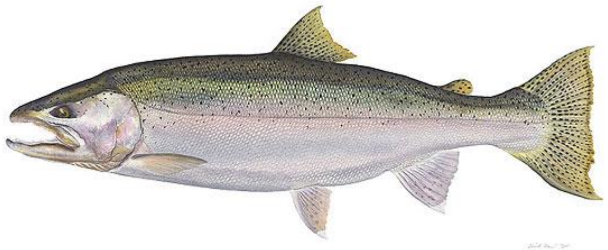
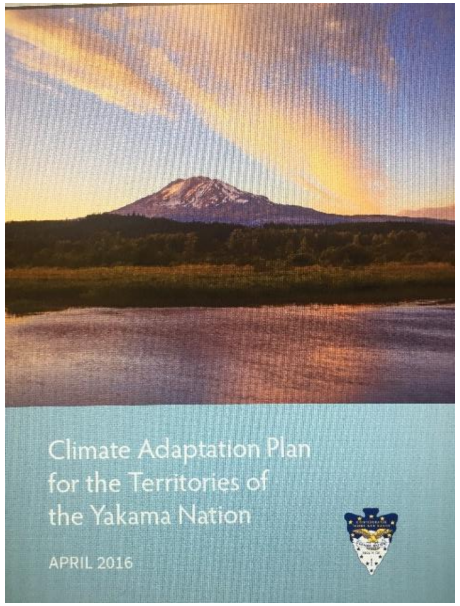
  

Life-cycle models for Yakima River *O. mykiss*: a tool for evaluating environmental influence on life history strategy and abundance

Neala Kendall* and Chris Frederiksen§

*Washington Department of Fish and Wildlife
§Yakama Nation Fisheries

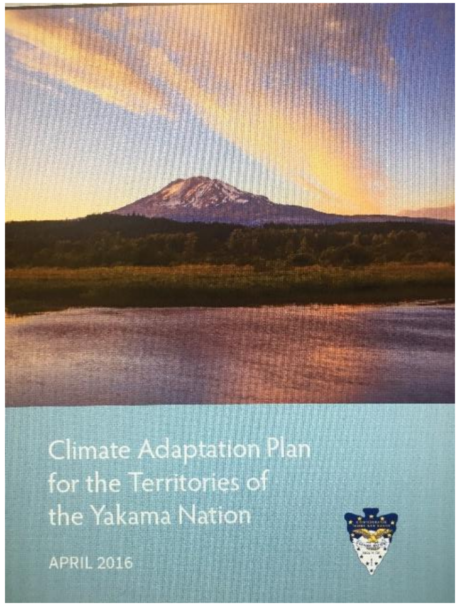
Big questions—how will climate change, restoration, changes in downstream migration, and ocean conditions affect abundance and life history of Yakima River *O. mykiss*?



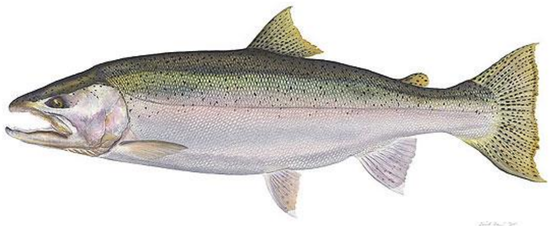
Why approach these questions from a life cycle perspective?

Current and future *O. mykiss* model applications in the Yakima Basin

- Climate Adaptation Plan
  - Current and future life history and abundance changes due to flow and temperature changes?
  - Restoration/preservation priorities under altered climate?



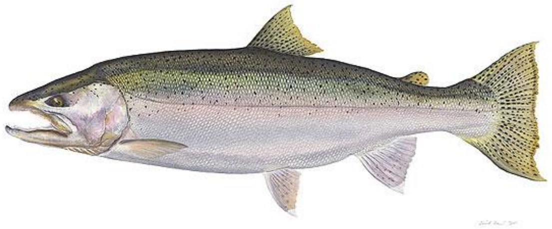
Model scenarios



In basin:

- Freshwater temperature and flow changes due to global warming
- Manastash habitat opening, Lake Cle Elum passage restoration
- Flow conditions affecting Roza Dam to McNary Dam survival
- Kelt reconditioning

Model scenarios



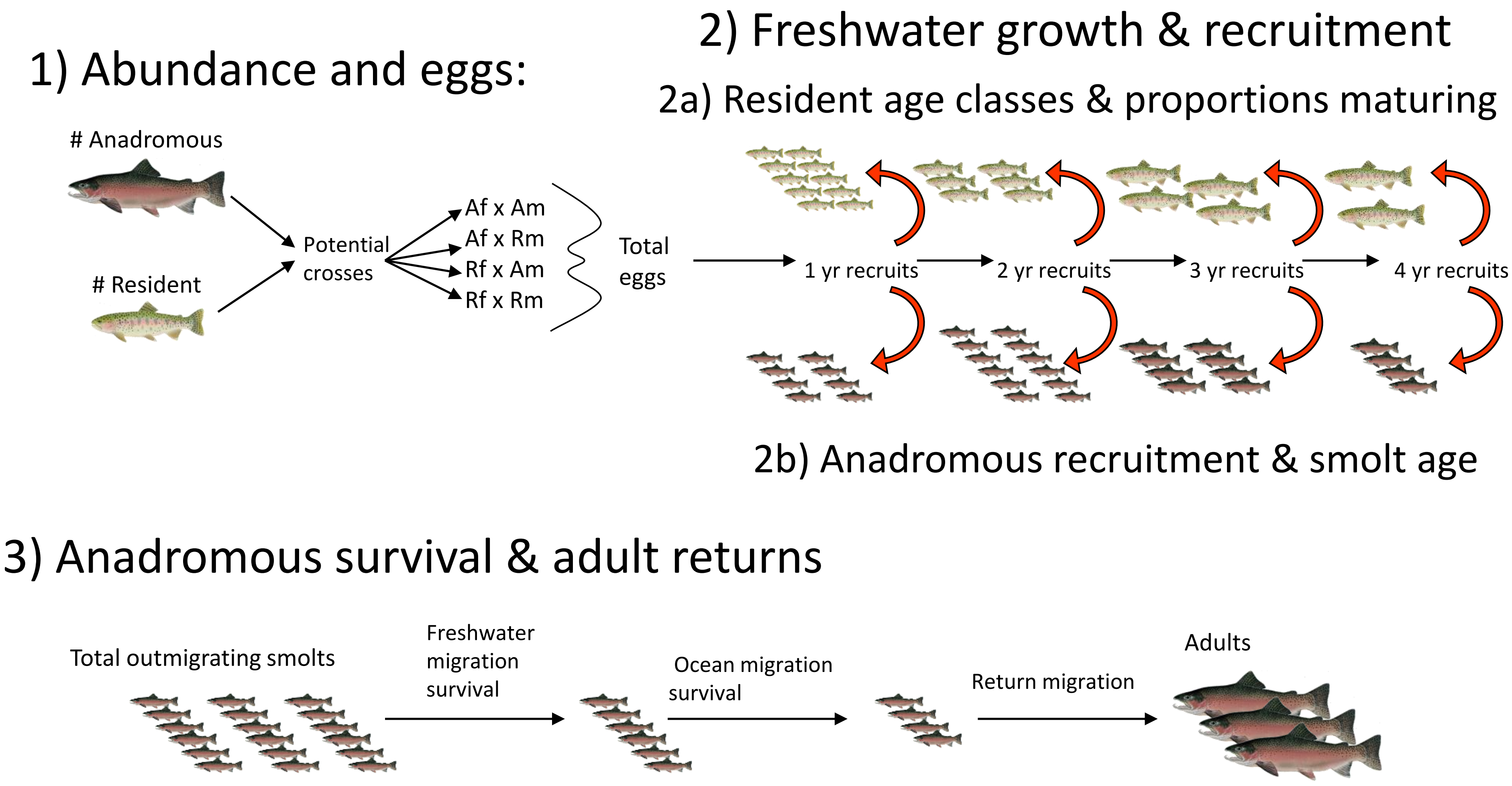
<u>Out of basin:</u>

- SAR variation due to ocean conditions
- SAR variation due to changes in smolt outmigration timing at Bonneville Dam
- Columbia River migration survival under different hydropower system conditions
- Avian and pinniped predation at Bonneville Dam area and lower Columbia River estuary

Existing models

1. Anadromous/resident *O. mykiss* abundance and reproductive success life-cycle models x 2 (developed for Yakima River by Ian Courter, Chris Frederiksen, et al.)

O. mykiss life-cycle model synopsis



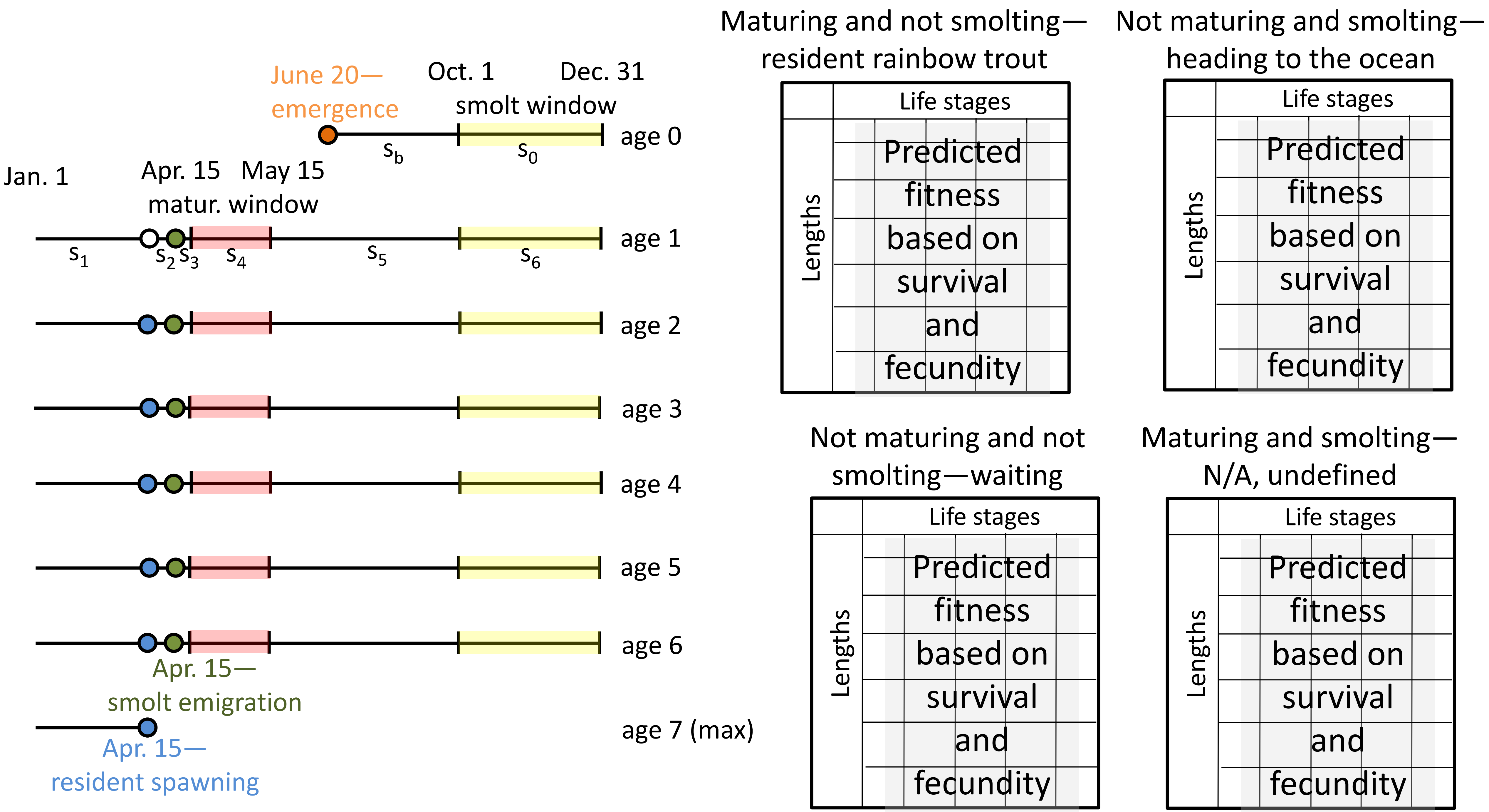
Existing models

1. Anadromous/resident *O. mykiss* abundance and reproductive success life-cycle models x 2 (developed for Yakima River by Ian Courter, Chris Frederiksen, et al.)

2. Anadromy/residency and smolt age decision for *O. mykiss* (developed for California populations based on fish condition; Satterthwaite et al. 2009, 2010)—FEMALES ONLY

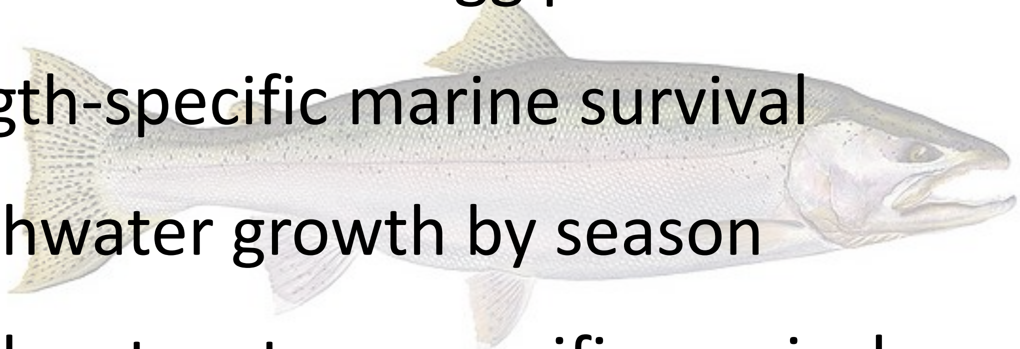
Fish condition life-cycle model

- Estimate “fitness” for maturing vs. not and smolting vs. not fish based on freshwater growth, survival, and fecundity observed for fish in a given system
- Predict maturation/residency and smolt age decision

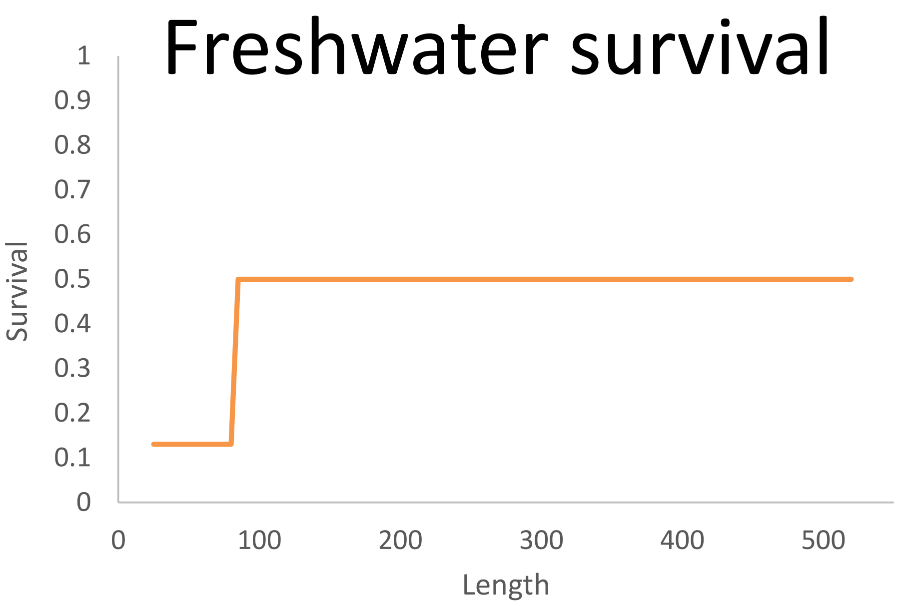


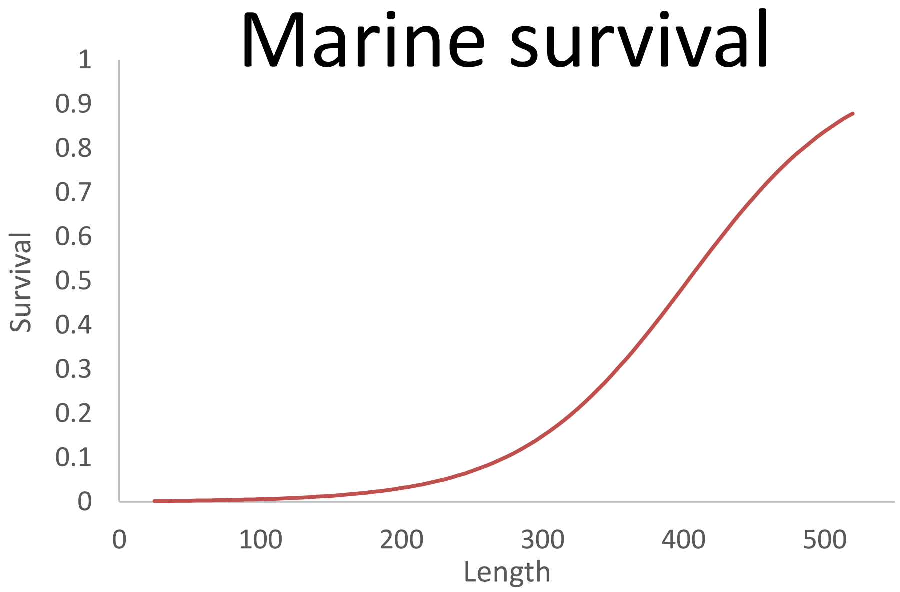
June 20—
emergence
Oct. 1
Dec. 31
smolt window
age 0
s_b
s_0
Jan. 1
Apr. 15
May 15
matur. window
age 1
s_1
s_2 s_3
s_4
s_5
s_6
age 2
age 3
age 4
age 5
age 6
Apr. 15—
smolt emigration
age 7 (max)
Apr. 15—
resident spawning
Maturing and not smolting—
resident rainbow trout
Not maturing and smolting—
heading to the ocean
Not maturing and not
smolting—waiting
Maturing and smolting—
N/A, undefined
Life stages
Lengths
Predicted
fitness
based on
survival
and
fecundity

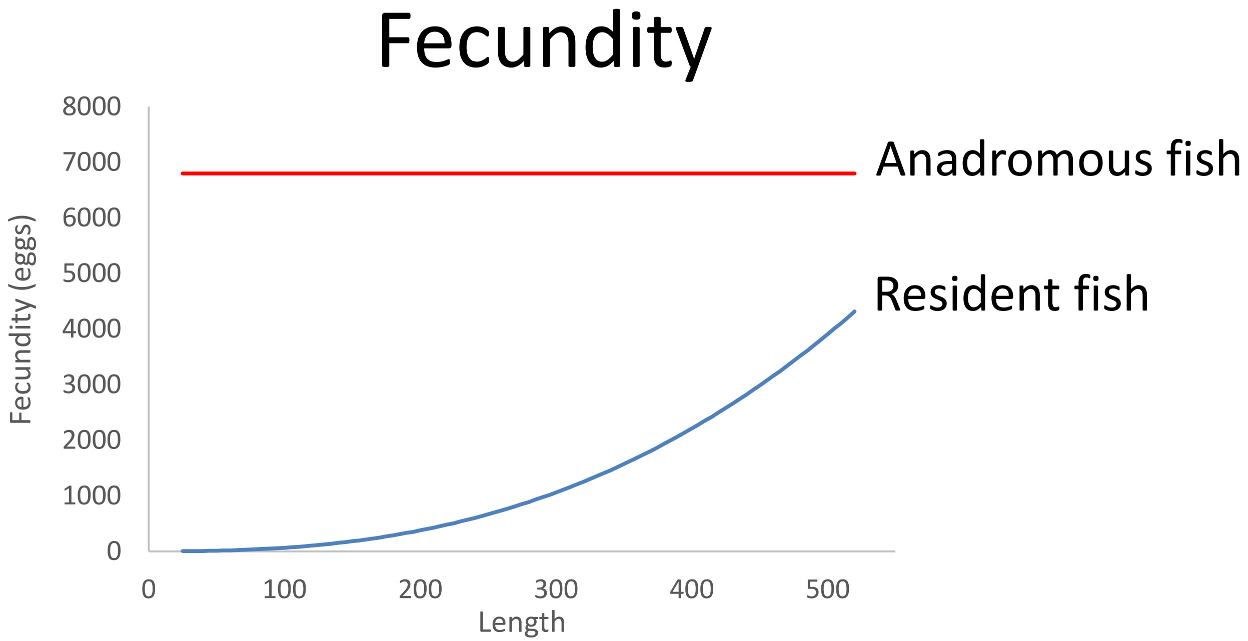
Input data



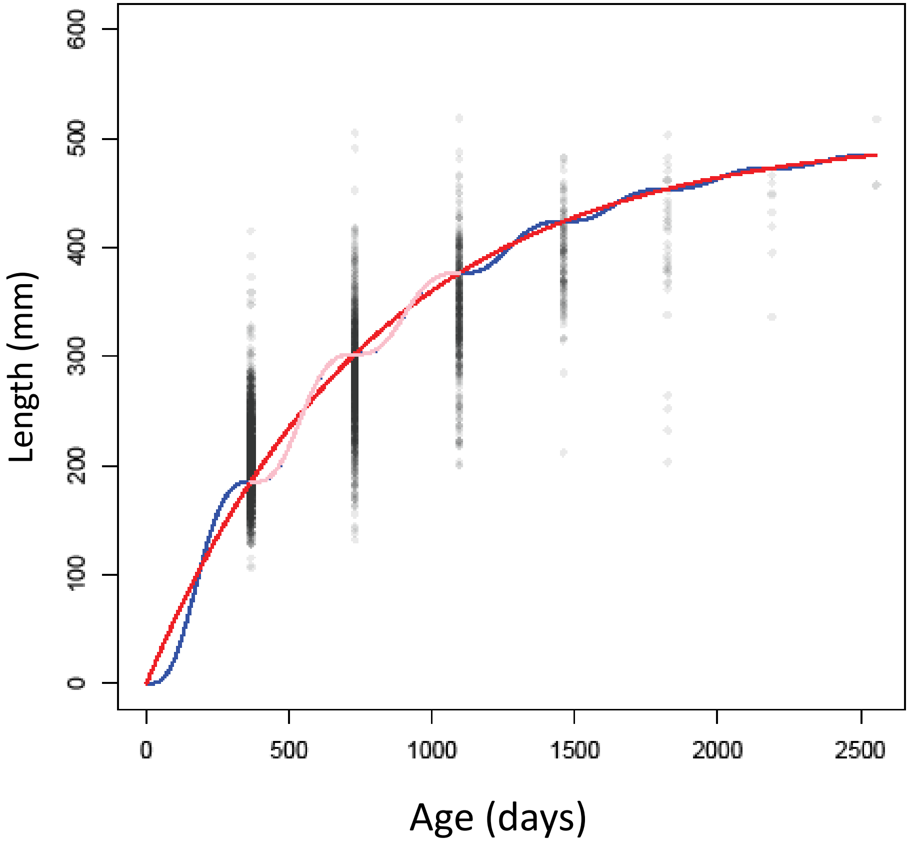
- Date of emergence, resident spawning, emigration, smolt and maturation windows
- Length-specific resident fish egg production
- Resident survival through spawning
- Expected lifetime egg production of steelhead
- Length-specific marine survival
- Freshwater growth by season
- Freshwater stage-specific survival
- Breeding interactions


Freshwater survival
Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
Length


Marine survival
Survival
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
Length


Fecundity
Fecundity (eggs)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
Length
Anadromous fish
Resident fish

Freshwater growth



Freshwater survival among age classes

Potential egg deposition (PED) to age

$$\frac{\text{Total number of eggs}}{\text{Total number of age 1 individuals}}$$

Age 1 to age 2:

$$\frac{\text{Total number of age 1 individuals}}{\text{Total number of age 2 individuals}}$$

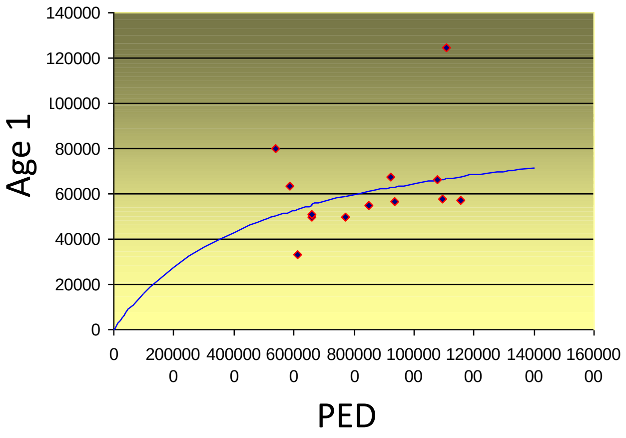
Age 2 to age 3:

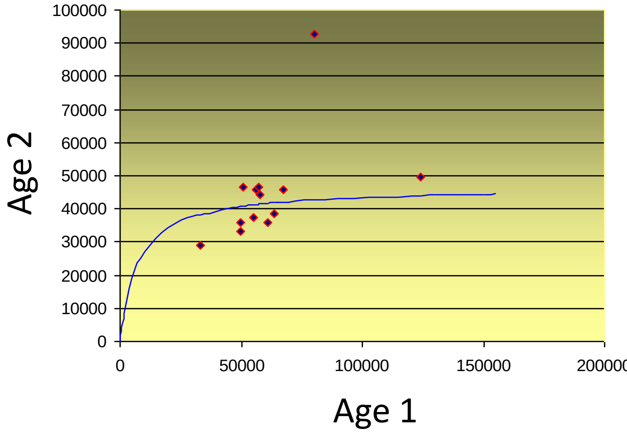
$$\frac{\text{Total number of age 2 individuals}}{\text{Total number of age 3 individuals}}$$

Age 3 to age 4:

$$\frac{\text{Total number of age 3 individuals}}{\text{Total number of age 4 individuals}}$$

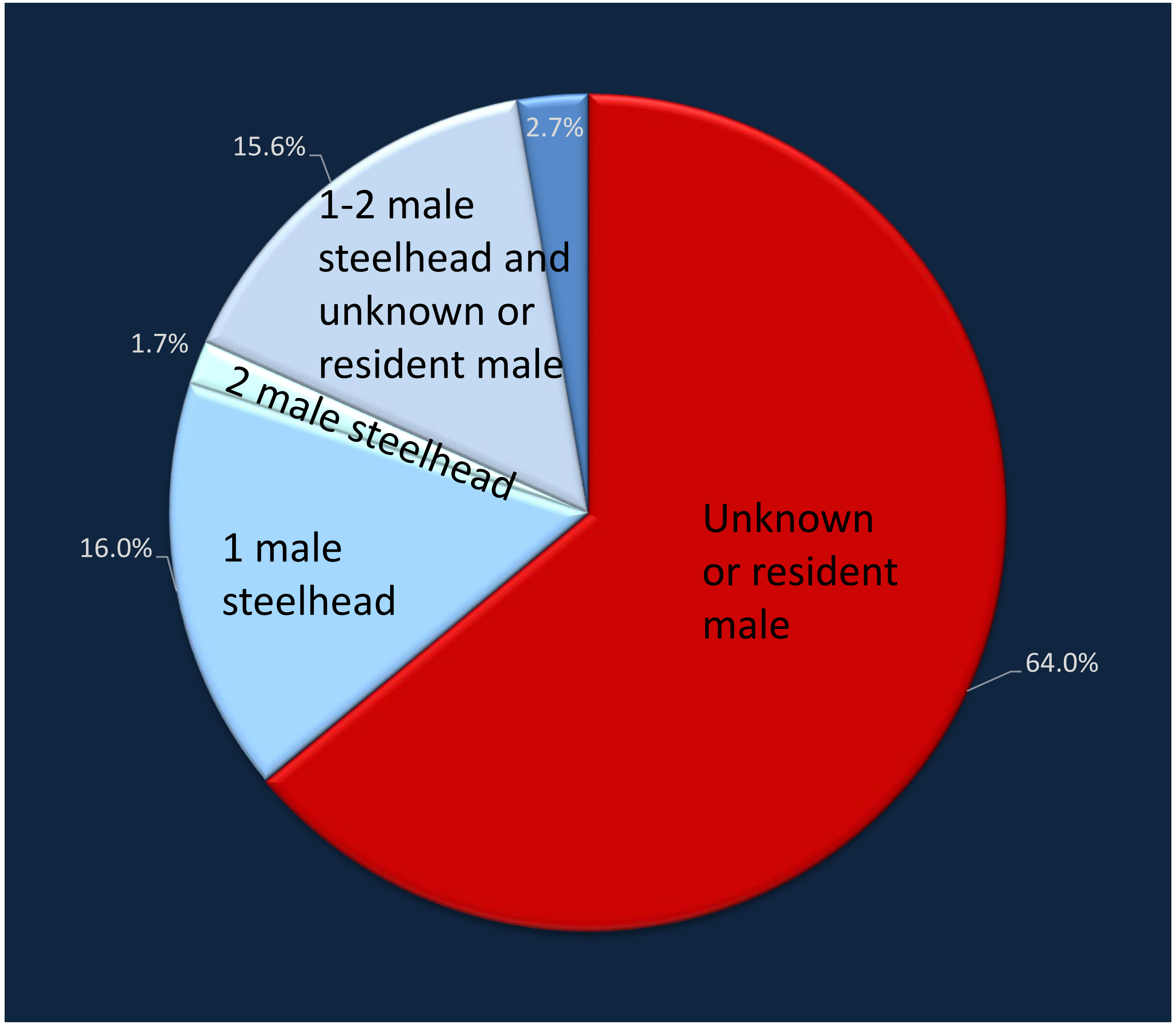
Average and range across years





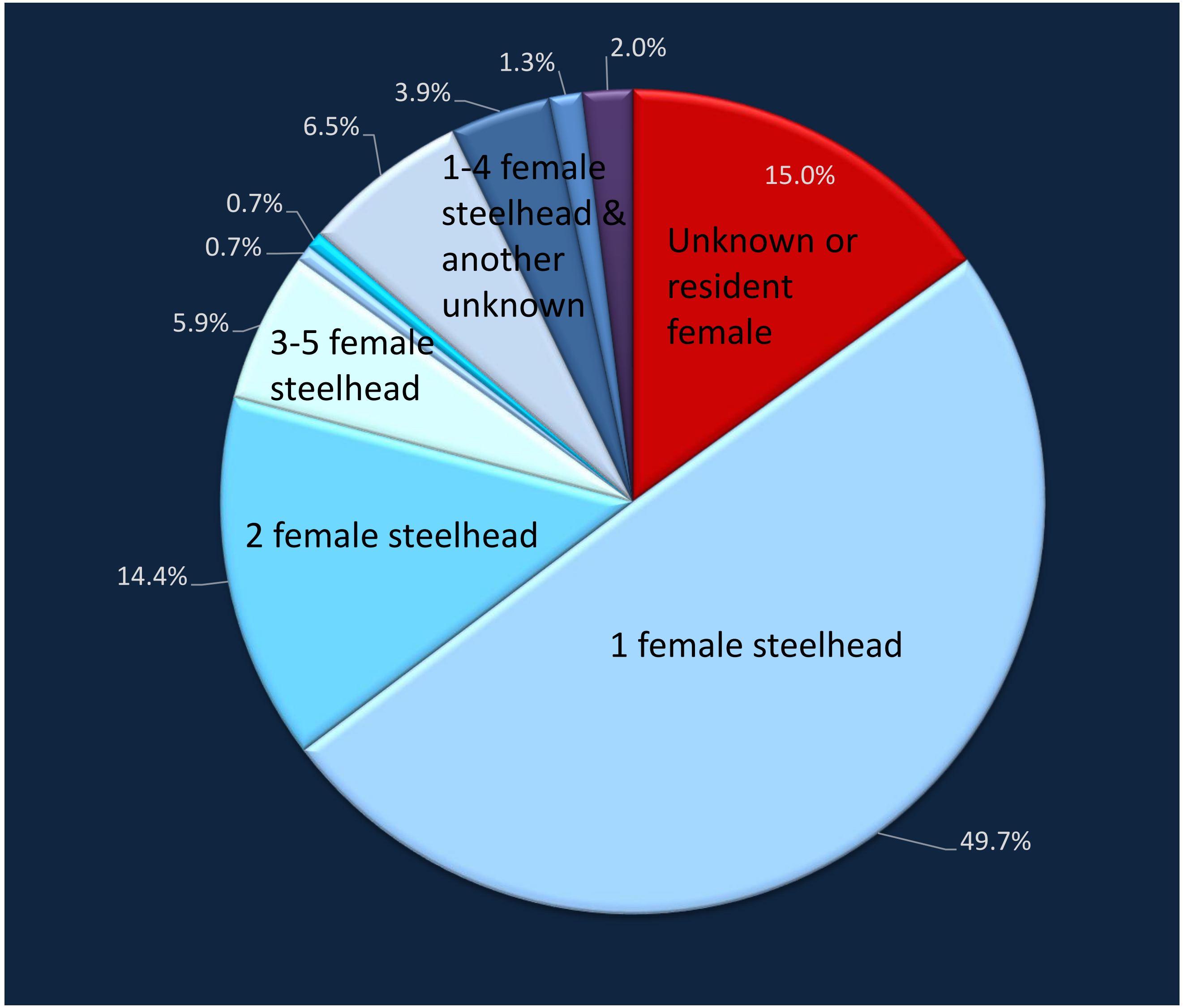
… for other ages

Female steelhead breeding interactions



→ 36% of female steelhead spawned with male steelhead
- Could be as high as 50%

Male steelhead breeding interactions

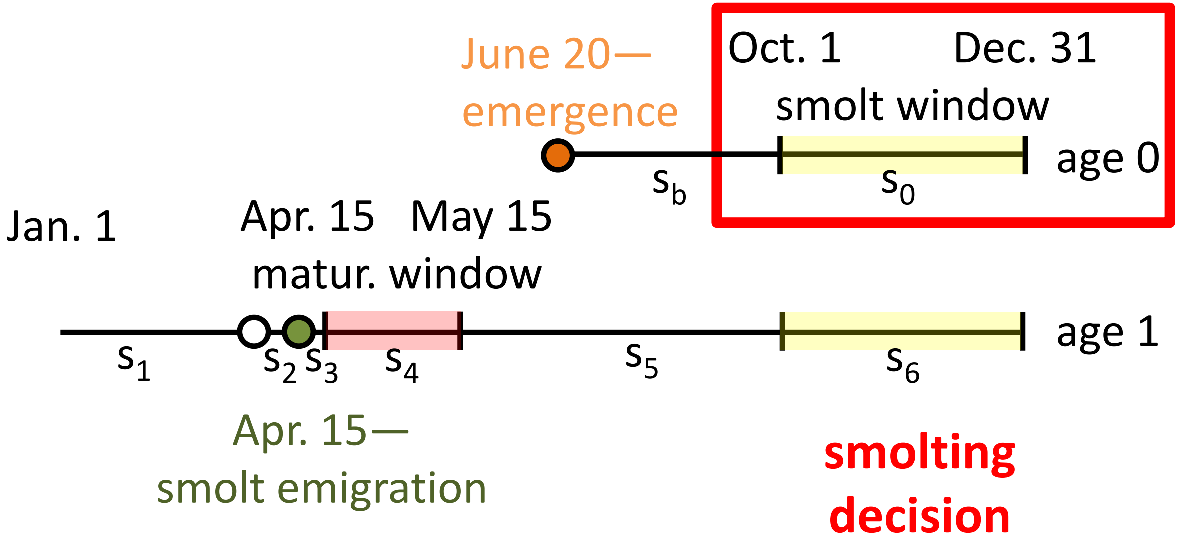


Modeling steps

- Parameterize the model with as much known data as possible
- Adjust inputs, especially uncertain values, to simulate observed patterns of resident maturation age and smolt age
- Call this parameterization “baseline”
- Modify baseline parameters based on scenarios of interest to understand potential life history
- Incorporate heritability via breeding interactions between anadromous and resident individuals

Preliminary results: age-1 smolting decision

					15% of fish smolt at age 1							
length (mm) at age-0 smolting decision window (so will smolt the following year at age 1)	40	50	60	70	80	90	100	110	120	130	140	150
baseline												

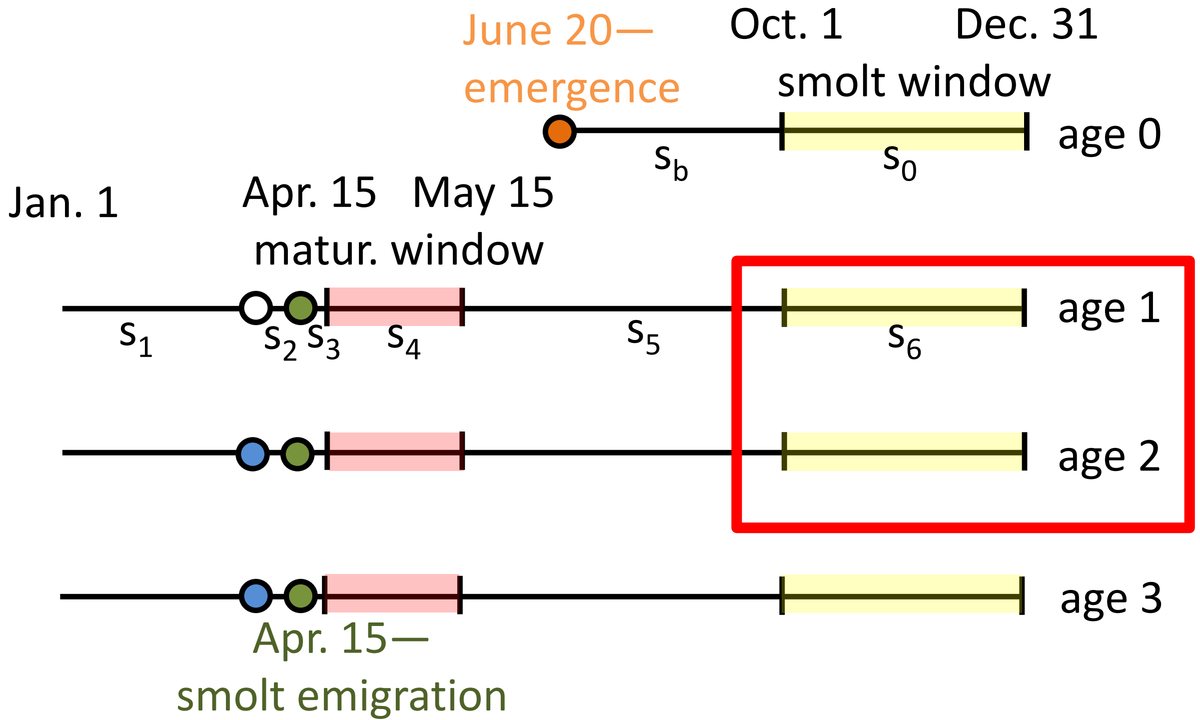


Preliminary results: age-1 smolting decision

					15% of fish smolt at age 1							
length (mm) at age-0 smolting decision window (so will smolt the following year at age 1)	40	50	60	70	80	90	100	110	120	130	140	150
baseline												
decrease fw survival 10%												
increase fw survival 10%												
decrease SAR 10%												
increase SAR 10%												
increase fw growth 5%												
increase fw growth 10%												
decrease fw growth 5%												
decrease fw growth 10%												
spawn and emigrate 10 days earlier												

Preliminary results: age-2 and 3 smolting decision

											73% of fish smolt at age 2										11% of fish smolt at age 3					
length (mm) at age 1+ smolting decision window (so will smolt the following year at age 2+)	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
baseline																										

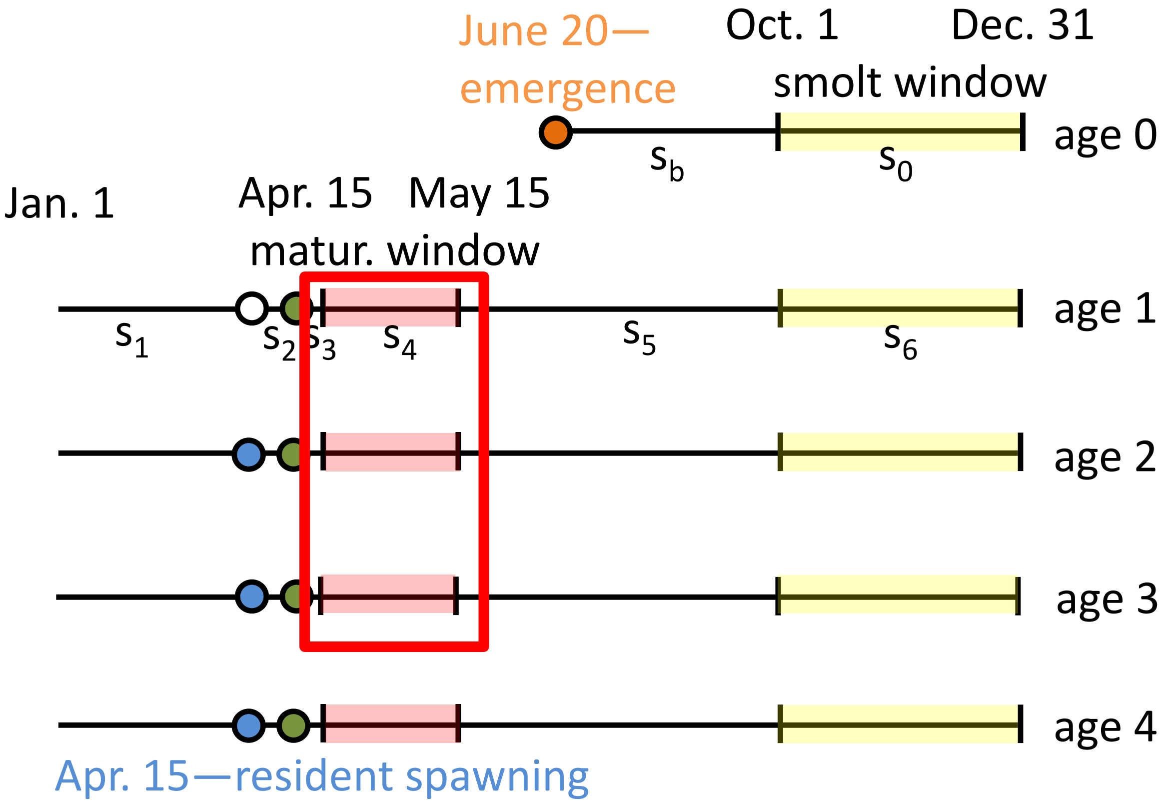


Preliminary results: age-2 and 3 smolting decision

											73% of fish smolt at age 2										11% of fish smolt at age 3					
length (mm) at age 1+ smolting decision window (so will smolt the following year at age 2+)	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300
baseline																										
decrease fw survival 10%																										
increase fw survival 10%																										
decrease SAR 10%																										
increase SAR 10%																										
increase fw growth 5%																										
increase fw growth 10%																										
decrease fw growth 5%																										
decrease fw growth 10%																										
spawn and emigrate 10 days earlier																										

Preliminary results: age-2, 3, and 4 maturation decision

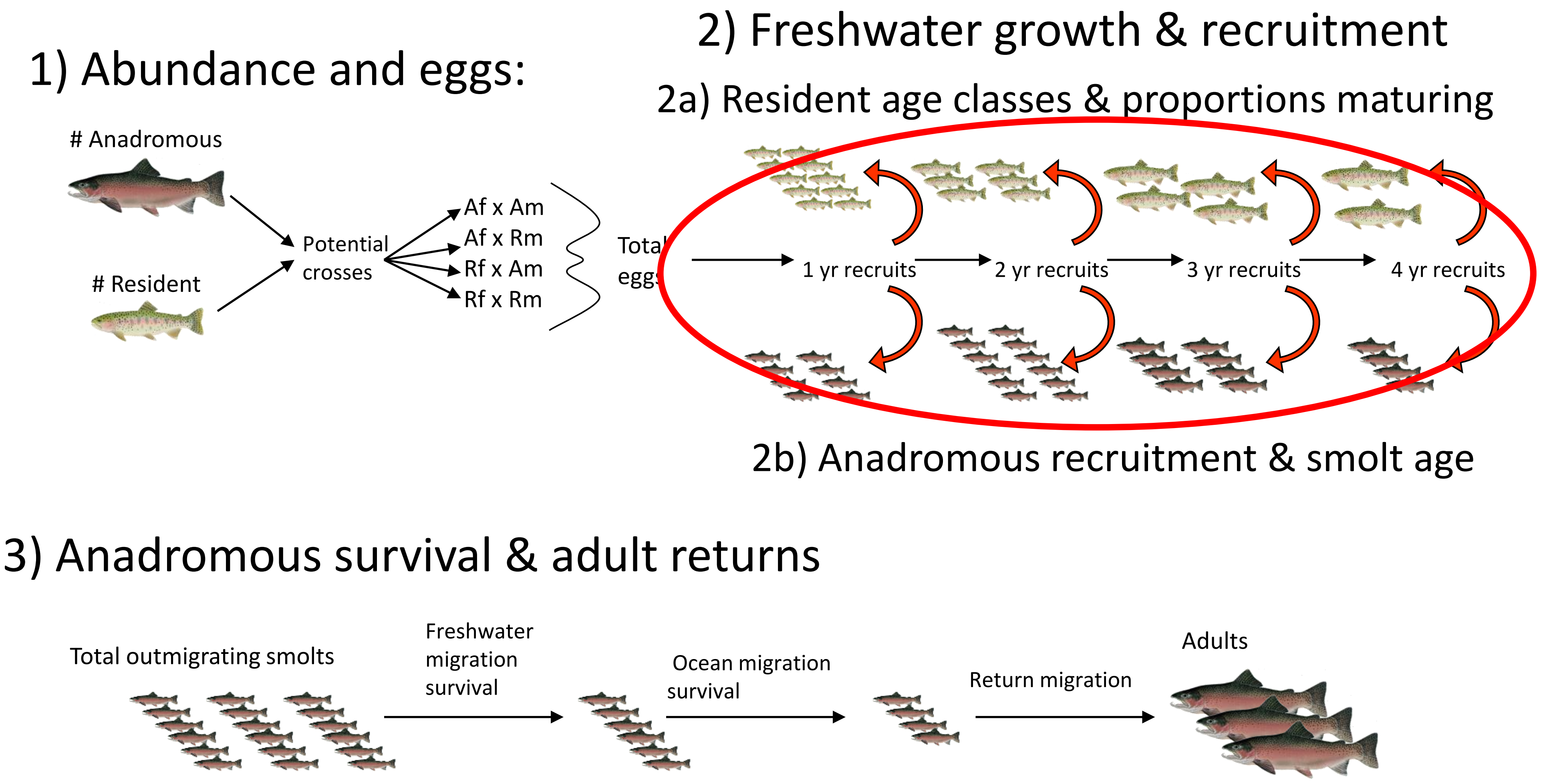
					15% of fish are mature by age 2							40% of fish are mature by													80% of fish are mature by age 4							
length (mm) at age 1+ maturation decision window (so will mature as a rainbow trout the following year at age 2+)	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
baseline																															



Preliminary results: age-2, 3, and 4 maturation decision

					15% of fish are mature by age 2							40% of fish are mature by												80% of fish are mature by age 4							
length (mm) at age 1+ maturation decision window (so will mature as a rainbow trout the following year at age 2+)	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
baseline																															
decrease fw survival 10%																															
increase fw survival 10%																															
decrease SAR 10%																															
increase SAR 10%																															
increase fw growth 5%																															
increase fw growth 10%																															
decrease fw growth 5%																															
decrease fw growth 10%																															
spawn and emigrate 10 days earlier																															

O. mykiss life-cycle model synopsis



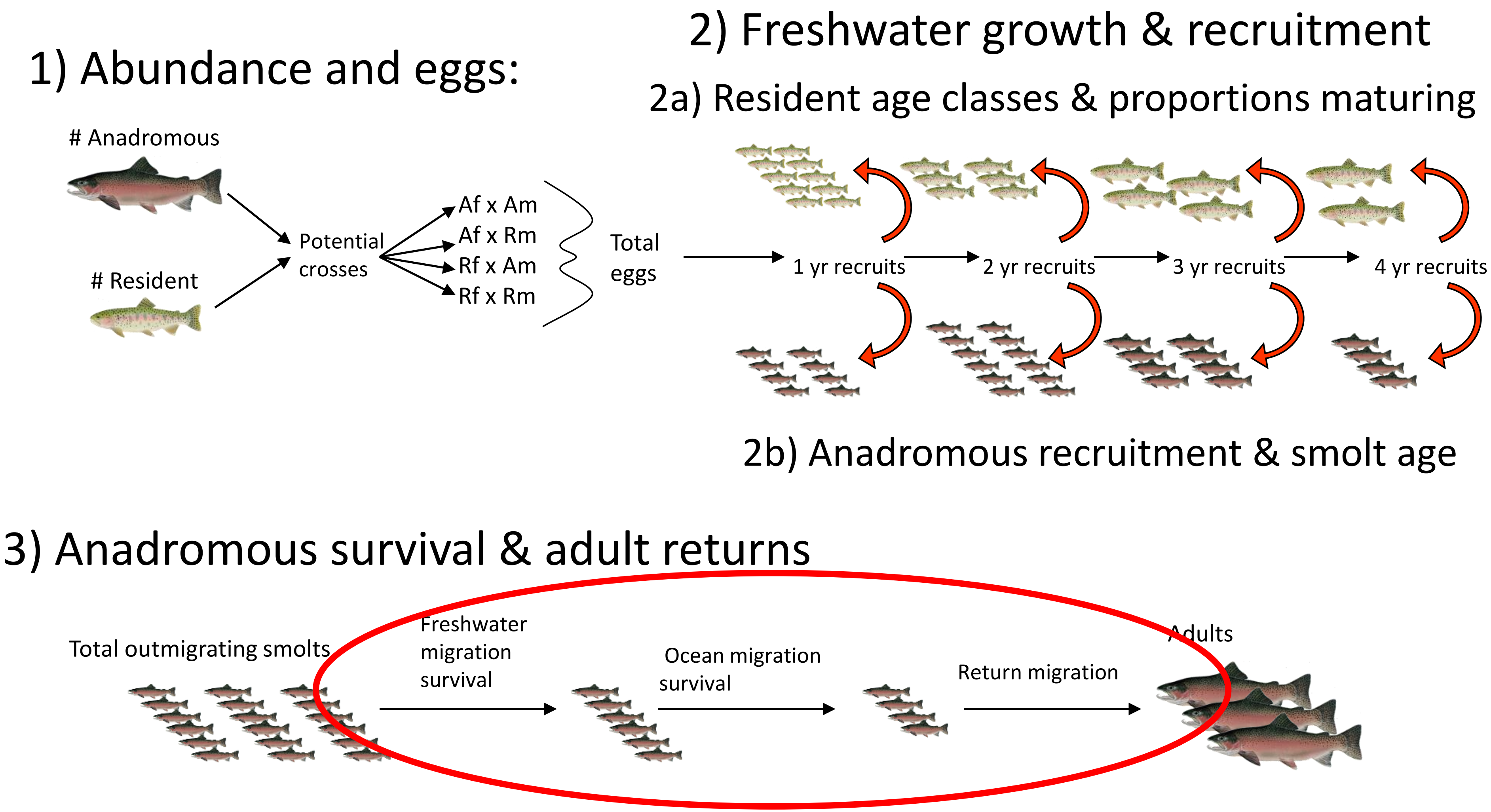
Existing models

1. Anadromous/resident *O. mykiss* abundance and reproductive success life-cycle models x 2 (developed for Yakima River by Ian Courter, Chris Frederiksen, et al.)

2. Anadromy/residency and smolt age decision for *O. mykiss* (developed for California populations based on fish condition; Satterthwaite et al. 2009, 2010)

3. Chinook and steelhead life-cycle matrix models (developed for Interior Columbia River Basin; Zabel et al. 2006; ICTRT and Zabel 2007)

O. mykiss life-cycle model synopsis

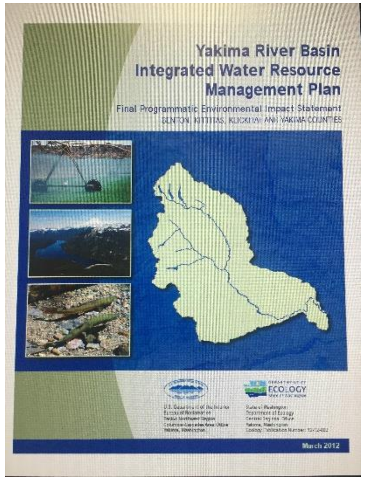


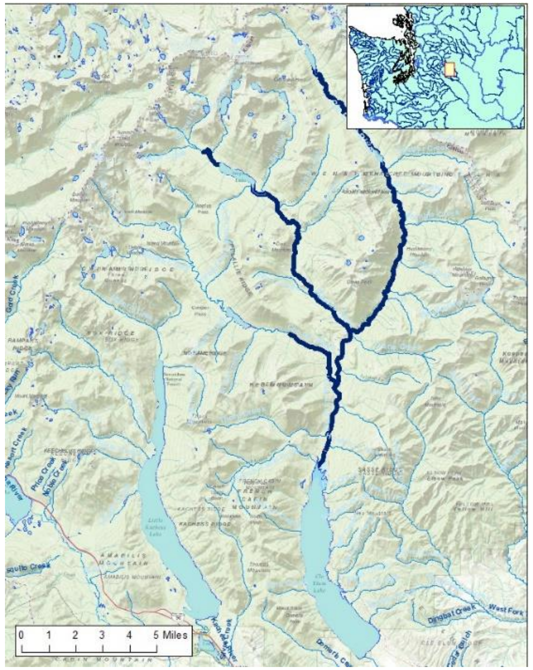
Acknowledgements

- Yakama Nation and WDFW
- Tom Cooney, Rich Zabel, Jeff Jorgensen, and the AMIP Life-Cycle Modeling Group
- Will Satterthwaite
- Thomas Buehrens

Current and future *O. mykiss* model applications in the Yakima Basin

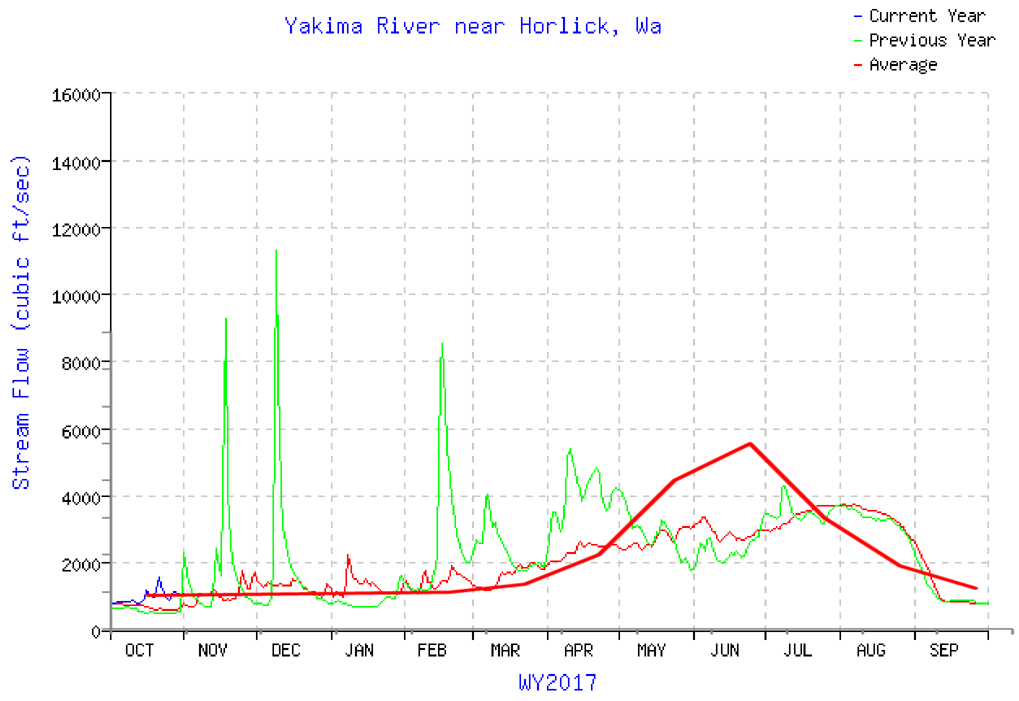
- Yakima River Basin Integrated Water Resource Management Plan
  - Evaluate benefits of habitat enhancement
    - Example: Lake Cle Elum fish passage-- 66 km of new habitat





Parts of basin are very flow regulated

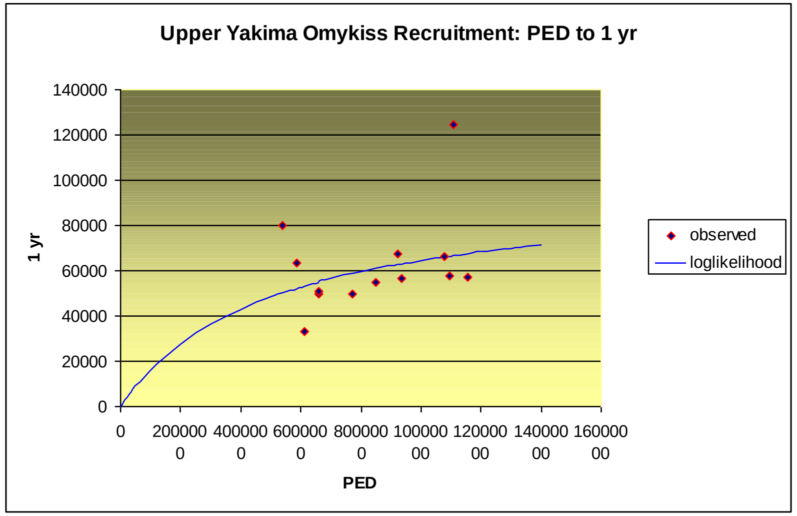
- Reservoirs, water delivery for agriculture
- Strong rainbow trout population
- Flow regulation favors rainbows?



Development of freshwater recruitment curves

1) <u>Upper Yakima age class abundance estimates</u>

- WDFW data set (1991-2004)
- Index reaches (fish/km) expanded



2) <u>Recruitment curves</u>

- 4 age class recruitment curves constructed
- Capture density dependent effects