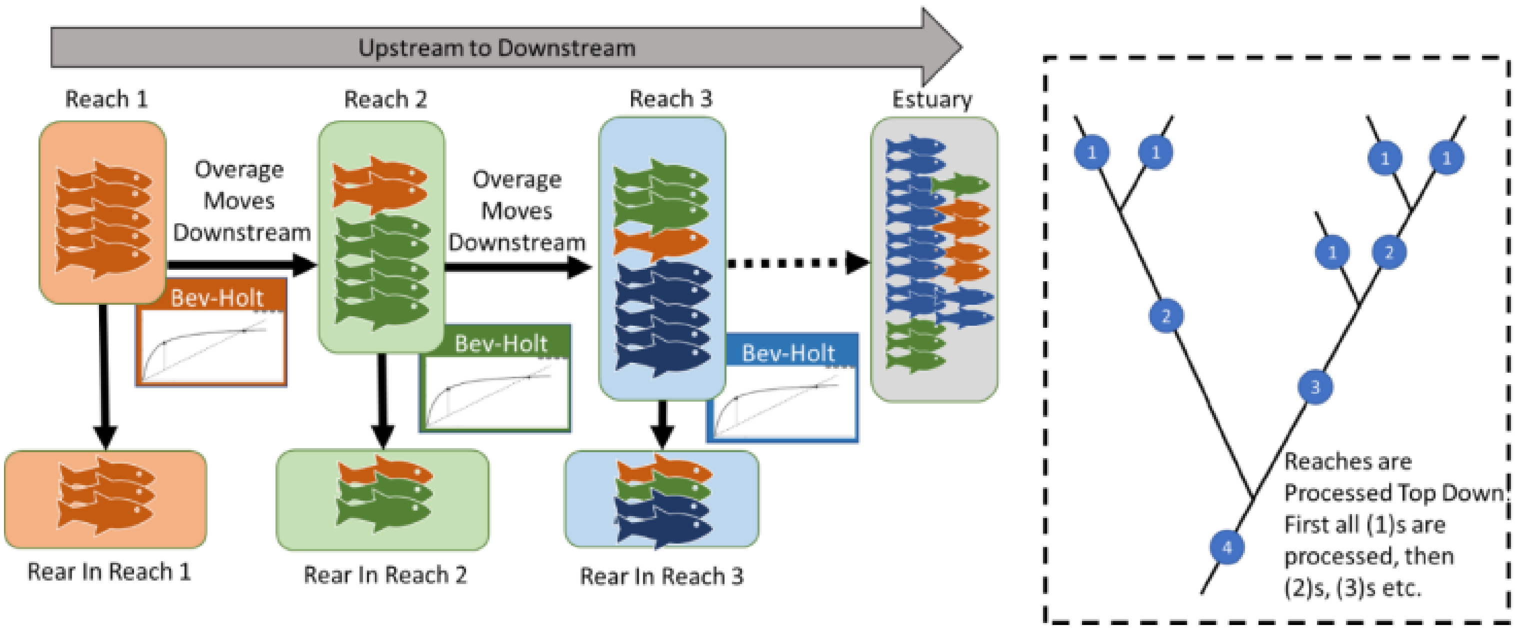
***Network Representation of Spatial Structure***




***Reaches within geographic strata including tributary network***



# LCM Framework: Fry cascade

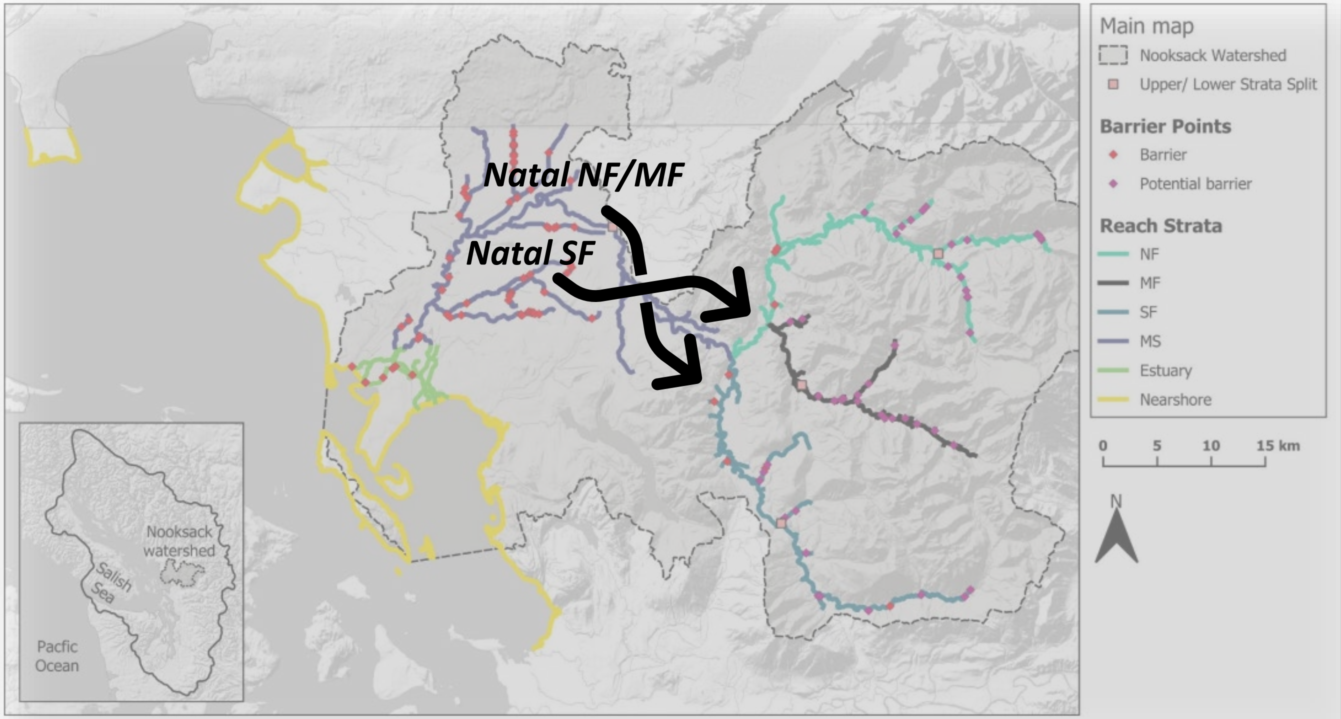



***Refinement from HARP-Based Approach:***

- *Allows for reach-scale use of capacity to move fish through system and drive life history expression and productivity*
- *Combined with cohort tracking allows for spatially explicit tracking of cohorts and populations*
- *Supports identification and prioritization of limiting factors*

# LCM Framework: Straying

***Strata-Scale Straying***

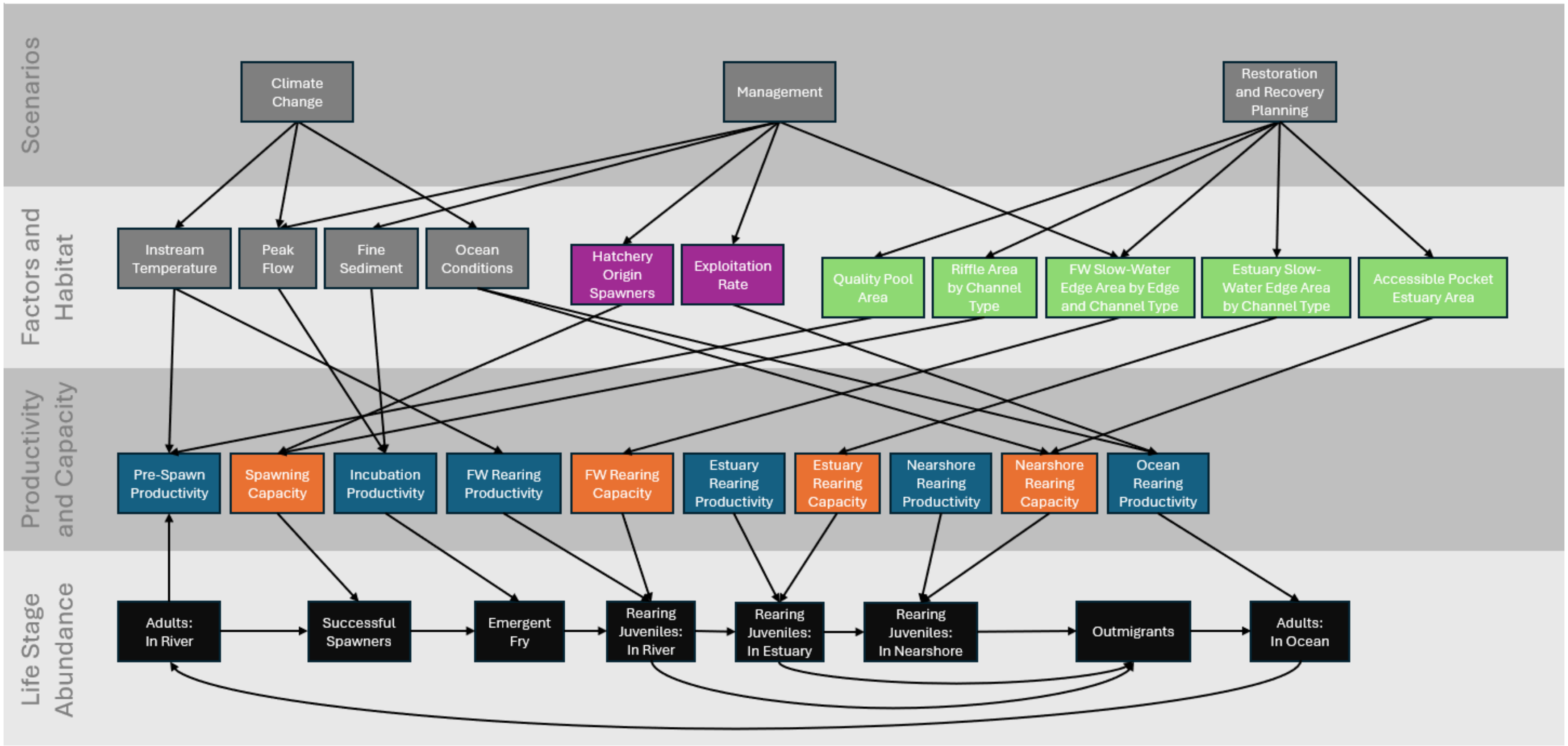



***The LCM includes straying functions at two scales:***

- *Strata scale straying – between forks*
- *Reach-scale straying – within forks between reaches*

# Inputs and Scenarios:

- *Capacity and Productivity functions linked to HS&T Monitoring and Recovery Targets*
- *Scenarios to support recovery planning and evaluation – identify limiting factors*



# Freshwater habitat and life stages

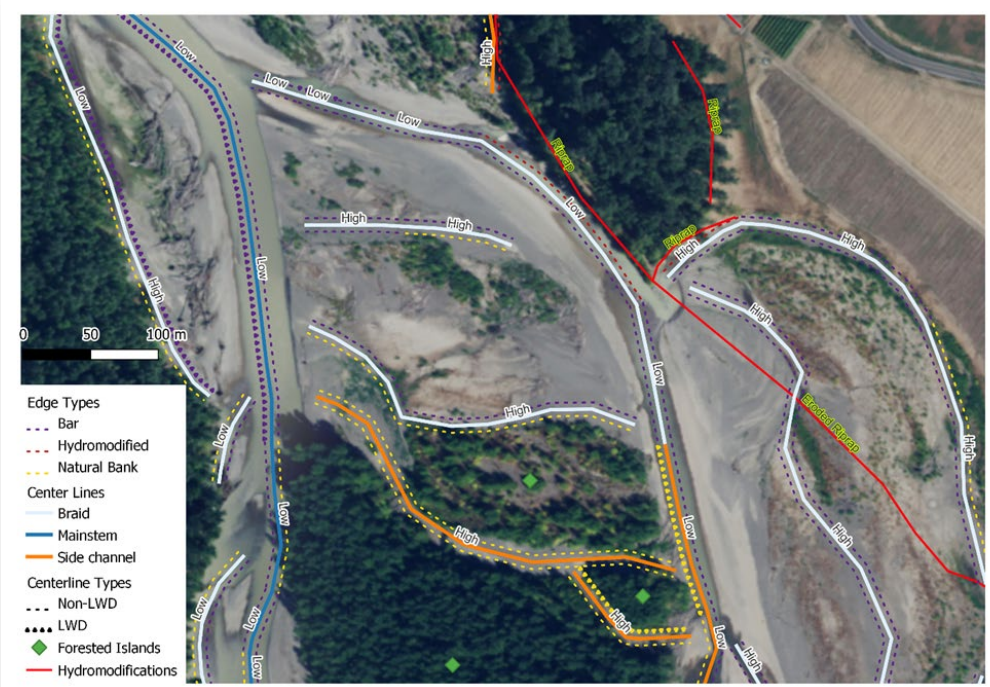
**Key concepts:**

- *Early run-timed adults rely on holding habitat, and quality pool habitat reduces pre-spawn mortality*
- *Available spawning habitat and quality drives spawning capacity*
- *Prespawn mortality driven by temperature*
- *Flows, fine sediment, and spawning location drive incubation productivity*
- *Slow-water edge habitat and edge type drive rearing capacities*
- *Rearing and life history expression are density-dependent, which drives production of fry migrants and natal rearing*

# Freshwater habitat and life stages

- Digitized habitat from **2017** low flow imagery
  - *Channel types*
  - *Edge type (RB/LB)*
  - *Width*
  - *Summer low flow and winter flow*
- Integrated data from habitat assessments
  - *Quality pool area*
  - *Riffle habitat area*
  - *Slow-water edge width by edge type*

***Example of digitized habitat features***




**Provided consistent habitat inputs for entire Nooksack watershed**

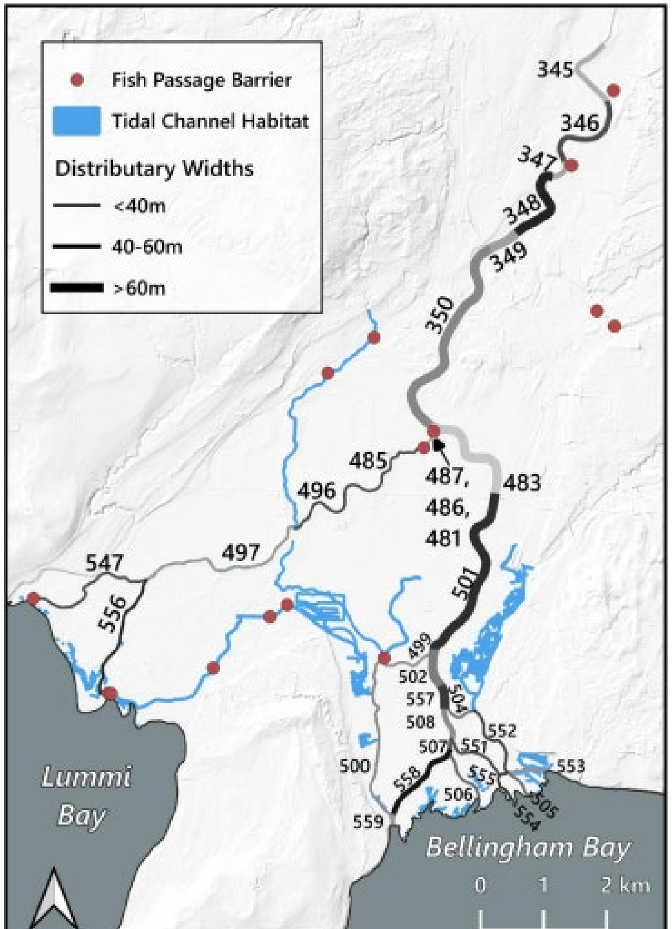
# Estuary And Nearshore Habitat

**Key concepts:**

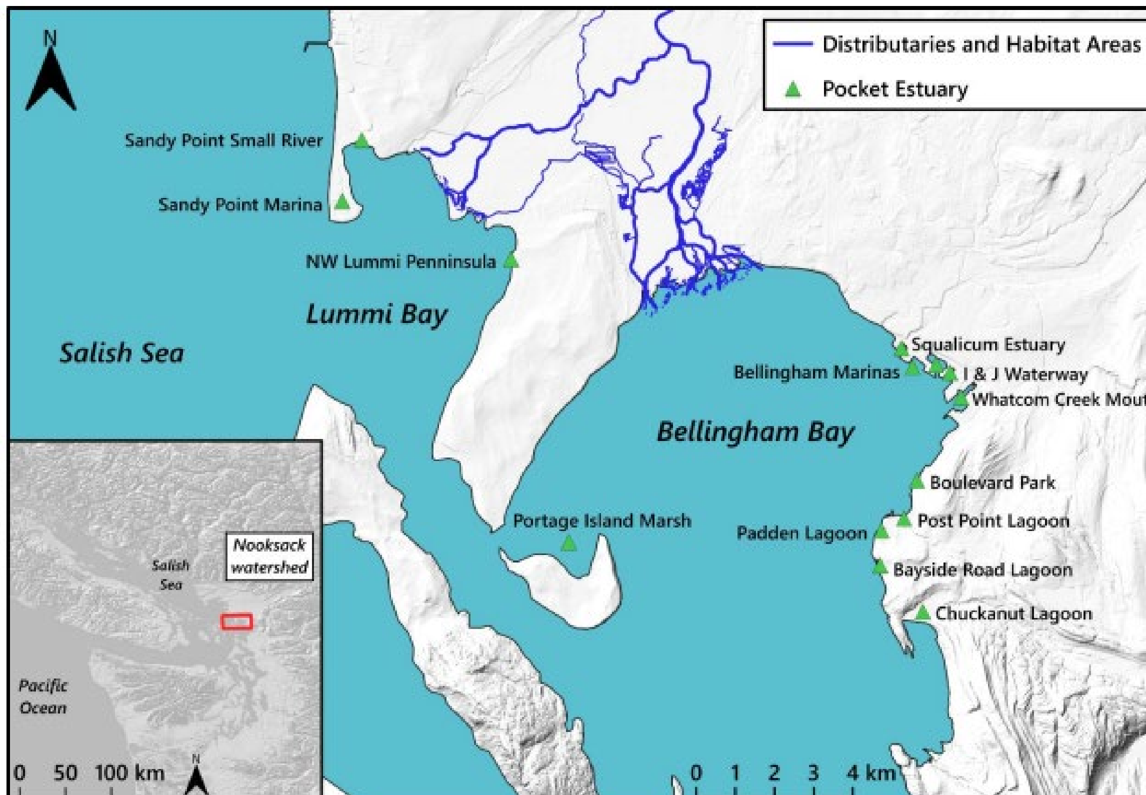
- *Juvenile Chinook densities strongly related to landscape connectivity*
- *Habitat availability along fish paths drive estuary rearing capacity*
- *Estuary habitat supports rearing for fry migrants – linked to freshwater rearing capacity and migrant fry production*
- *Pocket estuaries provide alternative rearing habitat for "surplus" migrant fry*
- *Pocket estuary rearing capacities driven by accessible habitat area*

# Estuary and Nearshore Habitat

***Distributary network used to route fish through estuary***




***Mapped "pocket estuary" habitats***



# Ocean/Marine Life Stages

**Key concepts:**

- *Life history type drives survival to adult return – size selective mortality*
- *Marine survival also linked to exploitation rates and ocean productivity*
- *Age structure and maturation rates drive year of return for cohorts*

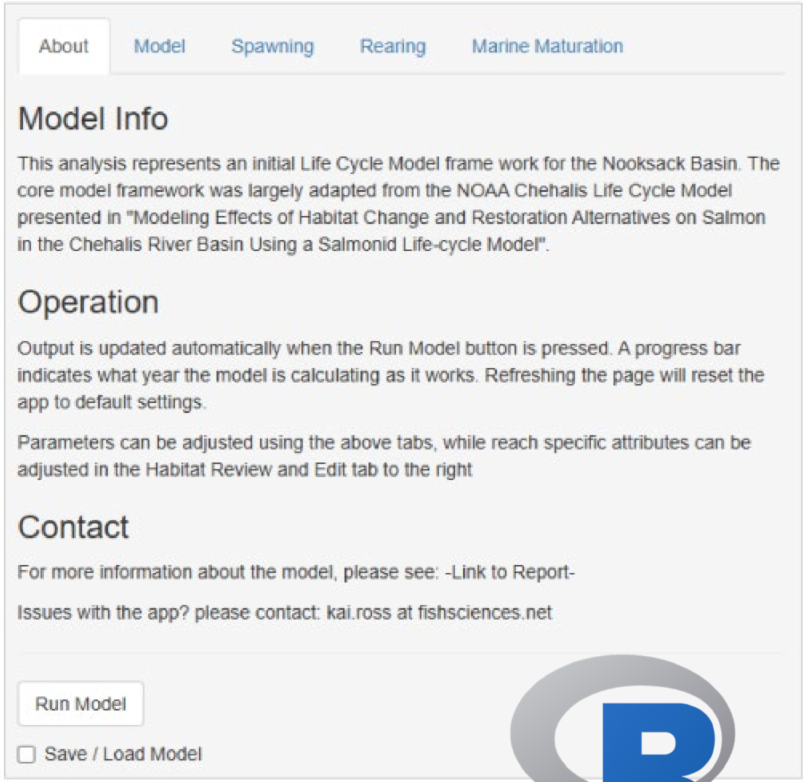
# Nooksack early Chinook LCM

Graphical User Interface

# Graphical User Interface

- R Shiny App contains entire analysis and code!
  - *Accessible online without any required software or input files*
  - *R code can be run without GUI as well*
- GUI allows for easy manipulation of model parameters
  - *Initial values provided with suggestions for ranges to consider*
  - *Save/load utilities*
- Sandbox utilities and scenario tools
  - *User editable inputs for custom scenarios*
  - *Predefined scenarios*
  - *Includes tabular, field, and spatial interfaces!*

***RShiny GUI***



# Sandbox utilities and scenarios

- **Sandbox utilities**
  - *User adjustable inputs/functions*
  - *Supports dynamic sandbox environment*
  - *Custom scenarios/simulations*
    - *Including bulk adjustment*
  - *Evaluate sensitivities and uncertainty*
- **Scenarios**
  - *Predefined scenarios*
  - *Focused on three key areas:*
    1. *Restoration and recovery planning,*
    2. *Management,*
    3. *Climate change*

# Scenarios

***1: Restoration and Recovery Planning Scenarios***

- 1.1 DFC Scenarios
- 1.2 Restoration implementation planning
- 1.3 Barriers and distribution
- 1.4 Historical condition

***2: Climate Change Scenarios***

- 2.1 Instream temperatures
- 2.2 Peak flow recurrence intervals

Note that all scenarios have not yet been implemented.

# Quick GUI Demo

# Nooksack early Chinook LCM

## Summary of Findings

# Key Findings

- Model tuned to current escapement patterns
  - *Usable spawning habitat multiplier*
  - *Rearing capacities*
- Represents conditions circa 2017
- Produces expected model behavior and life history variations
- Supports identification of limiting factors/stages

***Example Output from Baseline Model***

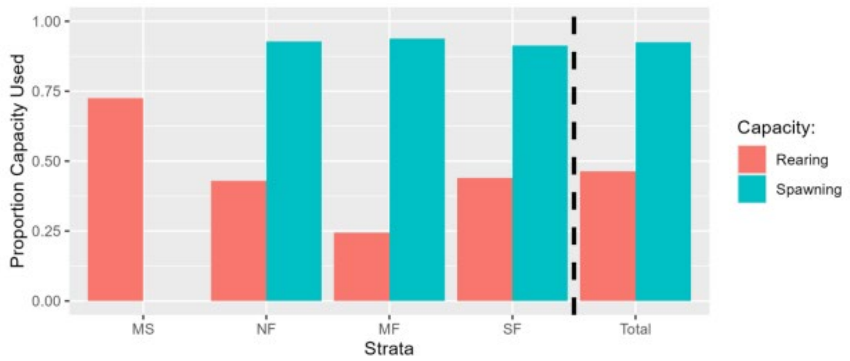
| Life Stage | NF | MF | SF | Total |
|---|---|---|---|---|
| Spawner | 140 | 60 | 84 | 284 |
| Emergent Fry | 18798 | 7130 | 9723 | 35651 |
| Natal Basin Fry | 2102 | 1667 | 2240 | 6009 |
| Mainstem Fry | 12581 | 4017 | 6796 | 23394 |
| Estuary Rearing Fry | 2609 | 917 | 436 | 3962 |
| Pocket Estuary Rearing Fry | 1265 | 445 | 211 | 1921 |
| Fry Migrants | 242 | 85 | 40 | 367 |
| Natal Basin Subyearling | 1617 | 1318 | 1753 | 4688 |
| Mainstem Subyearling | 9527 | 3057 | 5151 | 17735 |
| Subyearling Estuary | 1556 | 547 | 260 | 2363 |
| Subyearling Pocket Estuary | 1192 | 419 | 199 | 1810 |
| Natal Basin Yearling | 186 | 149 | 200 | 535 |
| Mainstem Yearling | 1066 | 342 | 576 | 1984 |
| Adults at age-1 | 533 | 205 | 283 | 1021 |
| Adults at age-2 | 884 | 342 | 516 | 1742 |
| Adults at age-3 | 413 | 160 | 240 | 813 |
| Adults at age-4 | 45 | 19 | 28 | 92 |
| Adults at age-5 | 9 | 5 | 5 | 19 |
| Returning Adults | 374 | 181 | 286 | 841 |
| Smolts per Spawner | 99.23 | 89.02 | 87.65 | 93.65 |

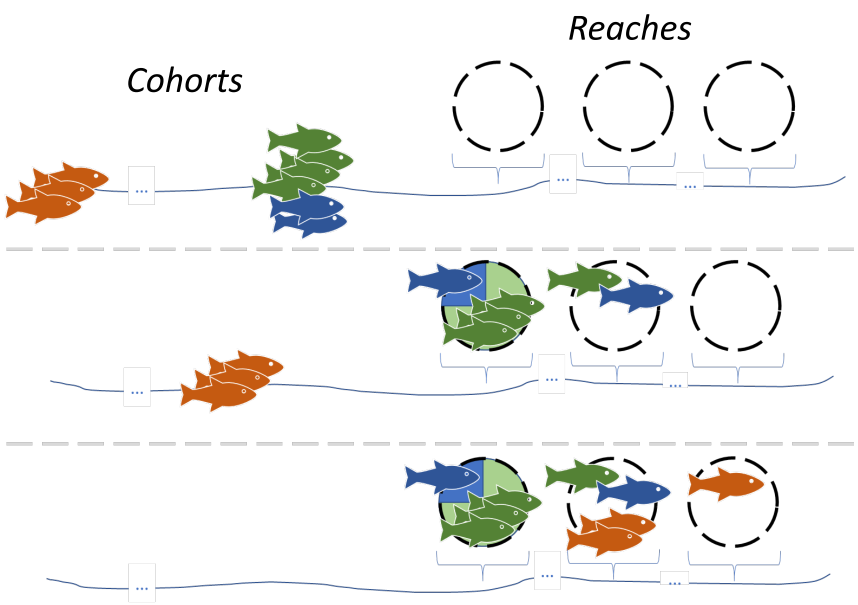
# Key Findings

Example #1:

- *Natal fork capacities vs lower mainstem*
- *Populations mix in lower mainstem*
- *Greater proportion of lower mainstem capacity used*
- *Cohort tracking allows identification of bottlenecks*
- *At population, spatial, and temporal scales*

***Example Output from Baseline Model***



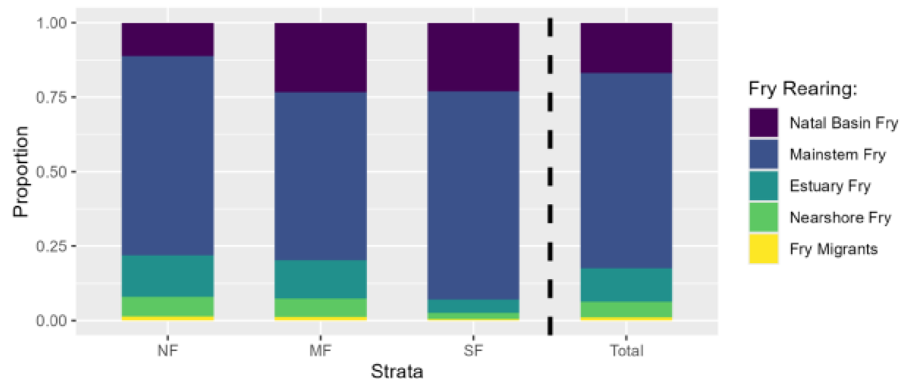

***Example of Fry Cascade Driven by Reach Capacities***

# Key Findings

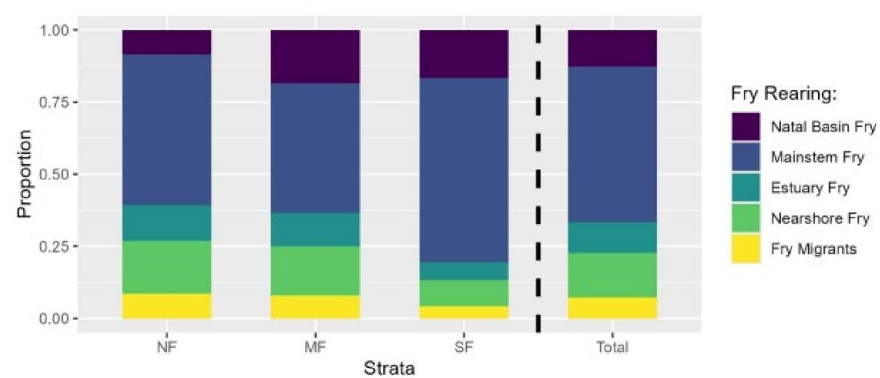
Example #2:

- *Increase emergent fry abundance*
- *Fry migrant production fills up more rearing habitat*
- *Increased production of estuary and nearshore rearing fry*
- *And surplus fry migrants*

***Example Output from Baseline Model***




***Increase Emergent Fry Abundance***



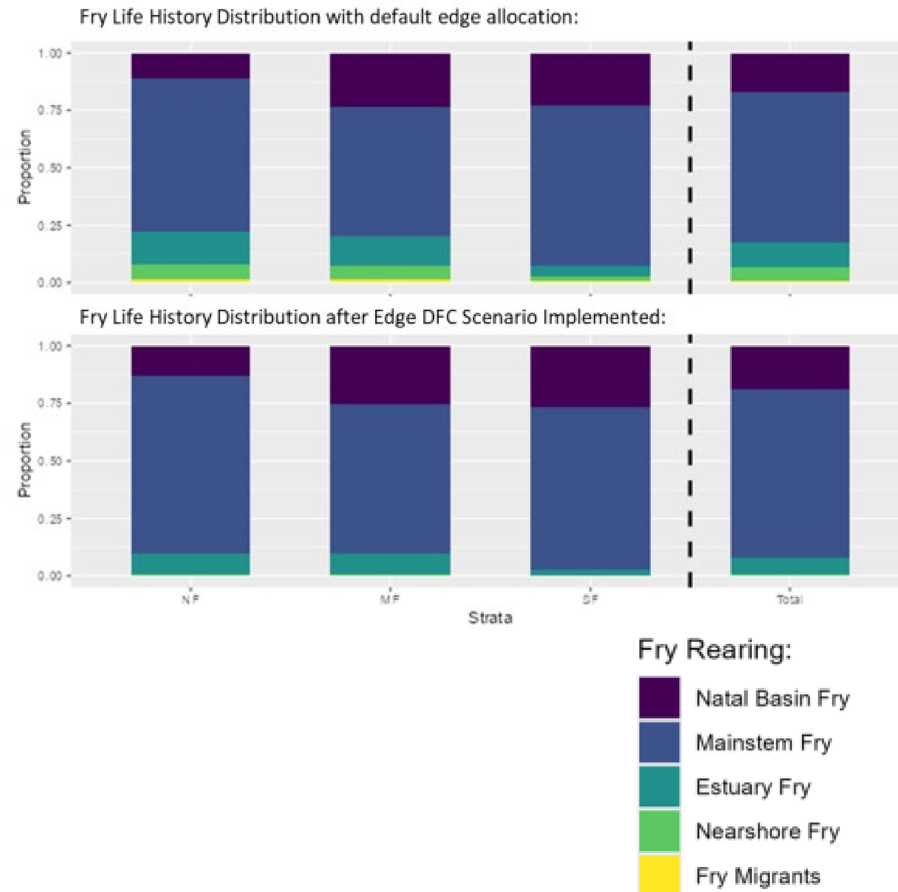

***Increased production of Estuary and Nearshore Rearing Fry, and surplus Fry Migrants***

# Key Findings

Example #3:

- *Scenario comparisons to baseline model*
- *Setting edge conditions to DFC Target (>90% natural edges)*
- *See increases in natal and mainstem rearing and overall parr production*
- *Reduced production of surplus fry migrants*

***Example Output from Baseline Model and DFC Scenario***

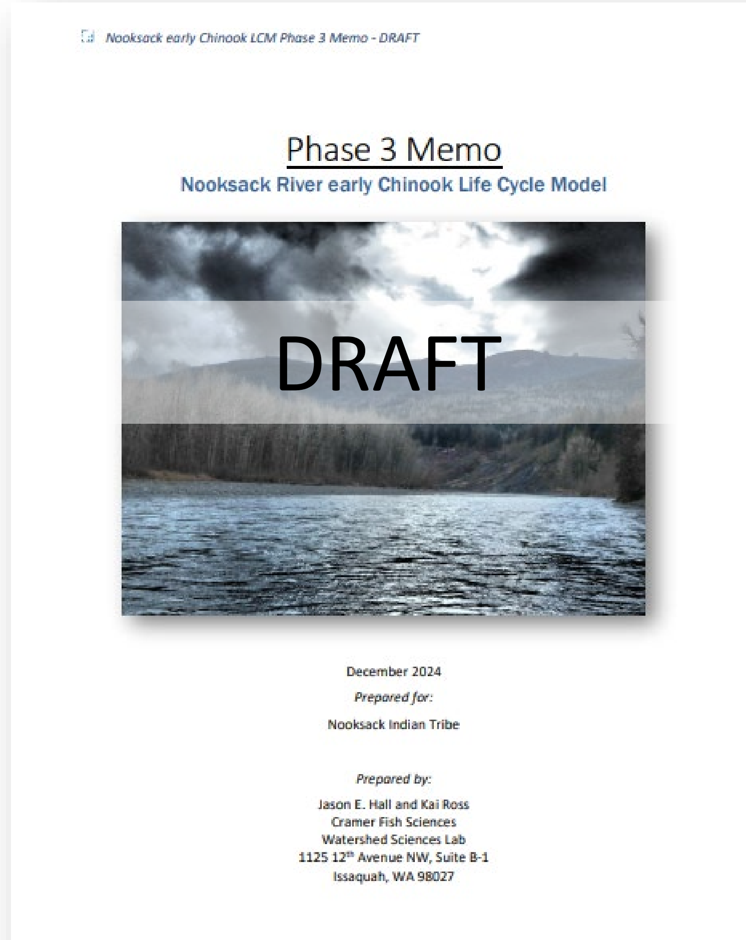


# Nooksack early Chinook LCM

## Next Steps

# Next Steps

- Complete Phase 3 Review and revise report and GUI
- Polish GUI to make a more aesthetic and user-friendly experience
- Address key data gaps and priority refinements identified in Phase 3
- Framing up phase 4 now



*Nooksack early Chinook LCM Phase 3 Memo - DRAFT*

Phase 3 Memo

Nooksack River early Chinook Life Cycle Model

DRAFT

December 2024

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# Questions?

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