Willamette Instream Flow Project: Estimation and modeling of Chinook salmon demographics

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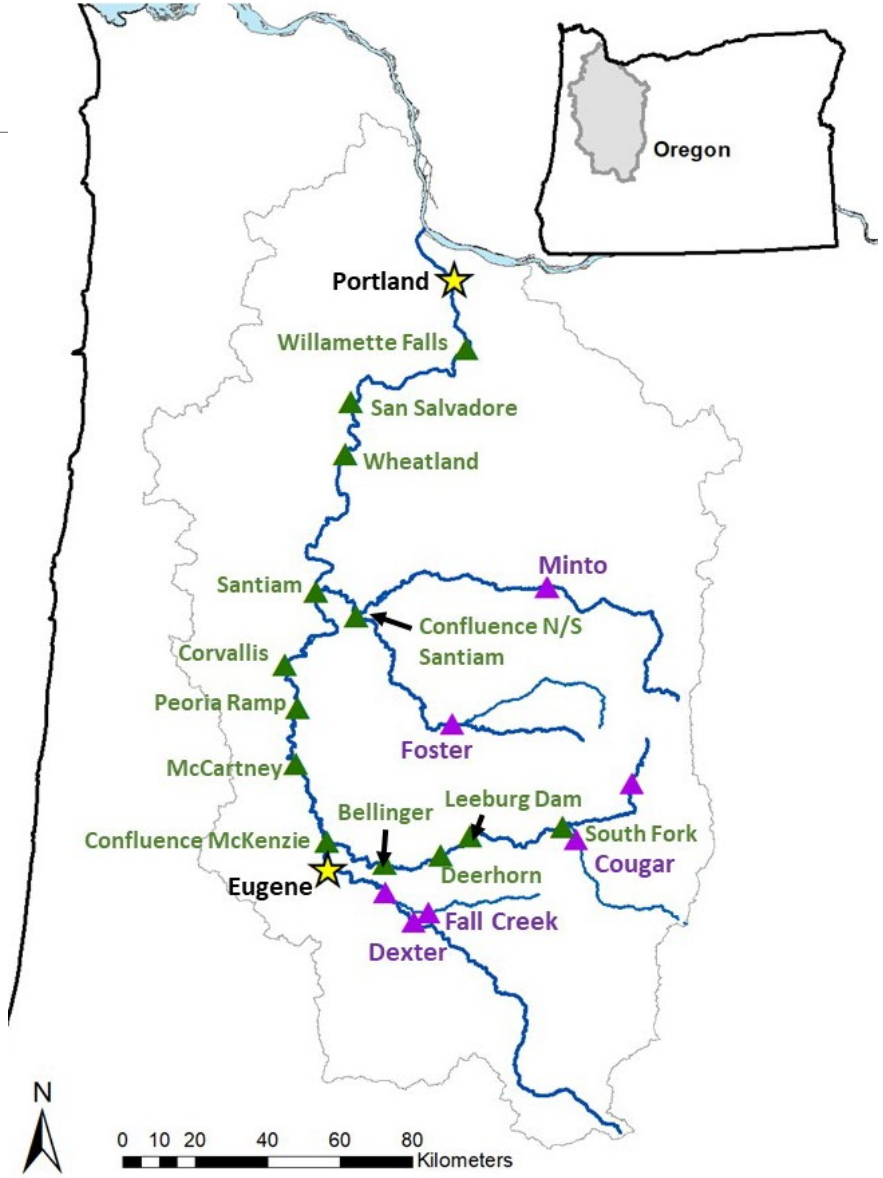
Context

- Water Distribution
  - Agricultural irrigation
  - Increasing urbanization
  - Industrial use
  - Ecosystem needs
  - Flood control
  - Many more…..
- BiOp
  - Flow targets
  - Temperature targets

Managers: What are the optimal flow regimes? What are the tradeoffs?

Study Area

- Mainstem Willamette
- Tributaries
  - Santiam
  - North and South Santiam
  - McKenzie River
  - Middle Fork Willamette
- 17 Reaches
- Below USACE projects



Willamette Instream Flows

Purpose: Identify instream flows to sustain the river ecosystem and dependent fish, wildlife, and vegetation

- **Social and economic water use considered subsequently**

Interdisciplinary Team:

Hydrologists

Geomorphologists

Water quality modelers

Ecologists

Managers

Stakeholders

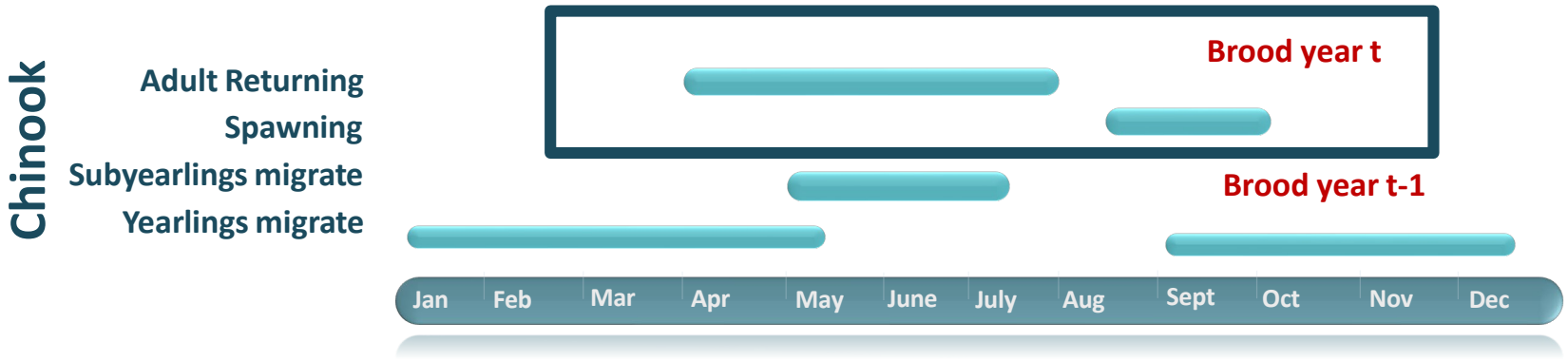
Fisheries experts

ODFW district biologists

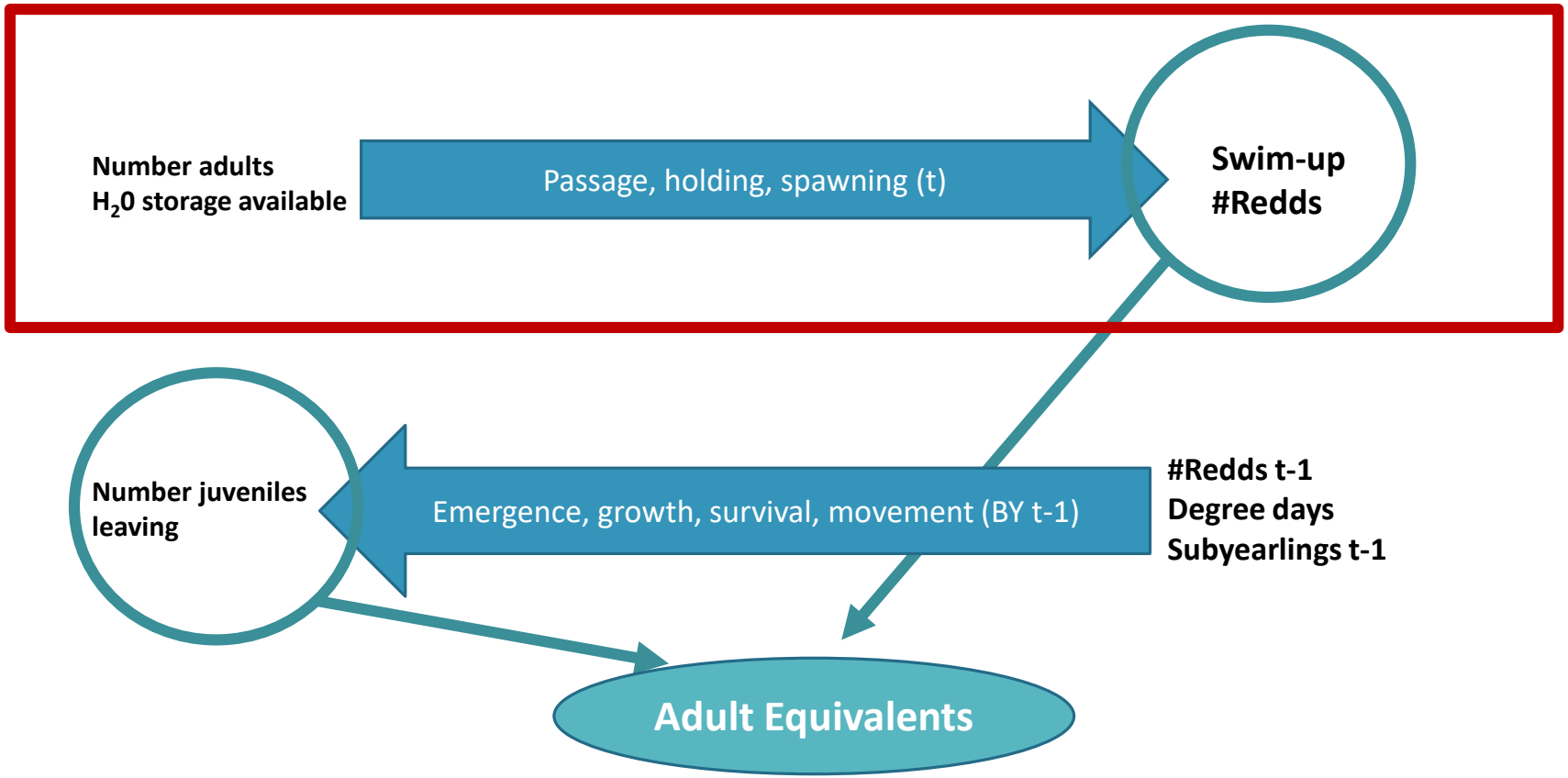
Chinook Streamflow Model

- Evaluate tradeoffs
- Distribution of flows
- Disconnect

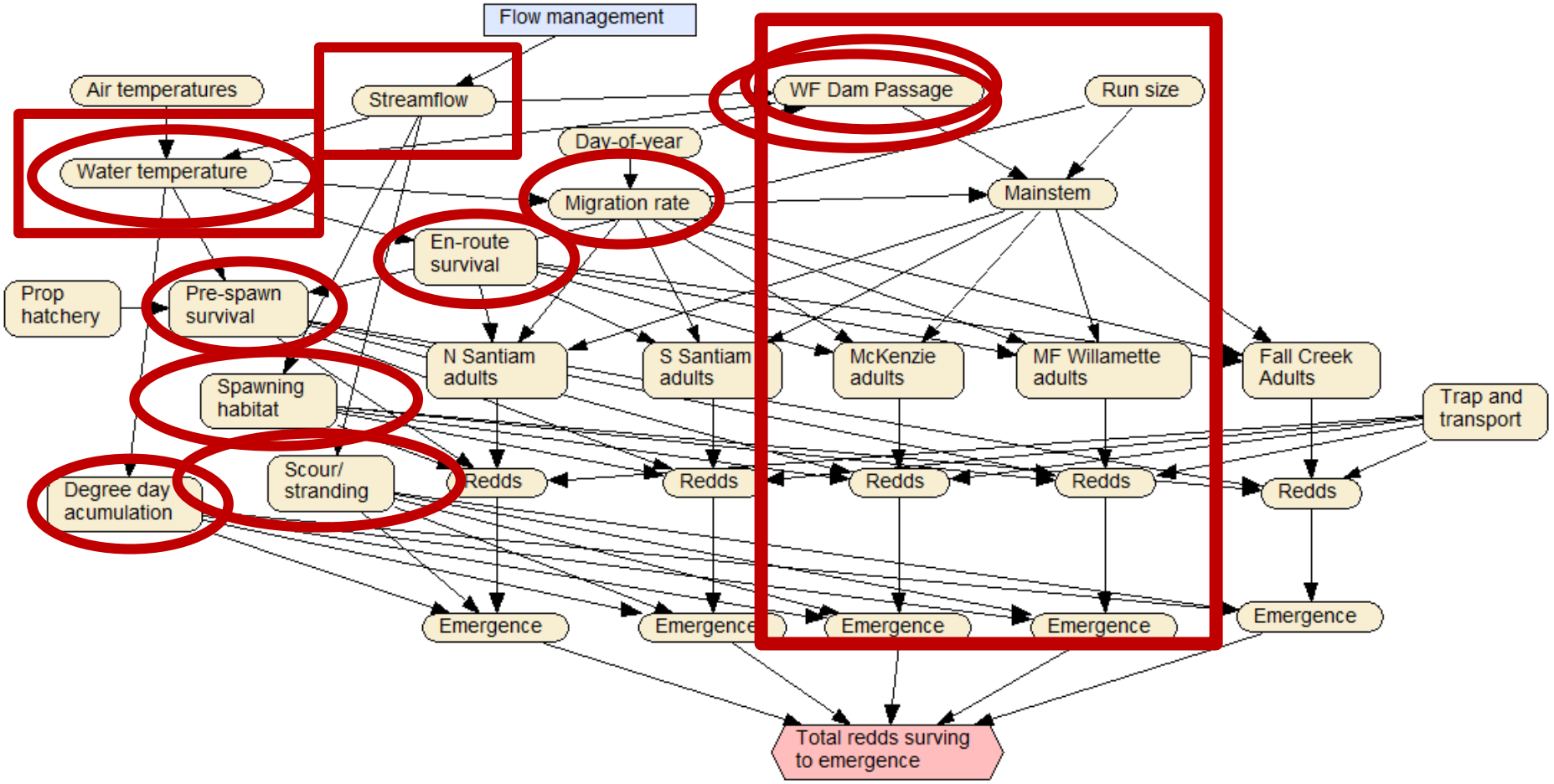
Chinook



Solution: 2 Sub-models



Adult Chinook Salmon Conceptual Model



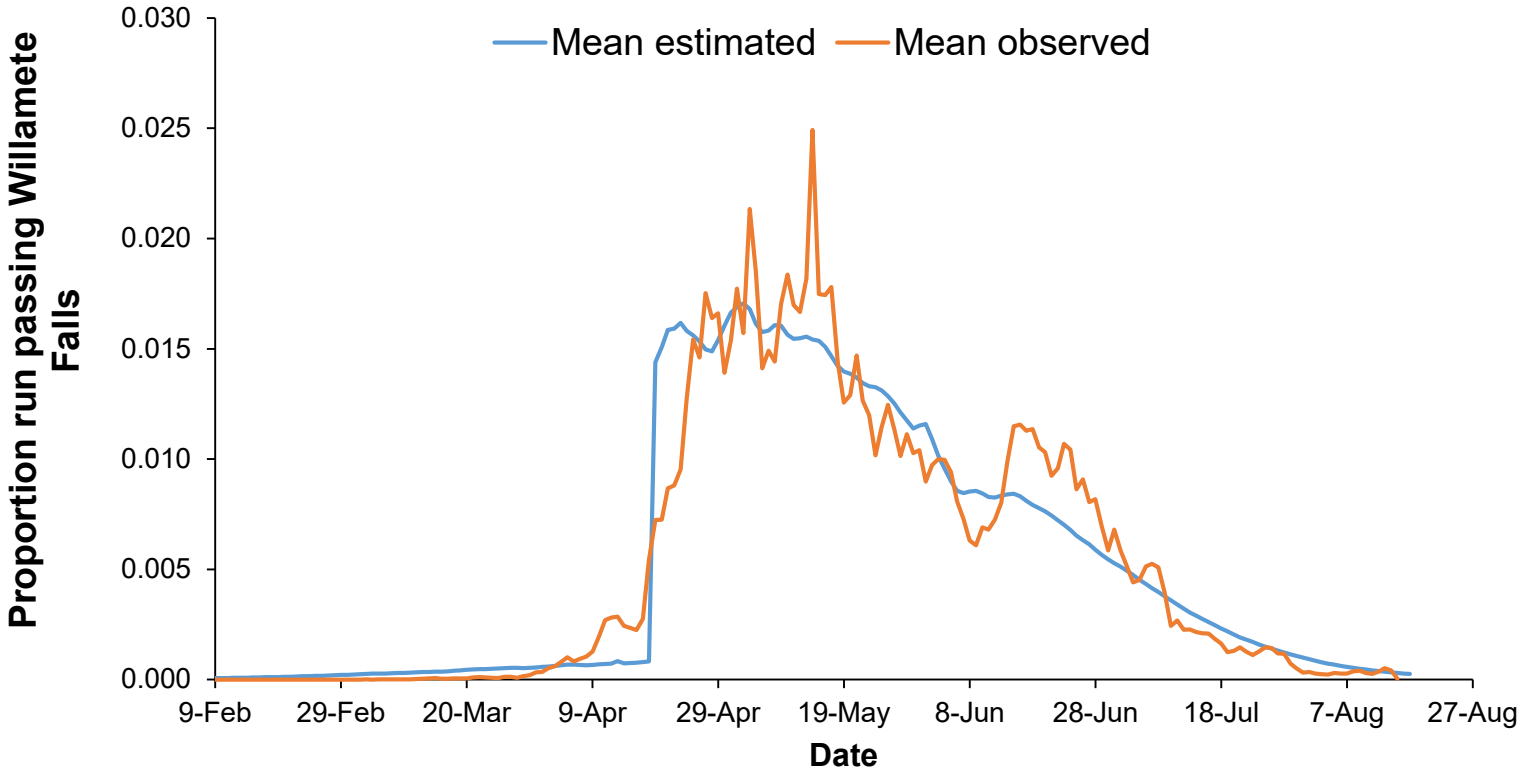
Willamette Falls Adult Timing Submodel

- Willamette Falls Spring Chinook salmon ODFW daily counts 2004 – 2018
- <u>Candidate predictor variables:</u>
  - Daily temperature and daily discharge Newberg
    - minimum, mean, maximum
    - mean daily temperature > 53 ^{o}C
    - Day-of-year
    - quadratic effects and two-way interactions

- Mixed-effects logistic regression (temporal autocorrelation)
  - Response: proportion run passing falls
  - Year random effects
- Model selection AICc

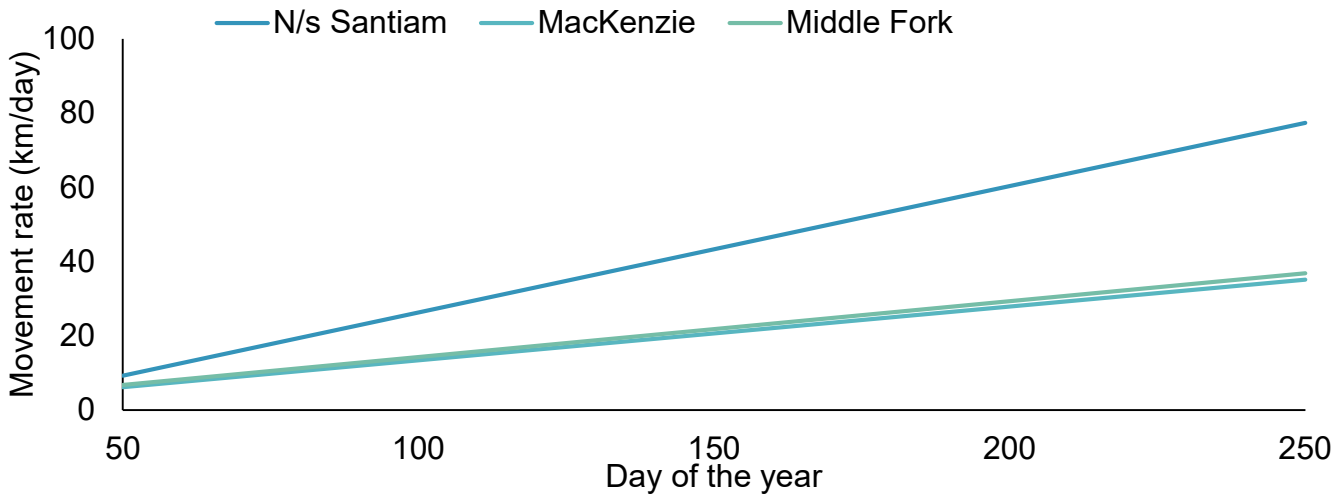
Results: WF Adult Timing Submodel

Best model: DOY - DOY^2 + meanQ + temp.gt.53 + DOY*meanQ + DOY*temp.gt.53
pseudo R^2 = 0.79



Adult Movement and Degree Day Accumulation

- Movement rate, random assignment normal distribution
- Models from meta analysis of University of Idaho 2011-2014 telemetry study
- Rate~*f*(day of year, average daily temperature)
- Accrue temperatures each segment, *f*(time in segment, ave. temperature segment)
- Temperature USGS (Laurel and Stewart)

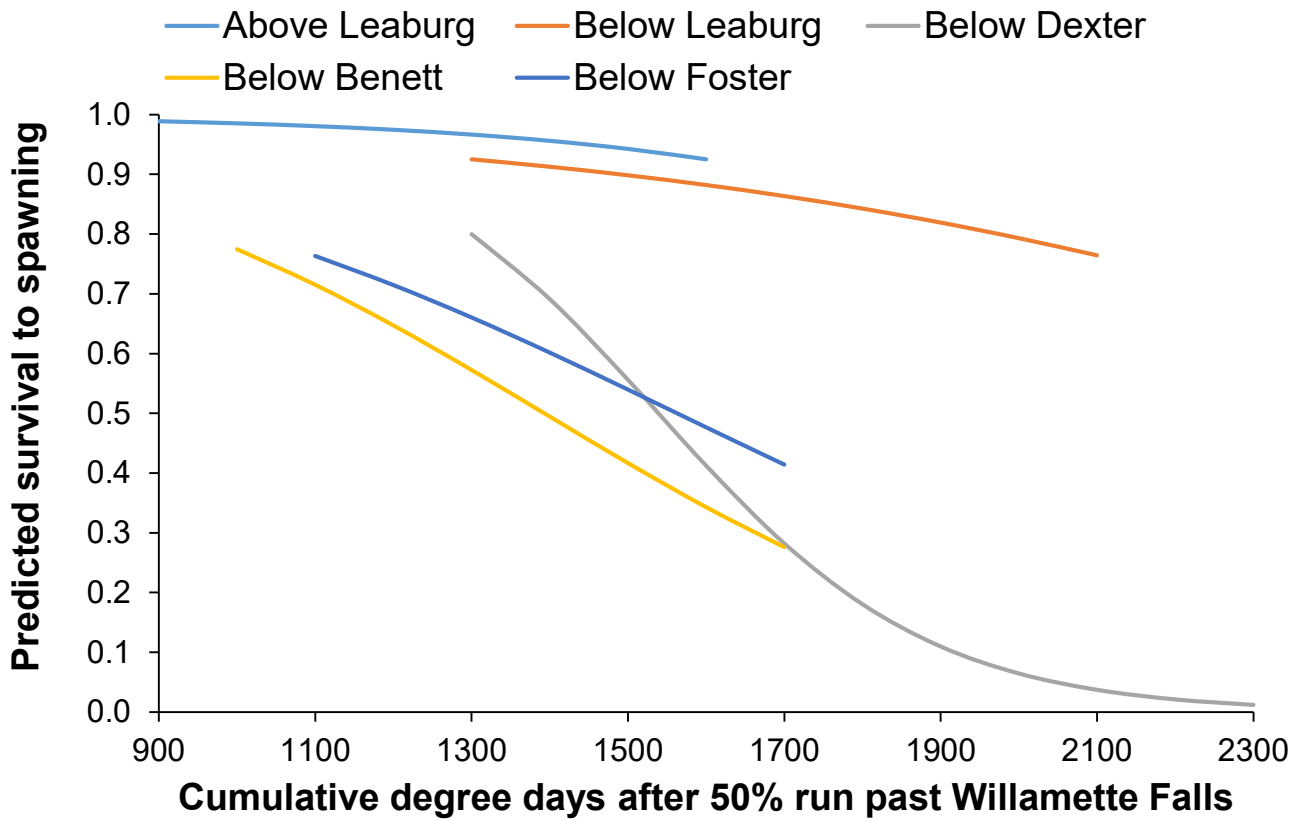


Prespawn Mortality Submodel

- ODFW spawning ground surveys 2004 – 2018 in tributaries
  - Multiple sections per tributary
- Candidate predictor variables:
- Daily temperature and daily discharge nearest gage
  - minimum, mean, maximum after 25%, 50%, 75% run passes WF
  - cumulative degree days after 25%, 50%, 75% run passes WF
  - % hatchery origin on spawning grounds
  - total number females on spawning grounds
  - total run size
  - quadratic terms and two-way interactions
- Mixed-effects logistic regression (spatial and temporal autocorrelation)
  - Response: probability of survival to spawning
  - Year and reach random effects
- Model selection AICc

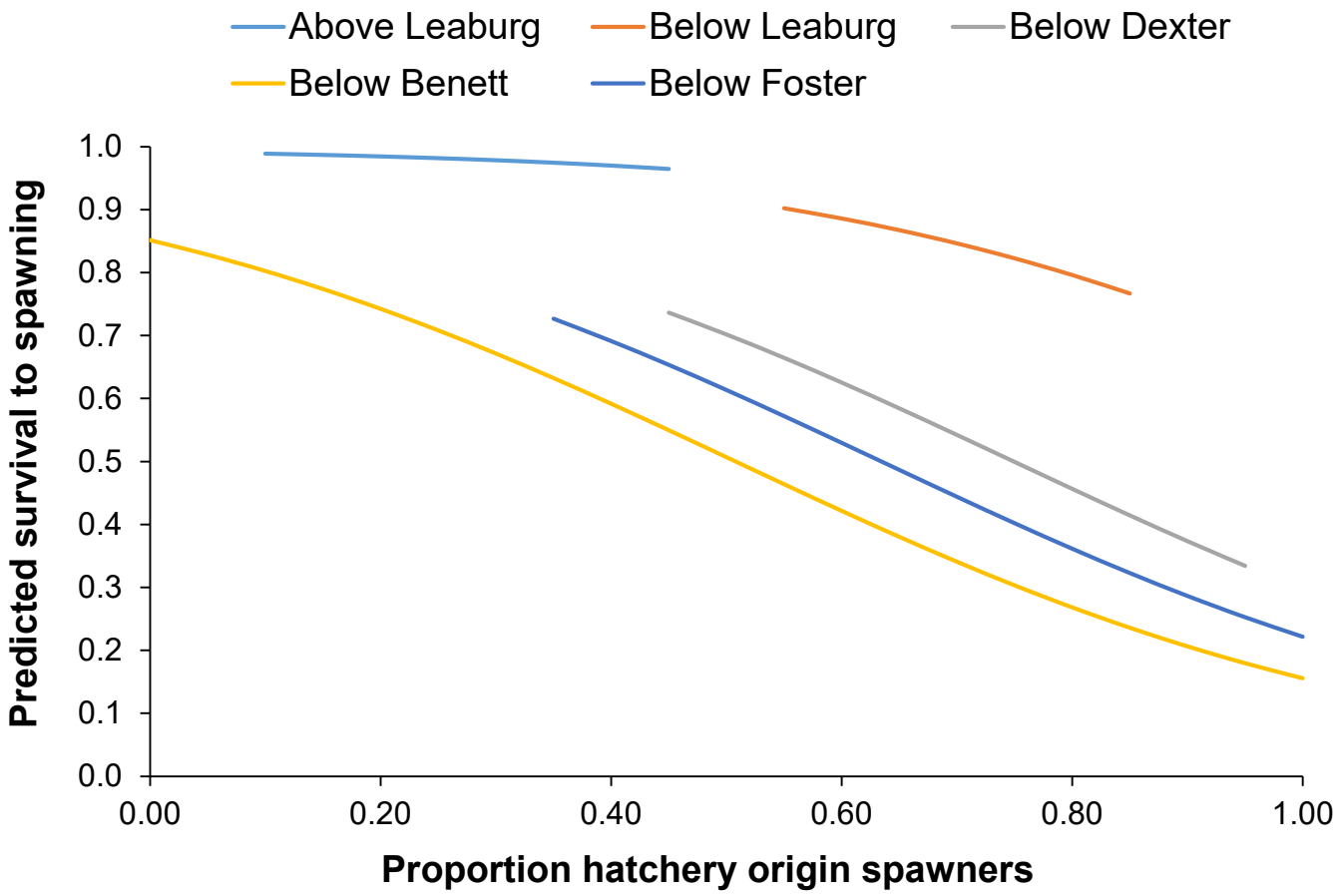
Results: Prespawn Mortality Submodel

Best model: degday50 - %hatchery - run.size
pseudo R^2 = 0.74



Assumes average 51% hatchery origin, Run size 30694

Results: Prespawn Mortality Submodel

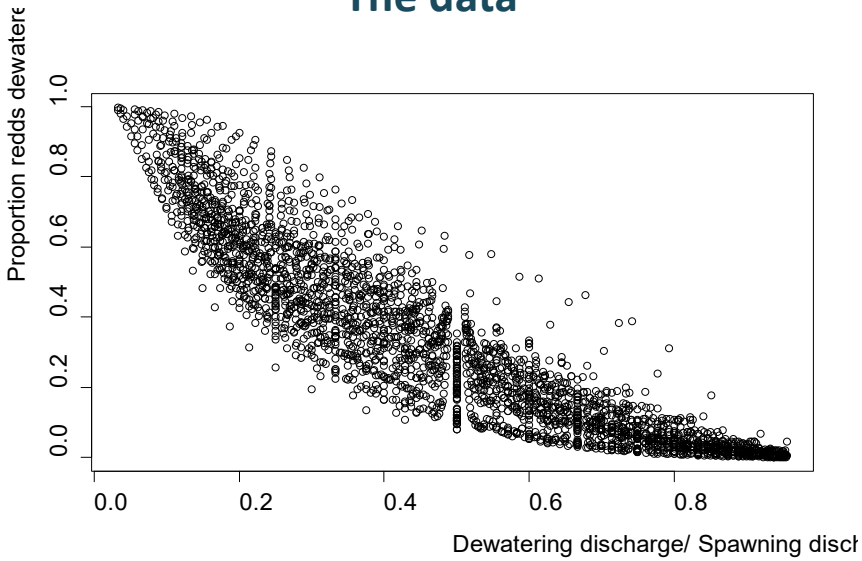


Assumes average 1399 degree days, Run size 30694

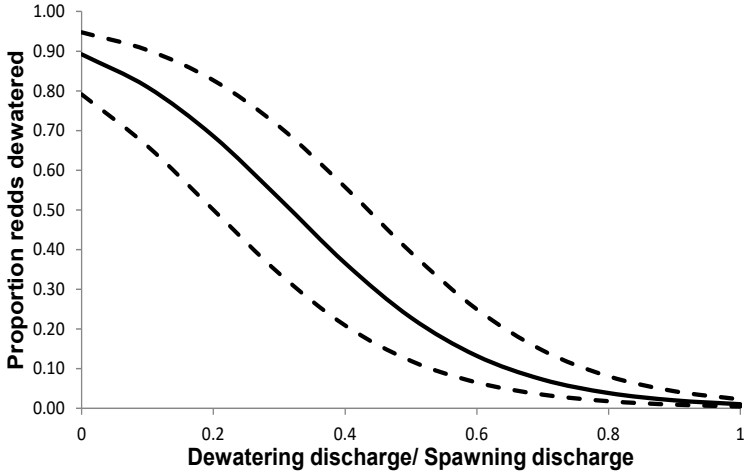
Redd Dewatering

- Meta-analysis of published FWS dewatering studies below dams
- Ratio of dewatered Q/ spawning Q

The data

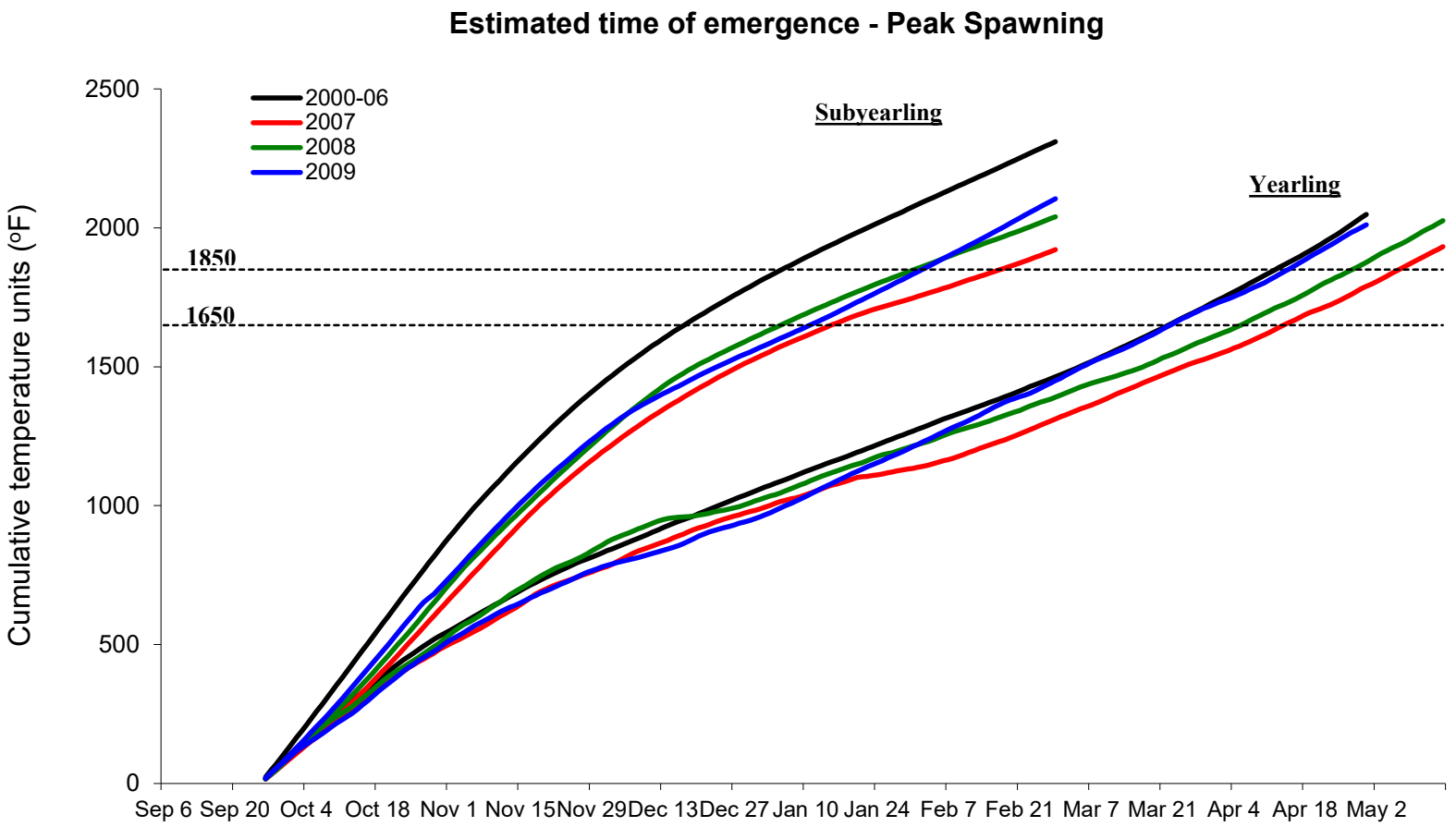


The model

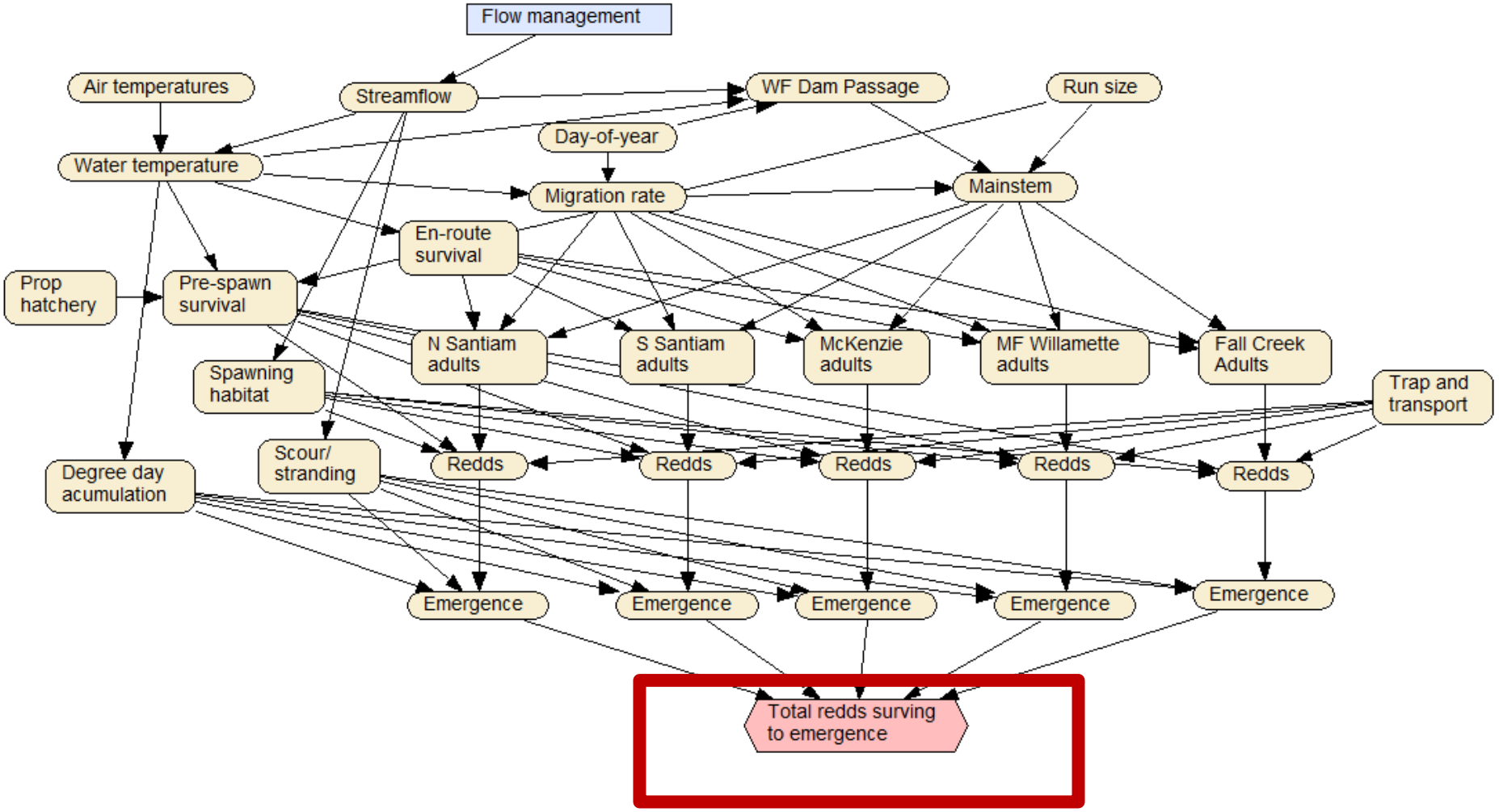


Incubation Timing

- Example Plot of North Santiam Observed temperature

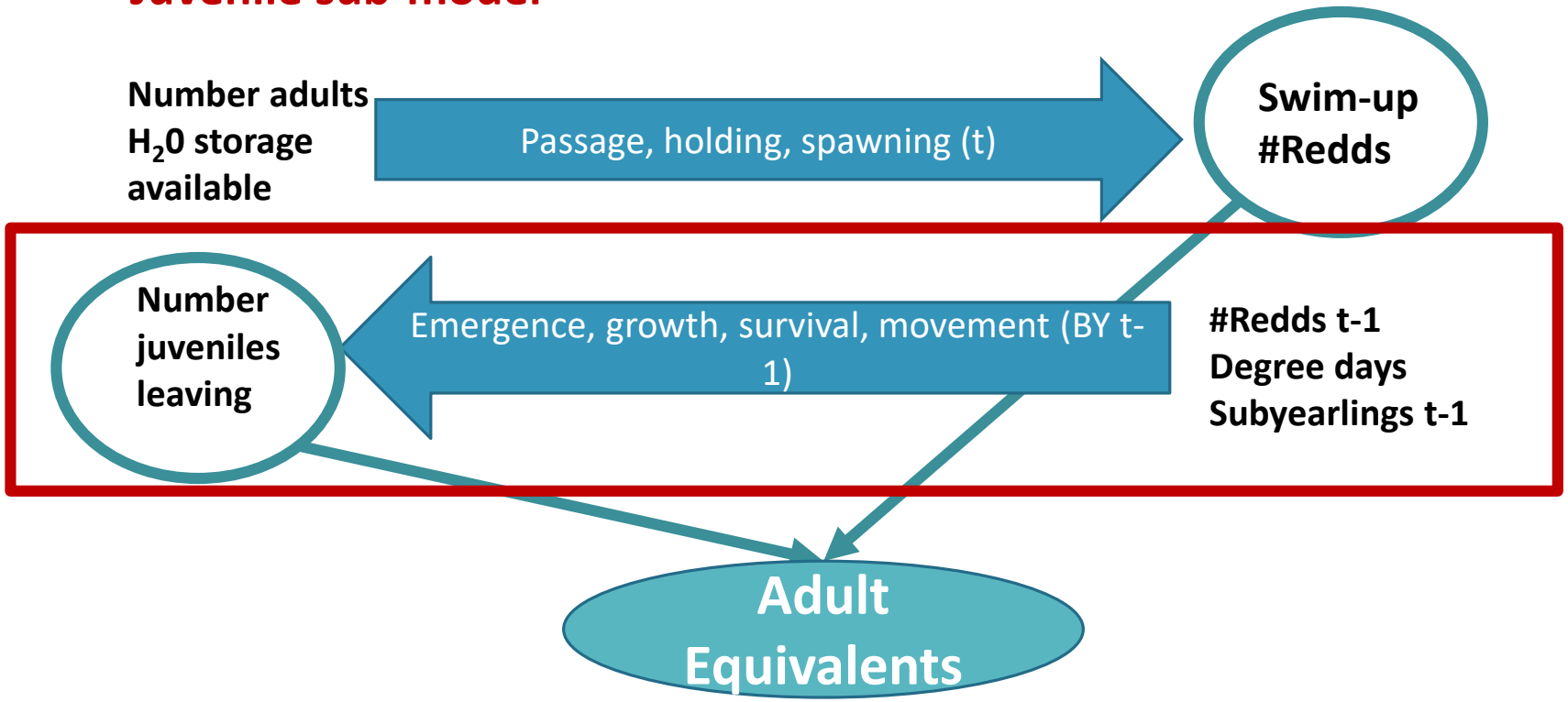


Adult Chinook Salmon Conceptual Model

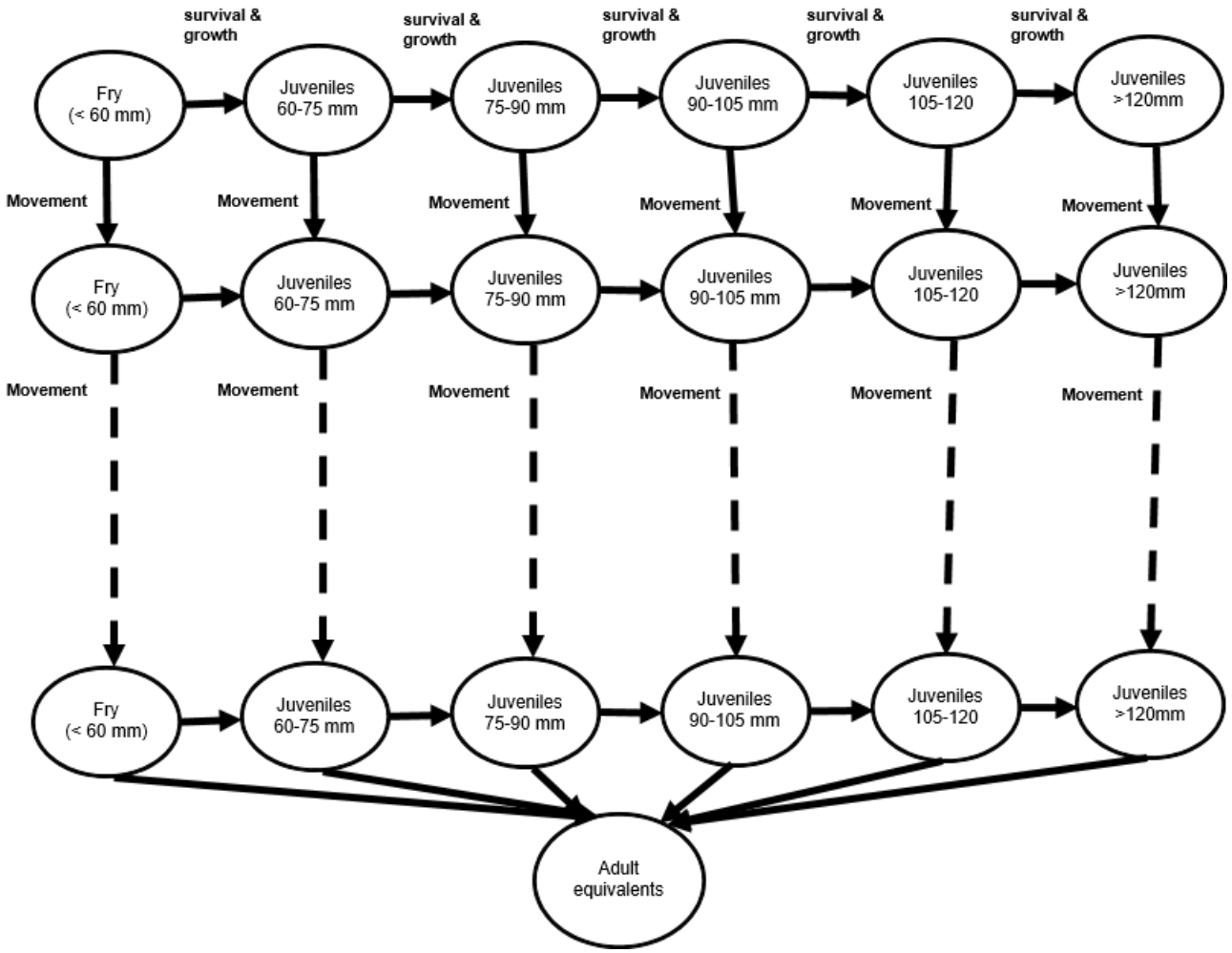


Total Redds Surviving to Emergence

- Egg to fry survival
  - 68% survival
  - 50% mortality above 61 degrees Fahrenheit
- **Juvenile sub-model**

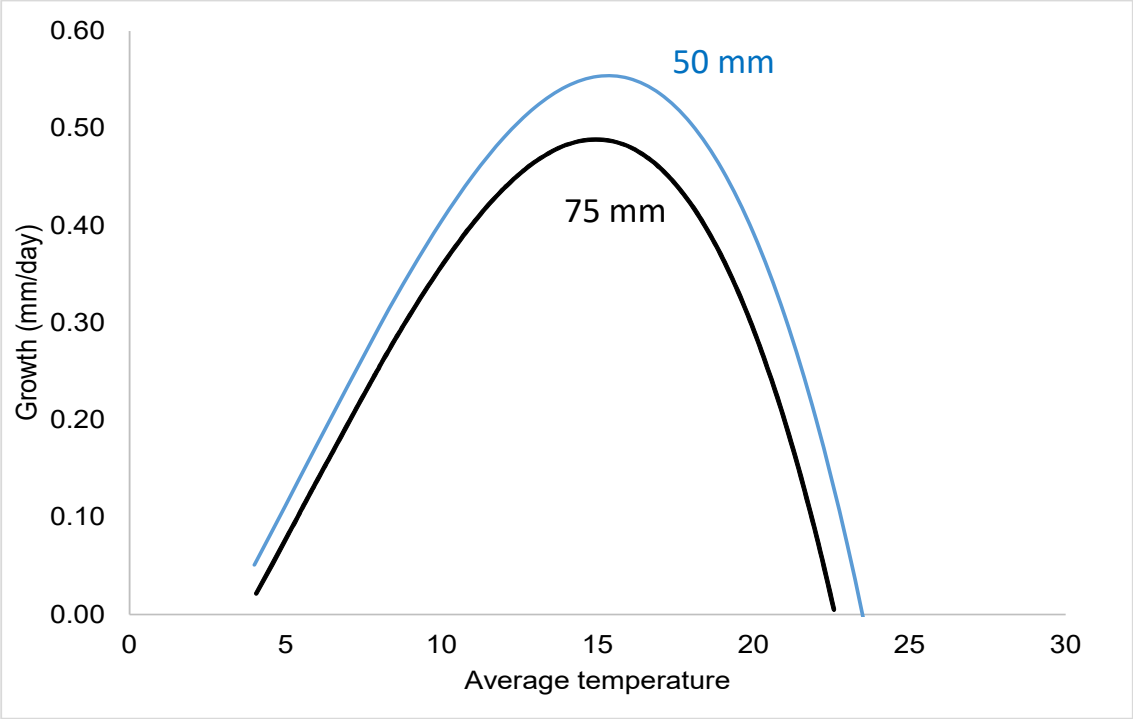


Juvenile Chinook Conceptual Model



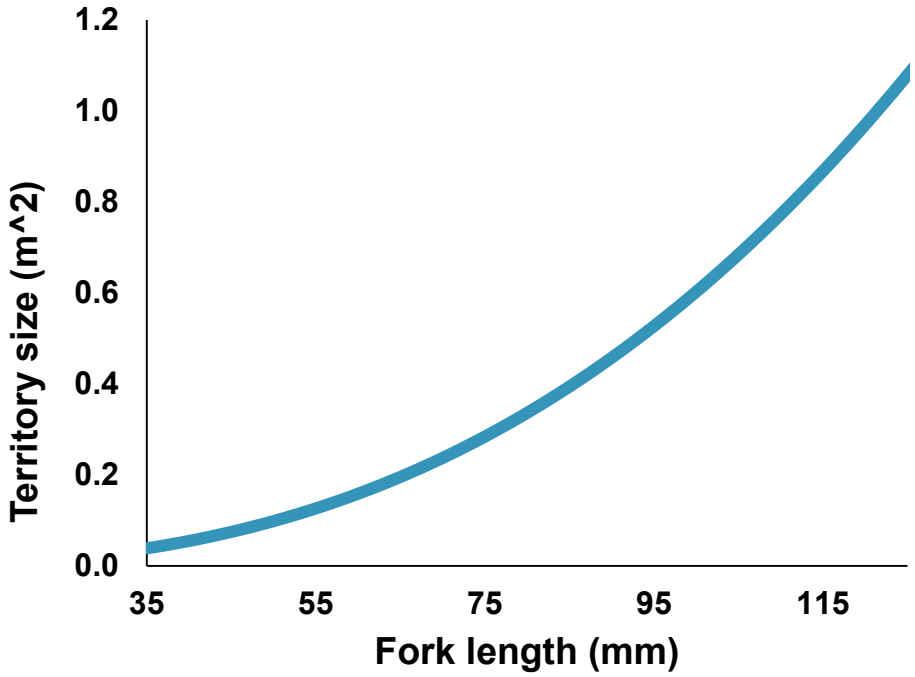
Juvenile Chinook Growth

- Bioenergetic Chinook growth model (Sullivan et al. 2000)
- Parameters fit using Willamette tagged juveniles 1999- 2017
- Assumed ration at 2/3 max.



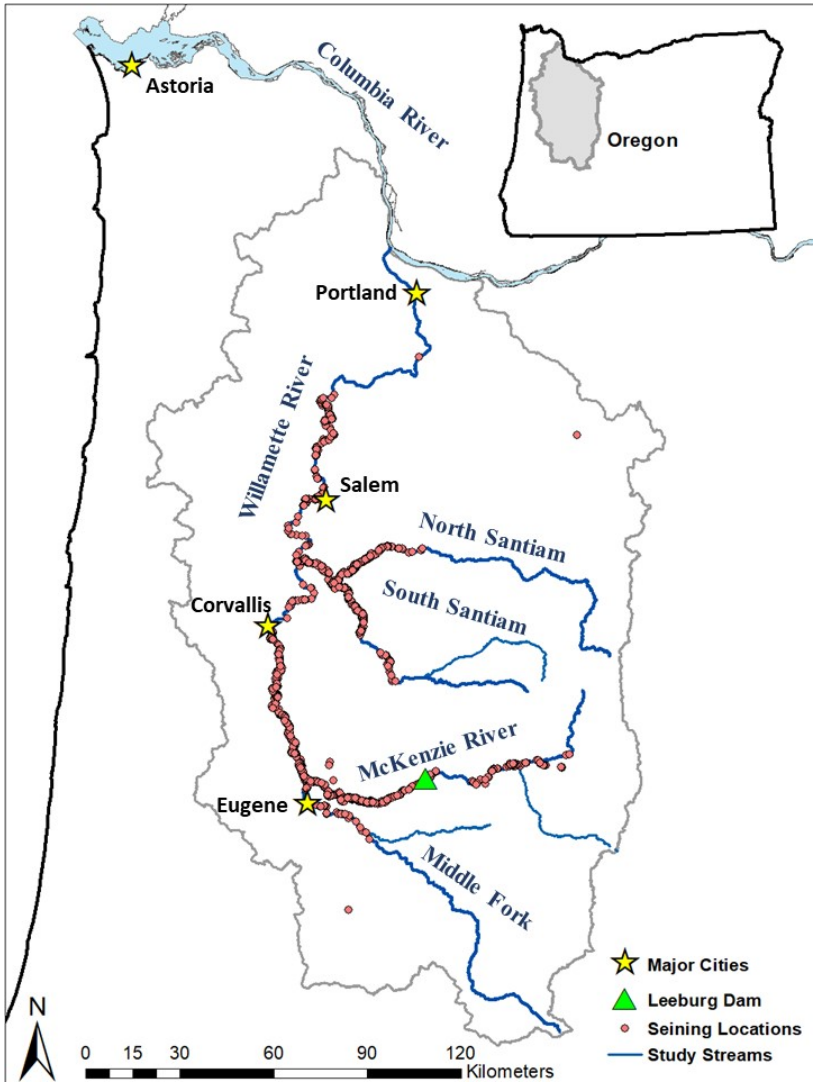
Juvenile Habitat Capacity

- Habitat estimates, USGS (James and Rose)
- Juvenile territory size, Grant and Kramer (1990)



Juvenile Chinook Survival and Movement

- ODFW 250,567 passive integrated transponders (PIT) tagged individuals
- Years: 1999-2017
- Beach seining (April - September)
- Modified juvenile rotary screw trap at Leaburg (November - March)
- ≥60-65 mm FL, present adipose fin



Schroeder et al. 2016

Methods

- Barker multi-strata recapture-resight-recovery model
  - Recapture= recaptured via seining
  - Resight= pit tag detections, capture by non-ODFW crews
  - Recovery = recovered mortalities/ tags
- 13 sections
- Time intervals- 2 weeks for 18 months, then annual
- Estimable parameters: recapture, recovery, resight, movement, survival probabilities
- Model selection AICc
- Survival and movement between sections and to estuary + smolt to adult survival (but S2A will be data limited)

Tagged Individuals

- 10,743 total detections/ 236 estuary

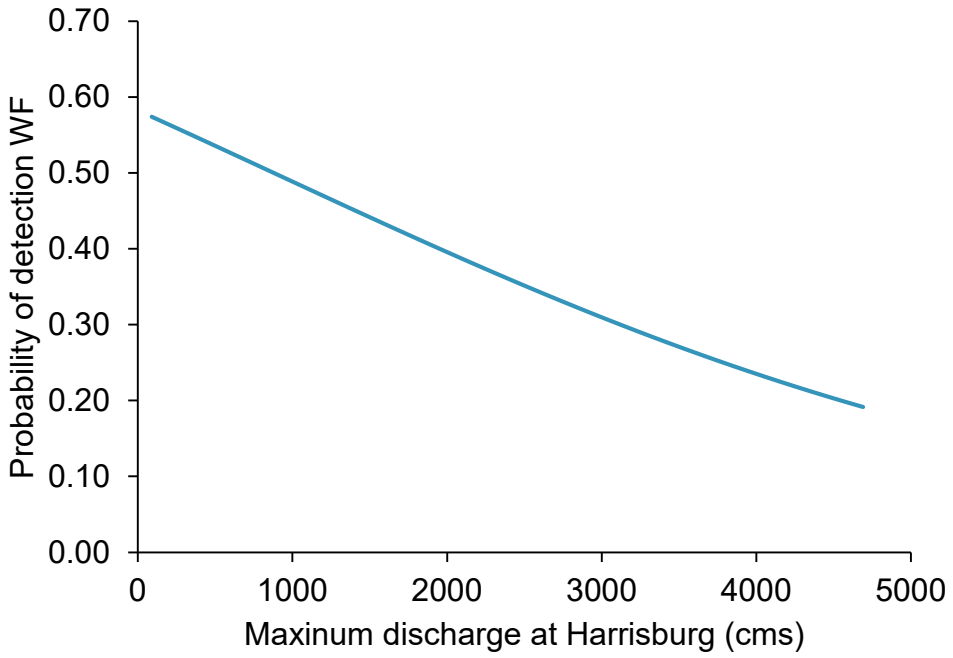
Provisional results subject to revision

Photo credit: Roger Tabor (USFWS)

Detection

Covariates

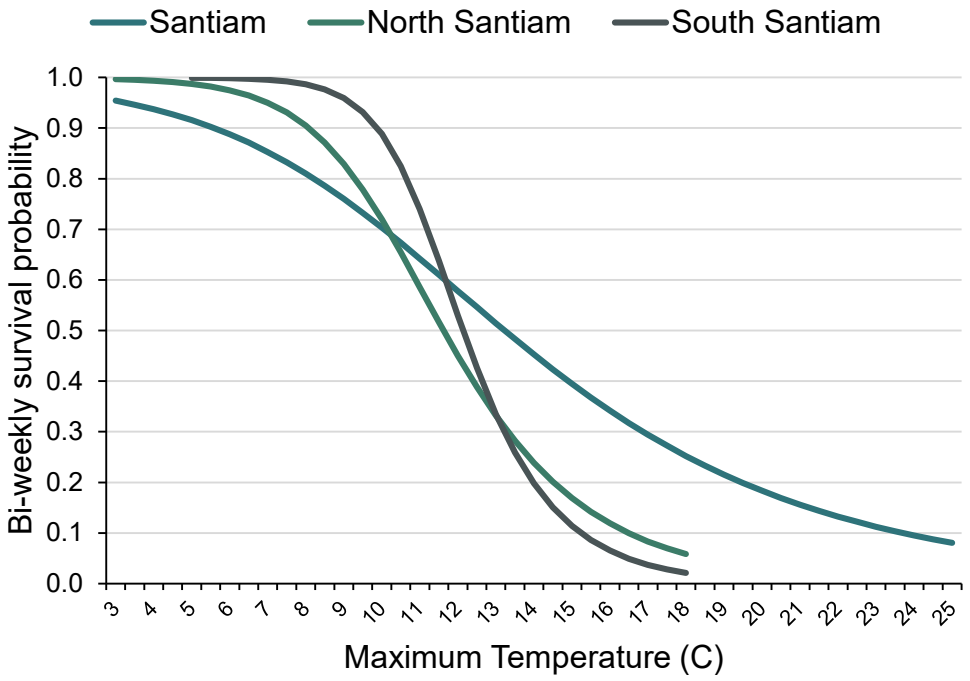
- Stratum (array)
- Max discharge closest gage
- Mean discharge closest gage
- Max temperature closest gage
- Mean temperature closest gage
- Upgrades to estuary array
- Estimated body size
- Others



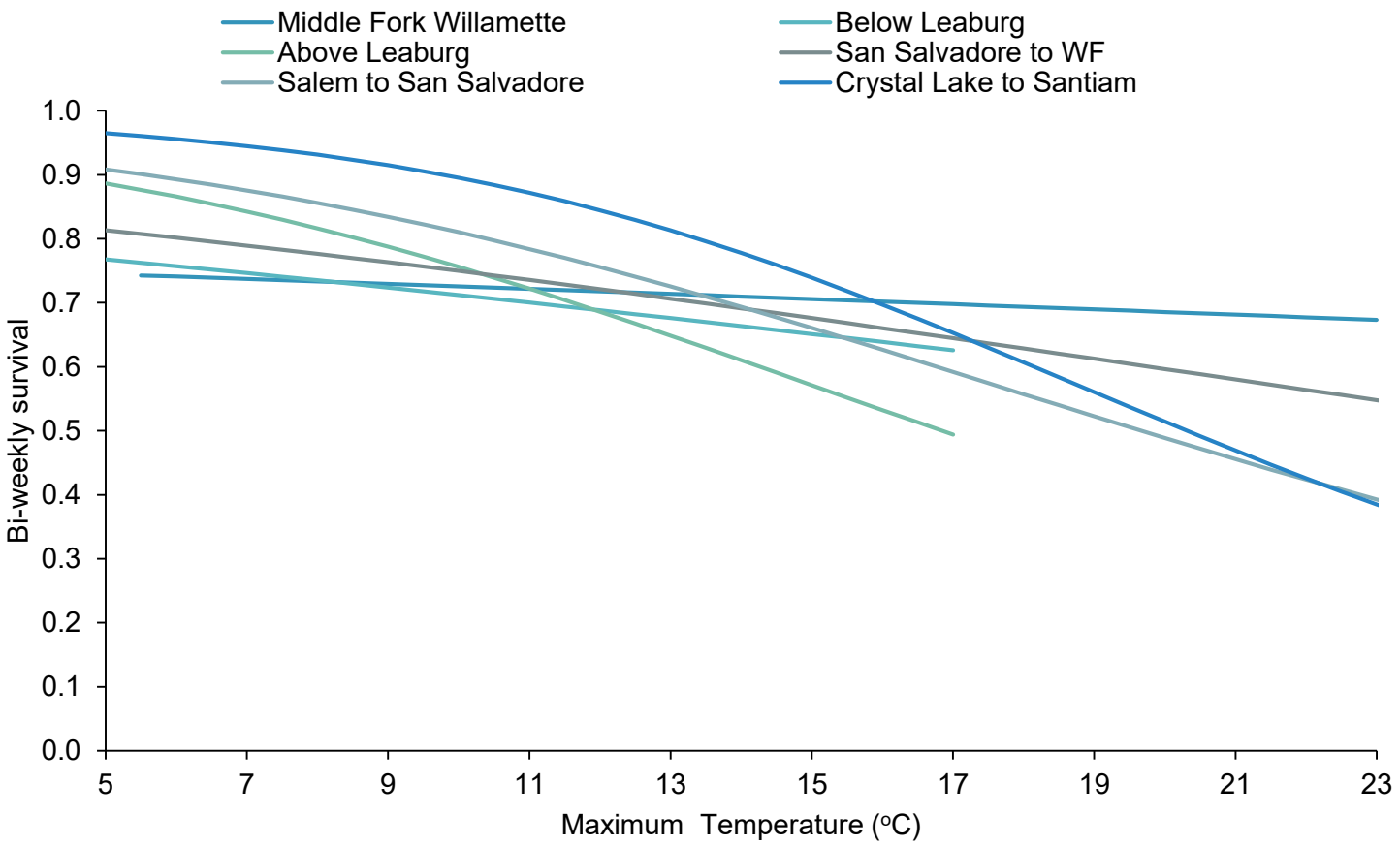
Survival

Covariates

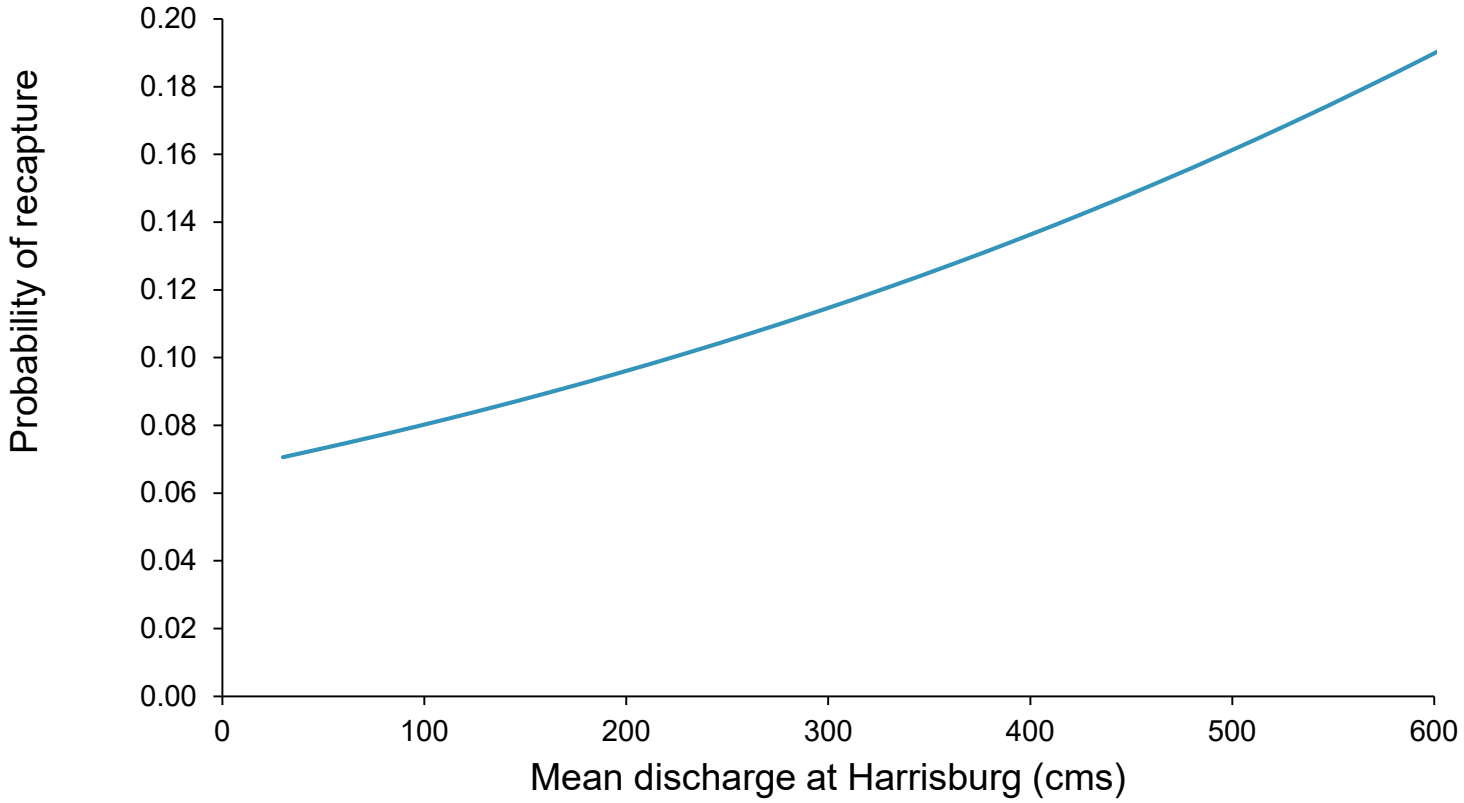
- Stratum (array)
- Max discharge closest gage
- Mean discharge closest gage
- Max temperature closest gage
- Mean temperature closest gage
- Proportion of days temp >20^{o}C
- SMB abundance
- Cumulative degree days >20^{o}C
- Upgrades to estuary array
- Estimated body size
- Day of Year
- Change in discharge from previous time interval
- Others



Survival

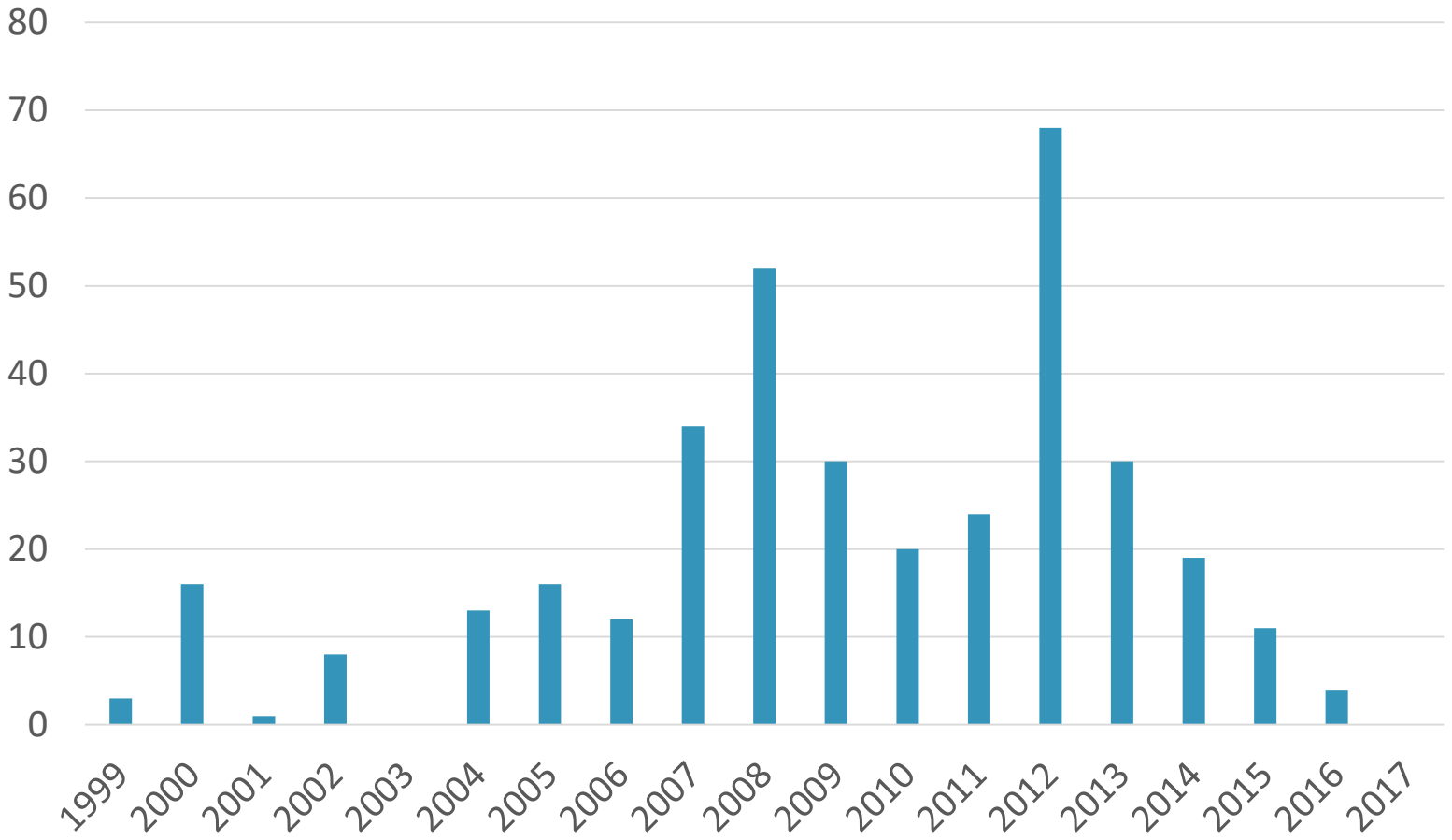

Middle Fork Willamette
Above Leaburg
Salem to San Salvadore
Below Leaburg
San Salvadore to WF
Crystal Lake to Santiam
Bi-weekly survival
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
5
7
9
11
13
15
17
19
21
23
Maximum Temperature (°C)

Recapture


Probability of recapture
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
100
200
300
400
500
600
Mean discharge at Harrisburg (cms)

Adult Returns

- 361 adult returns



Results

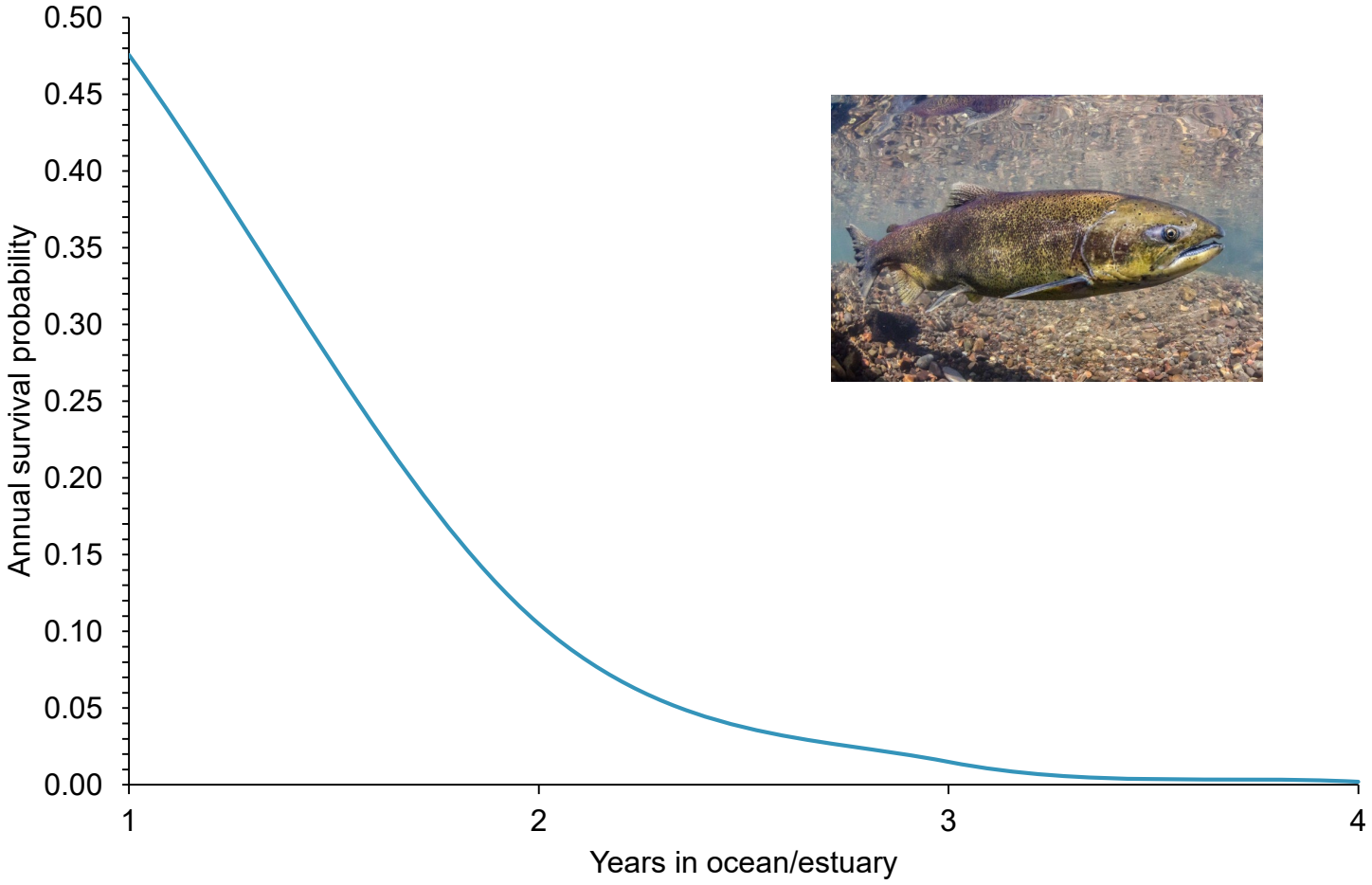


Photo credit: Morgan Bond

Provisional results subject to revision

Returning to Willamette Falls

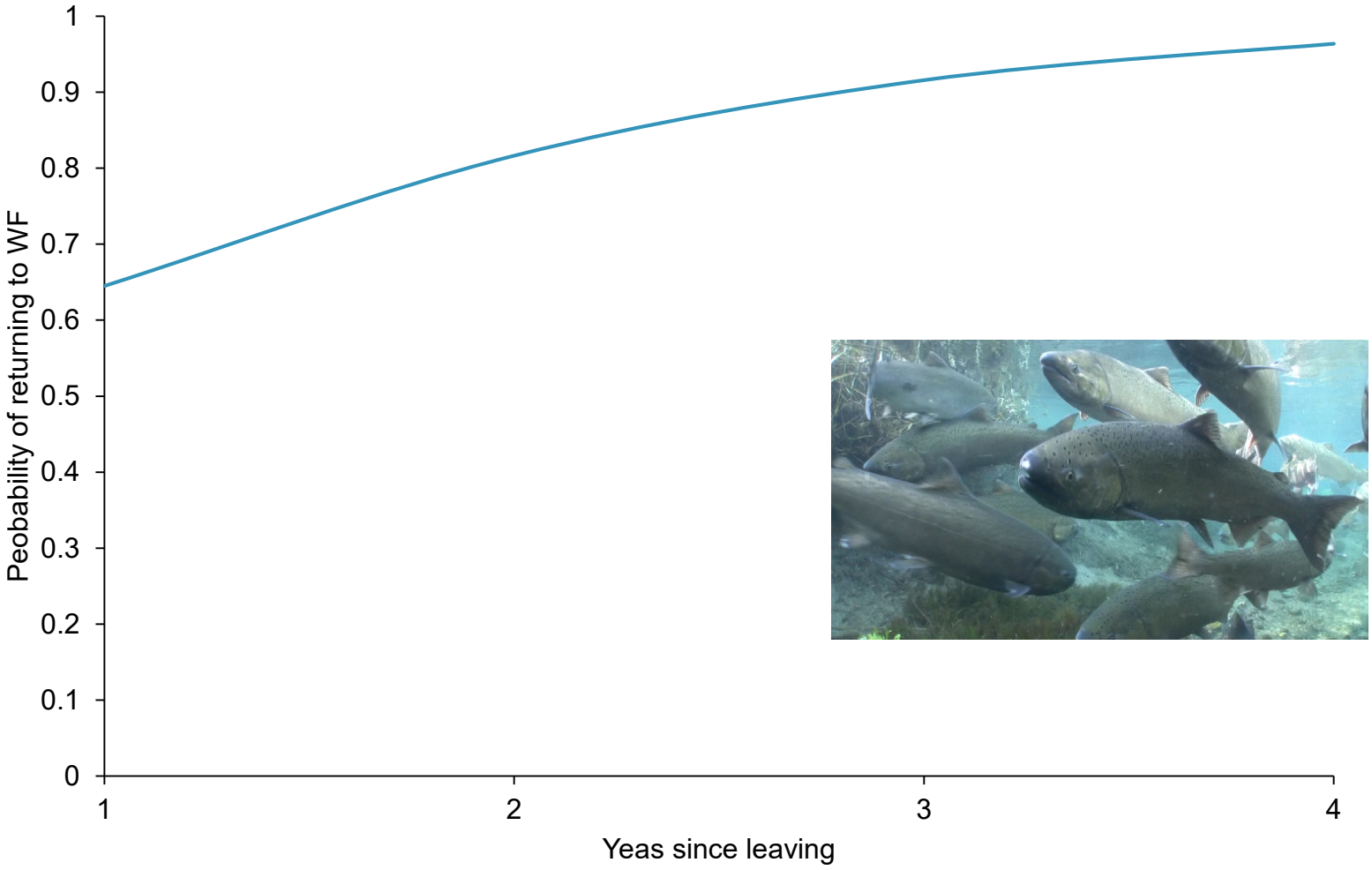
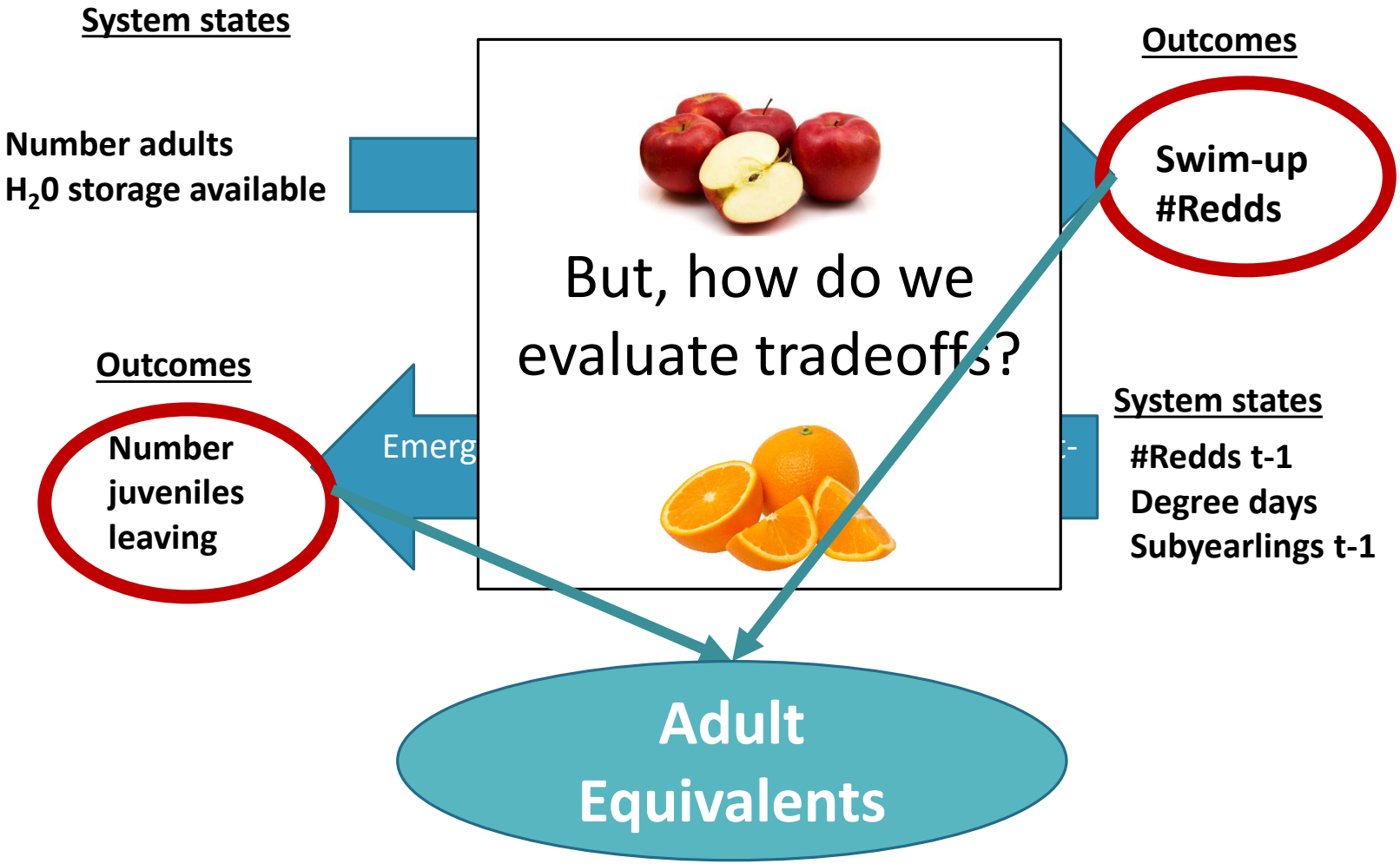


Photo credit: Michael Humling

Provisional results subject to revision

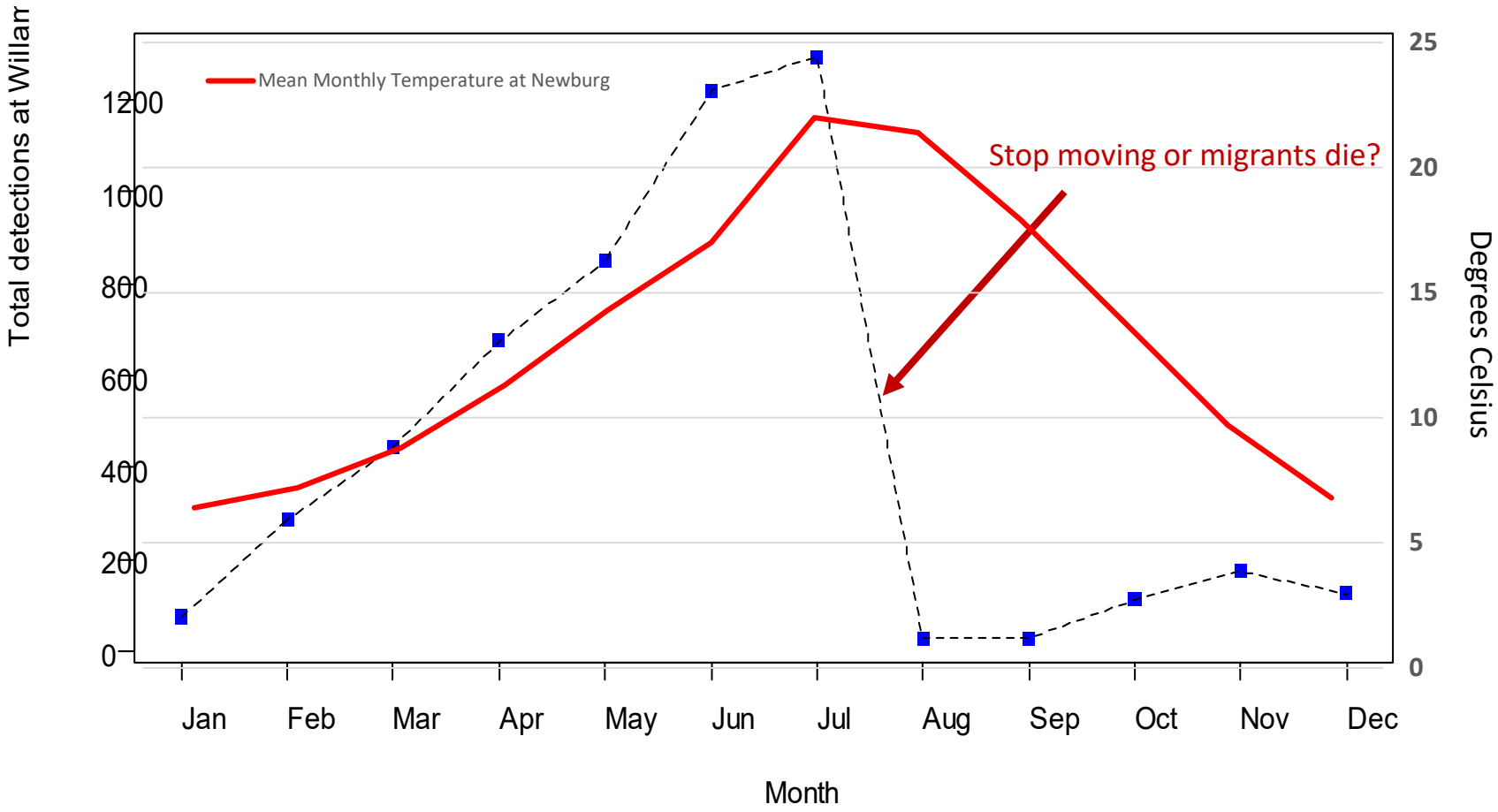
Solution: 2 Sub-models



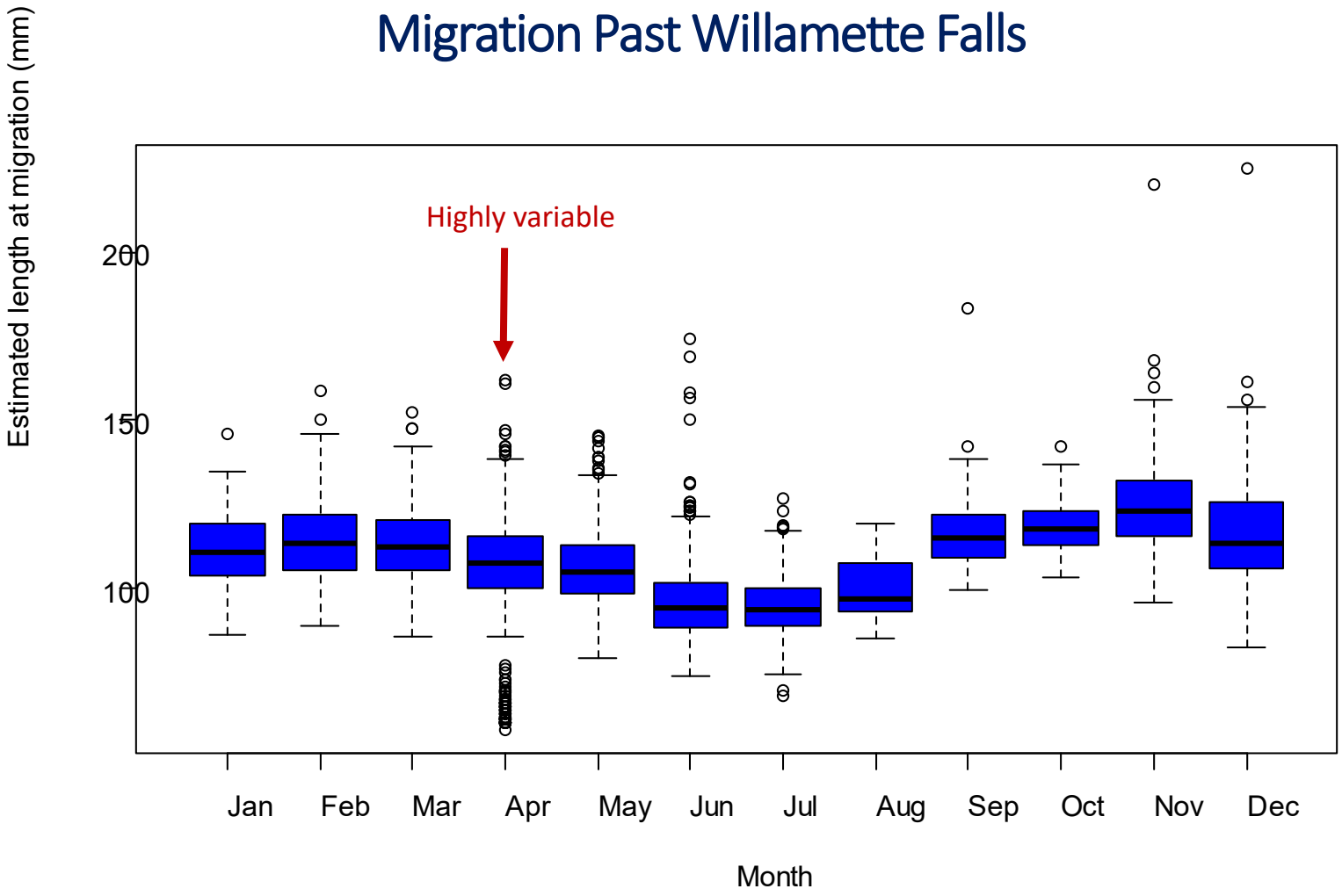
Adult Equivalents

- Estimate of smolt passing WF to Adult at WF
- Need to account for fish size at exit but…
- Do not know when undetected fish passed WF
- Solution
  - Analyze juvenile tag data fish detected past WF, n=5314
  - Assumption: detection returning adults = 1

Timing of juvenile detections at Willamette Falls



Estimated length at juvenile passing

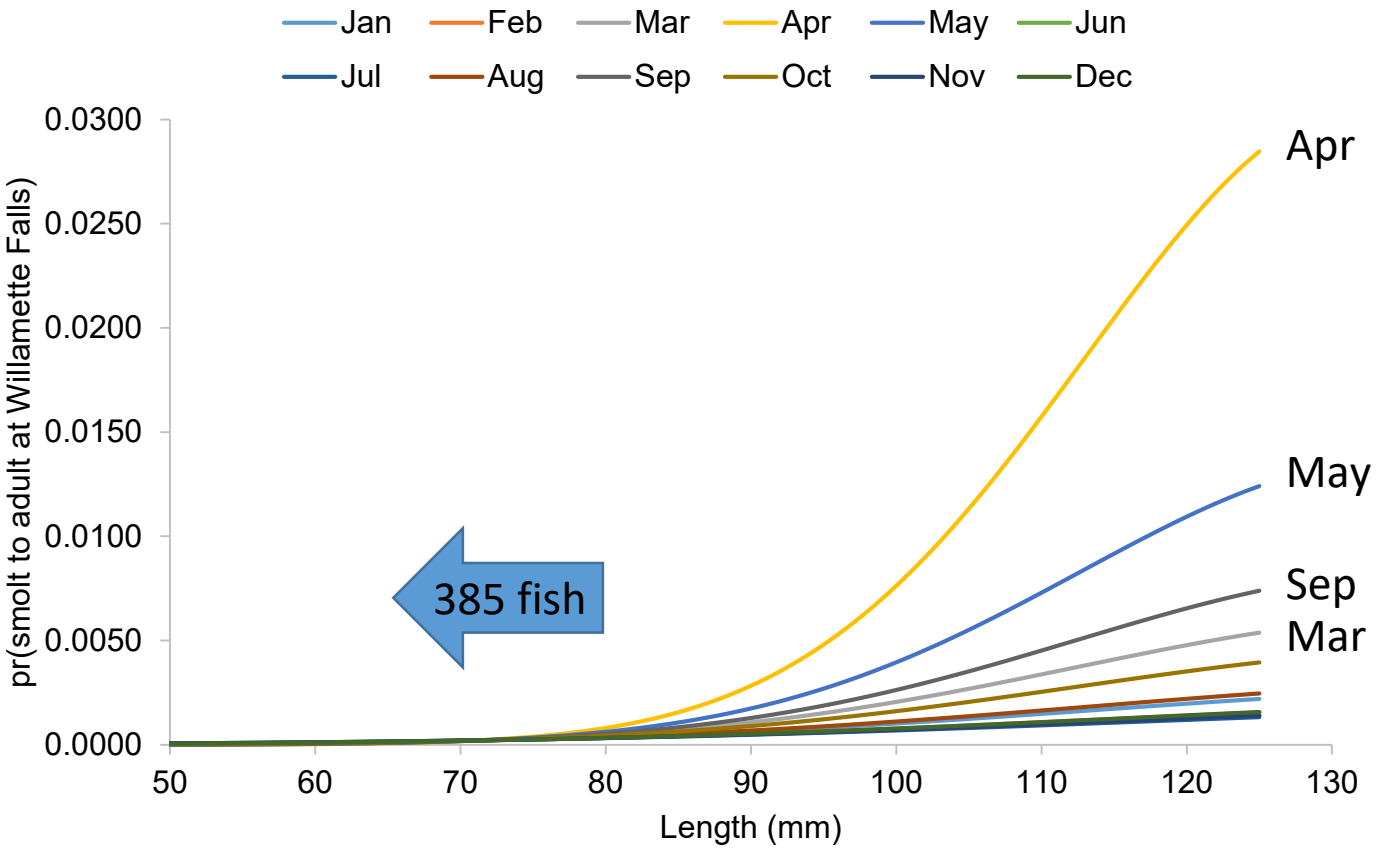


Adult Equivalents Modeling

- Candidate predictor variables:
- Average daily temperature and daily discharge time interval at Newberg
  - minimum, mean, maximum
- Mixed-effects logistic regression (temporal autocorrelation)
  - Response: probability of survival to Adult at WF
  - Year month random effects

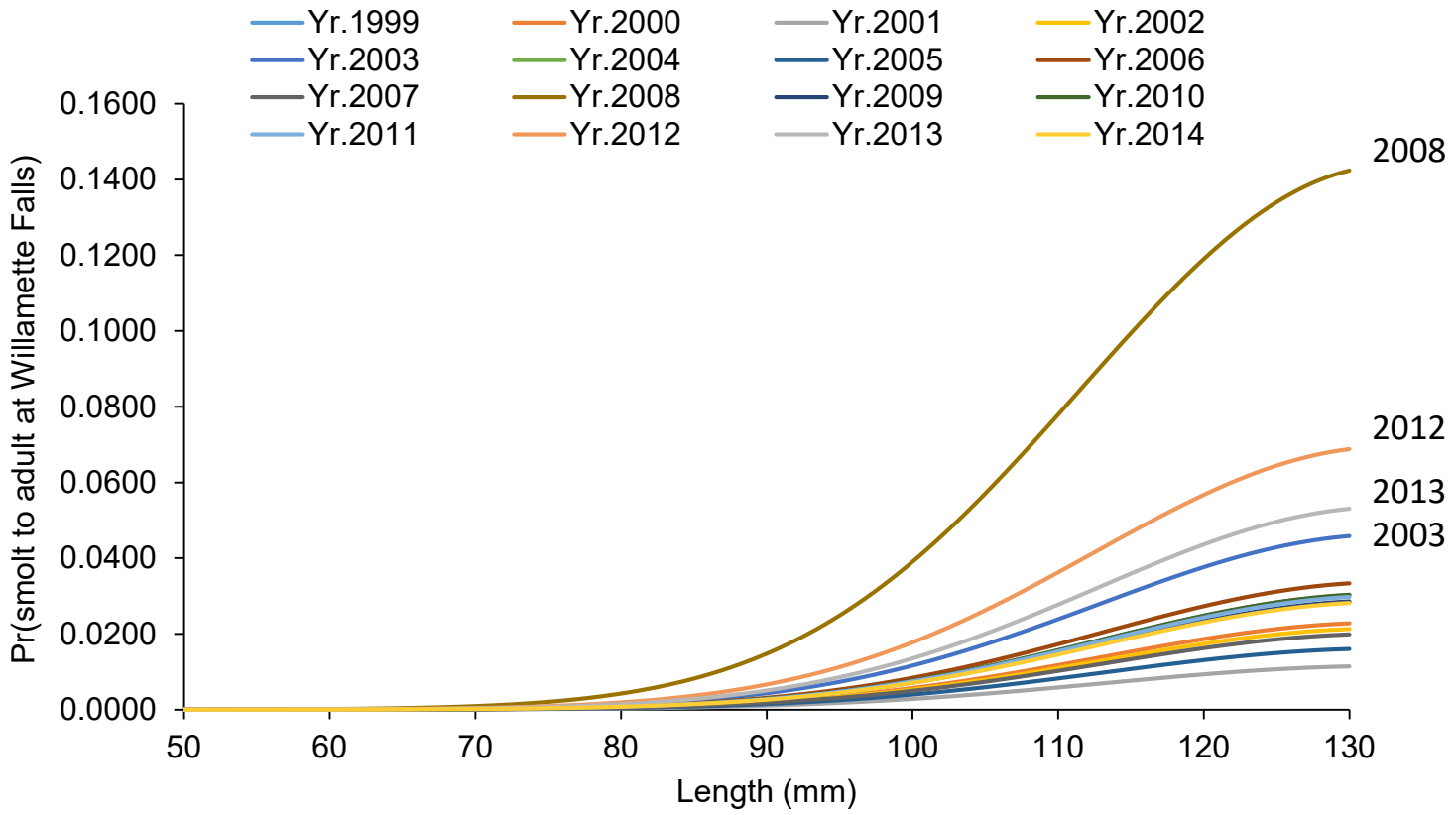
Results: Adult Equivalents Modeling

Length + Length^2, varied among months, pseudo R^2 = 0.59



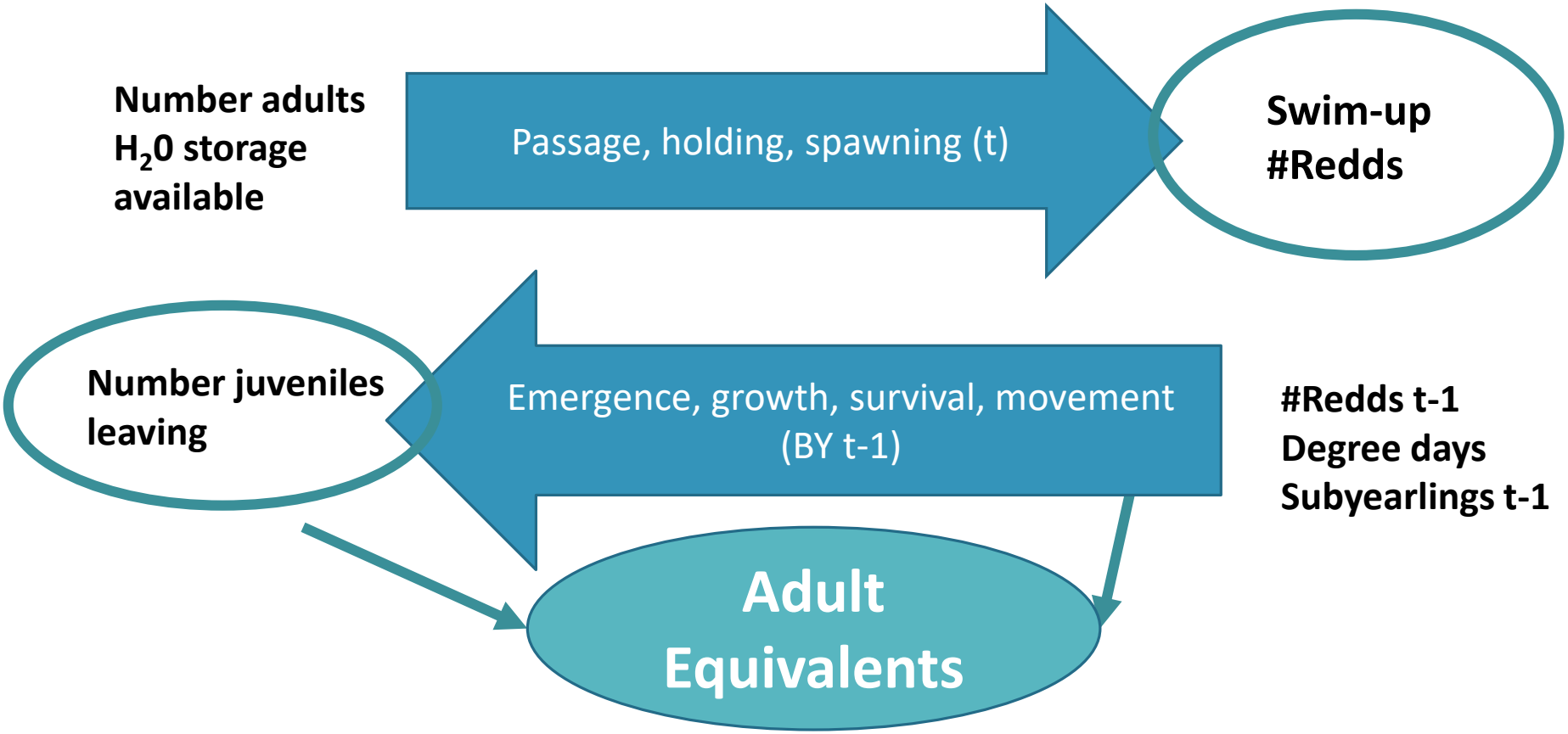
Results: Adult Equivalents Modeling

Smolts leaving in April



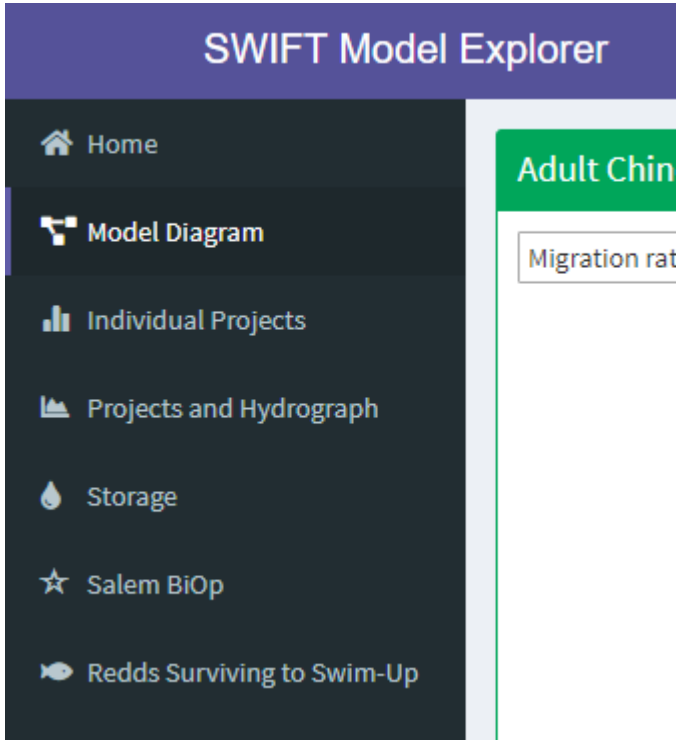
Making Models Accessible

- Visualize the objective tradeoffs (Chinook Example)

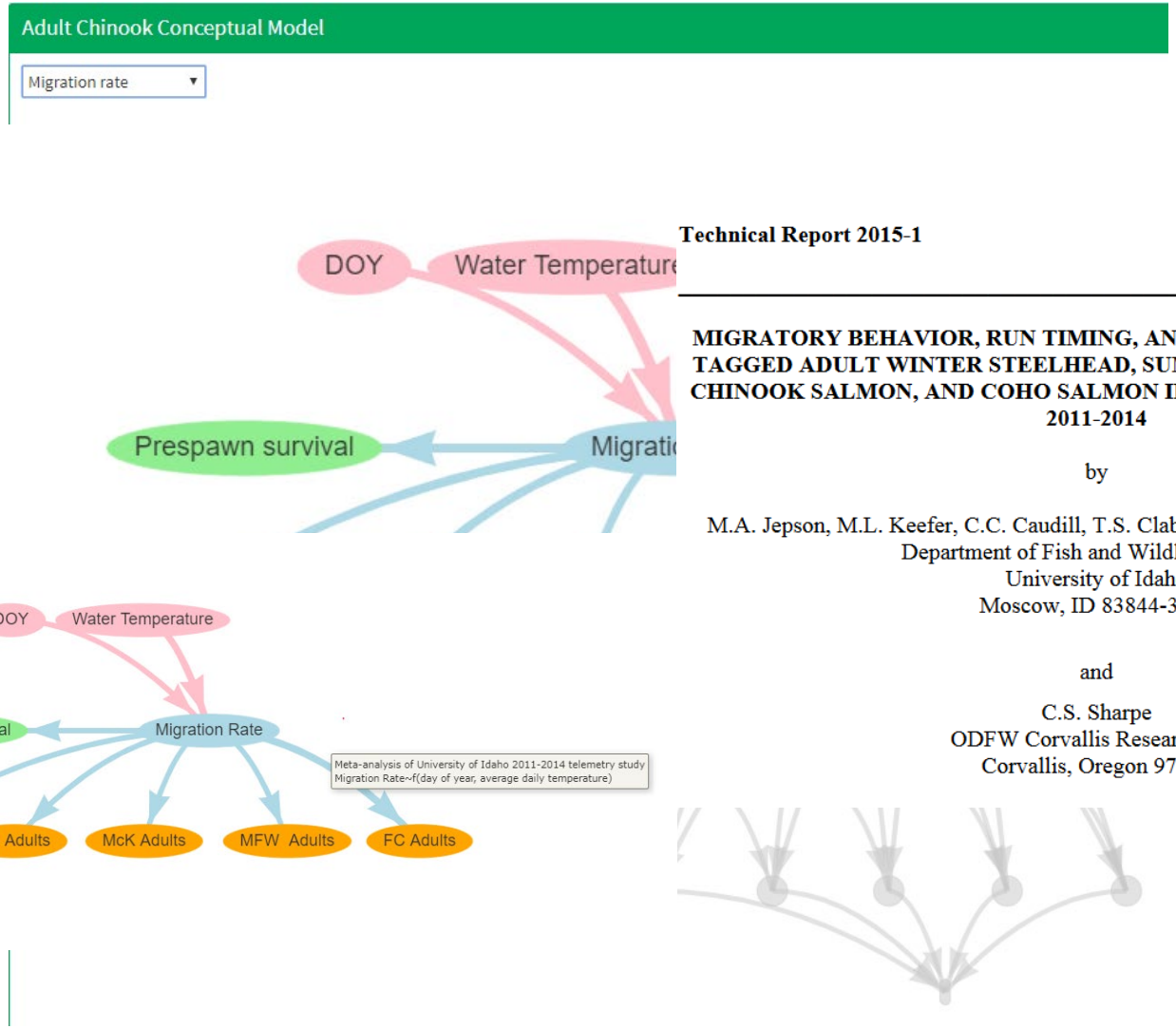


Shiny App

- Visualize tradeoffs
- Conceptual Model
- Compare Projects
- Compare to BiOp
- Different Scenarios
- Output in report form



Model Conceptual Model



Technical Report 2015-1

MIGRATORY BEHAVIOR, RUN TIMING, AND DISTRIBUTION OF RADIO-TAGGED ADULT WINTER STEELHEAD, SUMMER STEELHEAD, SPRING CHINOOK SALMON, AND COHO SALMON IN THE WILLAMETTE RIVER: 2011-2014

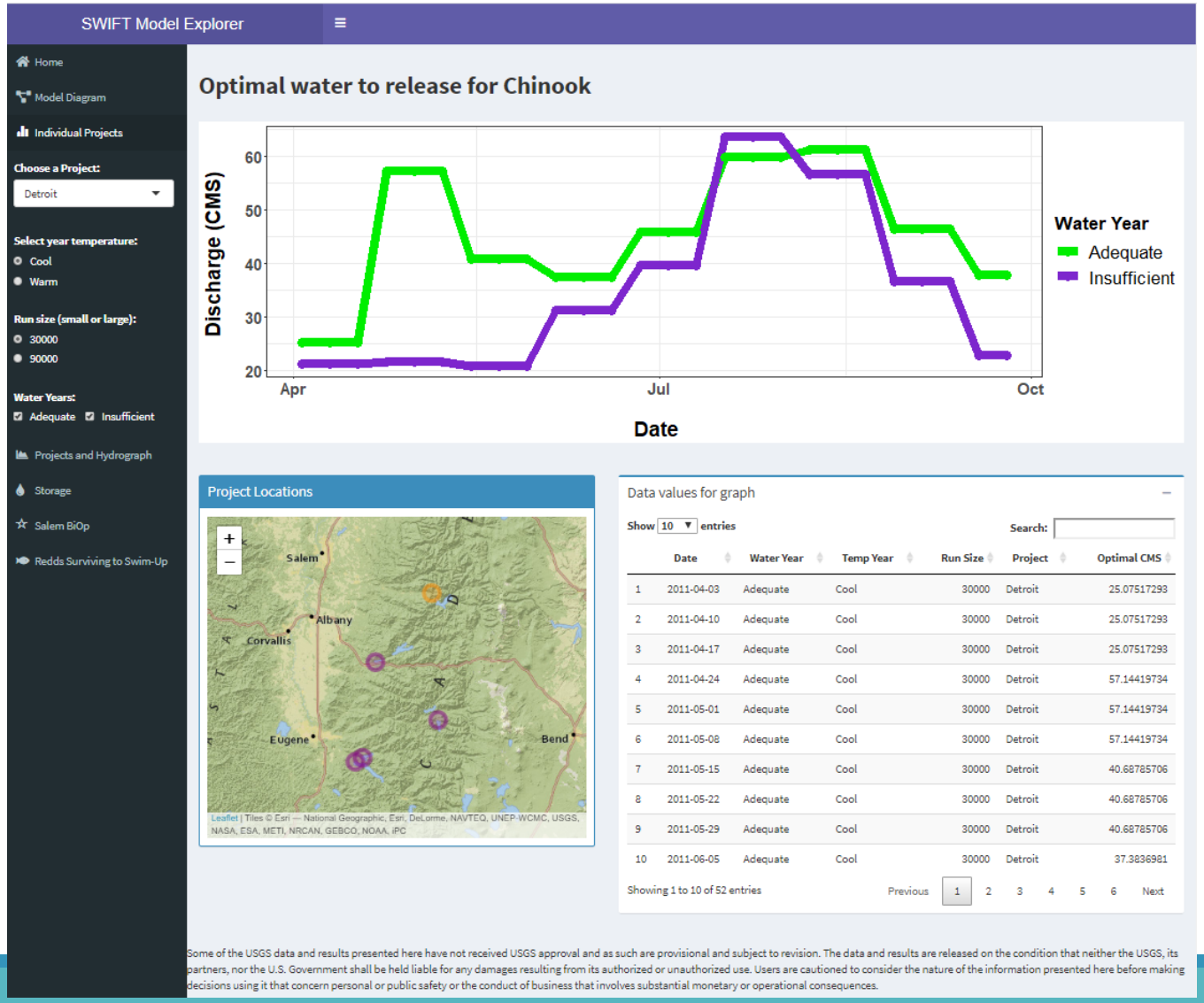
by

M.A. Jepson, M.L. Keefer, C.C. Caudill, T.S. Clabough, C.S. Erdman, T. Blubaugh
Department of Fish and Wildlife Sciences
University of Idaho
Moscow, ID 83844-3141

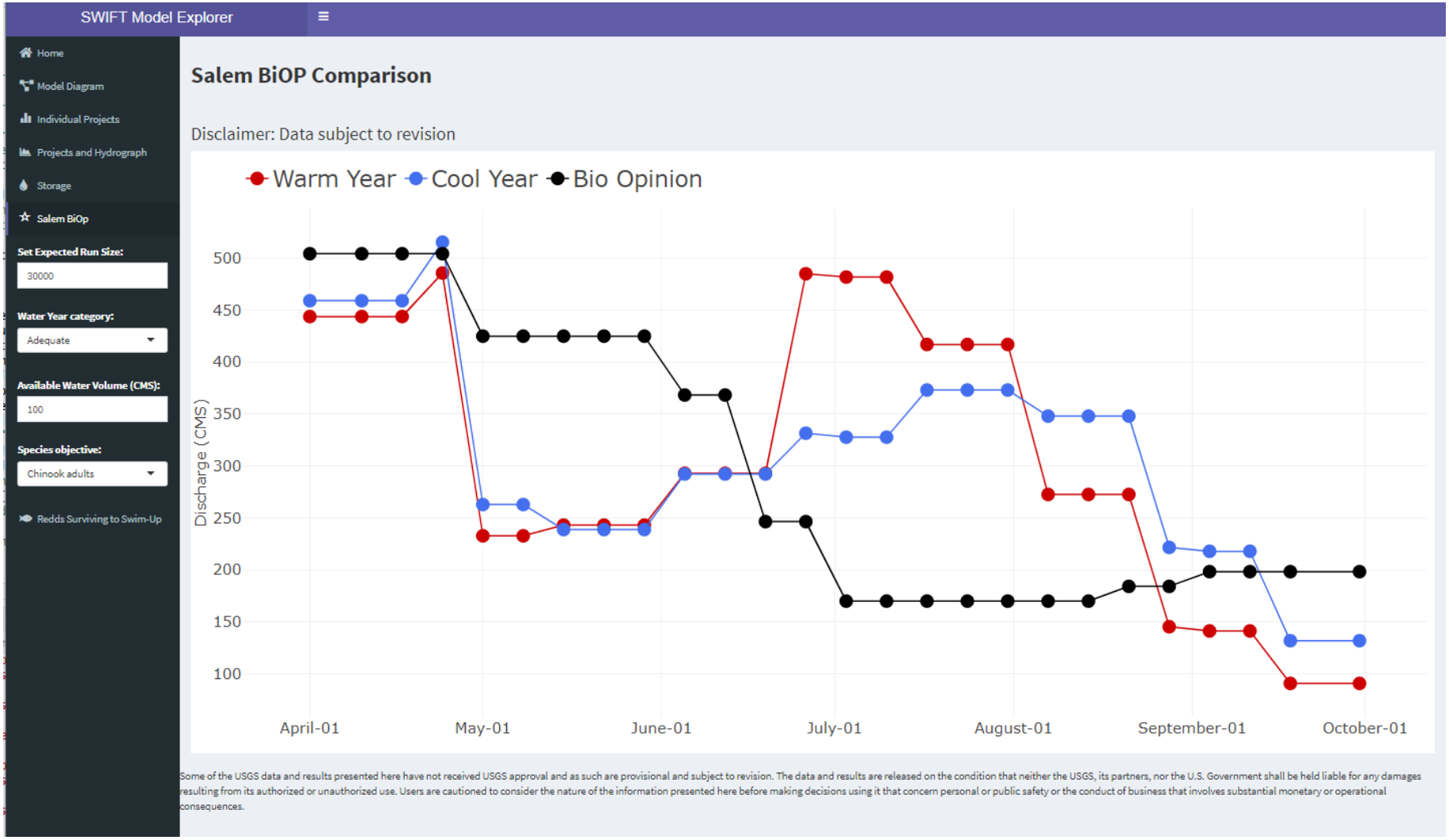
and

C.S. Sharpe
ODFW Corvallis Research Lab
Corvallis, Oregon 97333

Shiny App


SWIFT Model Explorer
Home
Model Diagram
Individual Projects
Choose a Project:
Detroit
Select year temperature:
Cool
Warm
Run size (small or large):
30000
90000
Water Years:
Adequate
Insufficient
Projects and Hydrograph
Storage
Salem BiOp
Redds Surviving to Swim-Up
Optimal water to release for Chinook
Discharge (CMS)
60
50
40
30
20
Apr
Jul
Oct
Date
Water Year
Adequate
Insufficient
Project Locations
Salem
Albany
Corvallis
Eugene
Bend
Leaflet | Tiles © Esri — National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC
Data values for graph
Show 10 entries
Search:
Date
Water Year
Temp Year
Run Size
Project
Optimal CMS
1 2011-04-03 Adequate Cool 30000 Detroit 25.07517293
2 2011-04-10 Adequate Cool 30000 Detroit 25.07517293
3 2011-04-17 Adequate Cool 30000 Detroit 25.07517293
4 2011-04-24 Adequate Cool 30000 Detroit 57.14419734
5 2011-05-01 Adequate Cool 30000 Detroit 57.14419734
6 2011-05-08 Adequate Cool 30000 Detroit 57.14419734
7 2011-05-15 Adequate Cool 30000 Detroit 40.68785706
8 2011-05-22 Adequate Cool 30000 Detroit 40.68785706
9 2011-05-29 Adequate Cool 30000 Detroit 40.68785706
10 2011-06-05 Adequate Cool 30000 Detroit 37.3836981
Showing 1 to 10 of 52 entries
Previous 1 2 3 4 5 6 Next
Some of the USGS data and results presented here have not received USGS approval and as such are provisional and subject to revision. The data and results are released on the condition that neither the USGS, its partners, nor the U.S. Government shall be held liable for any damages resulting from its authorized or unauthorized use. Users are cautioned to consider the nature of the information presented here before making decisions using it that concern personal or public safety or the conduct of business that involves substantial monetary or operational consequences.

Shiny App


SWIFT Model Explorer
Home
Model Diagram
Individual Projects
Projects and Hydrograph
Storage
Salem BiOp
Set Expected Run Size:
30000
Water Year category:
Adequate
Available Water Volume (CMS):
100
Species objective:
Chinook adults
Redds Surviving to Swim-Up
Salem BiOP Comparison
Disclaimer: Data subject to revision
Warm Year
Cool Year
Bio Opinion
Discharge (CMS)
500
450
400
350
300
250
200
150
100
April-01
May-01
June-01
July-01
August-01
September-01
October-01
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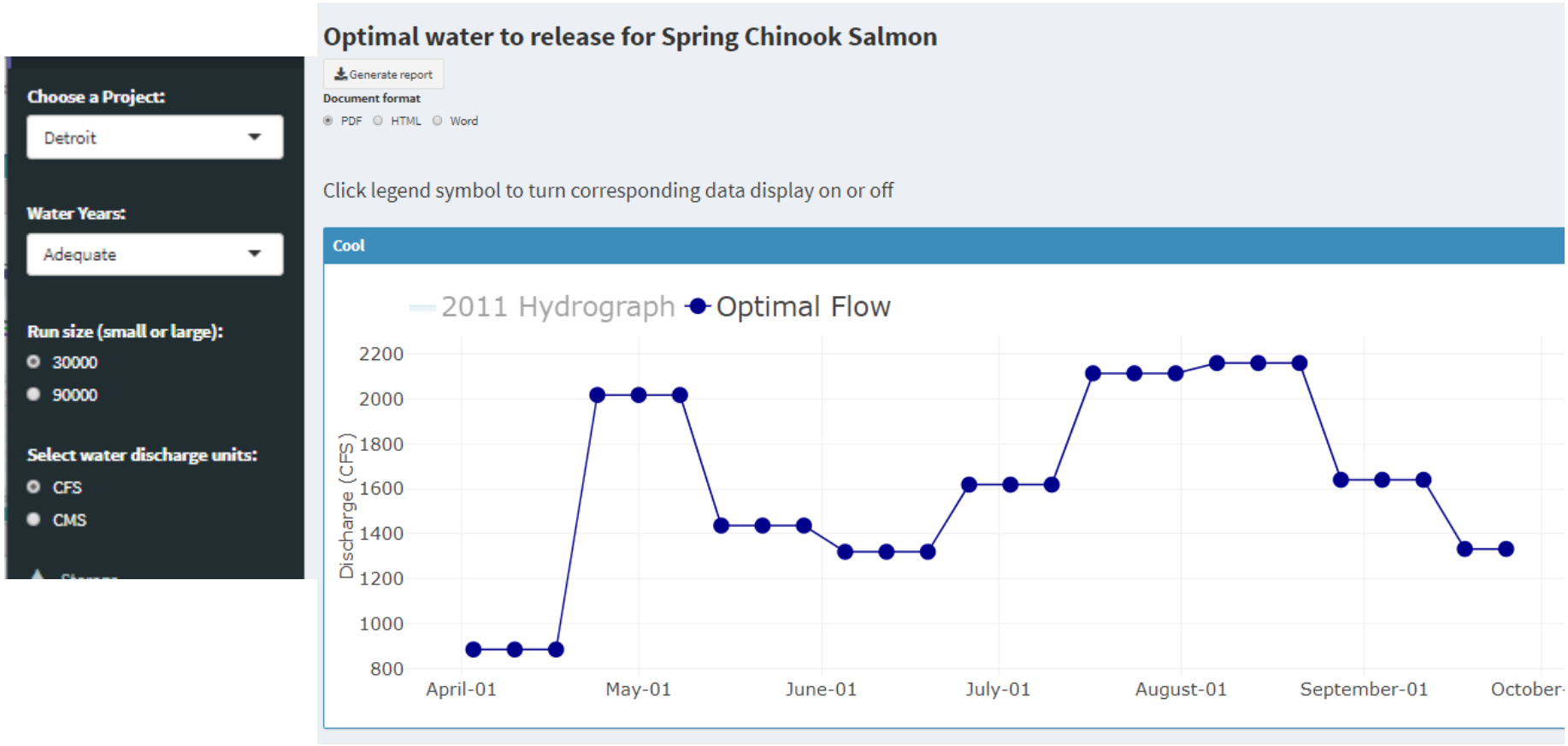
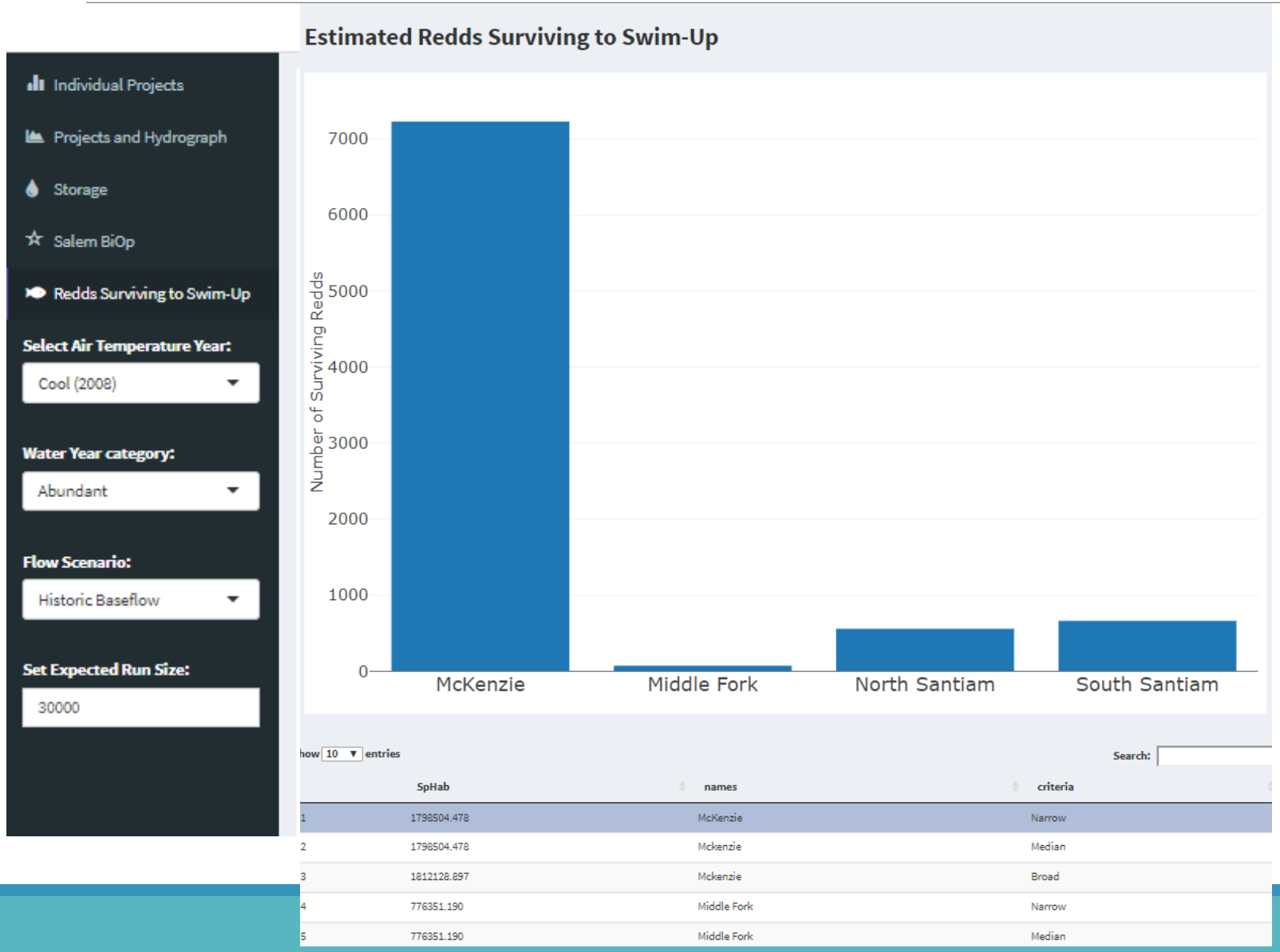

Choose a Project:
Detroit
Water Years:
Adequate
Run size (small or large):
30000
90000
Select water discharge units:
CFS
CMS
Optimal water to release for Spring Chinook Salmon
Generate report
Document format
PDF
HTML
Word
Click legend symbol to turn corresponding data display on or off
Cool
2011 Hydrograph
Optimal Flow
Discharge (CFS)
2200
2000
1800
1600
1400
1200
1000
800
April-01
May-01
June-01
July-01
August-01
September-01
October

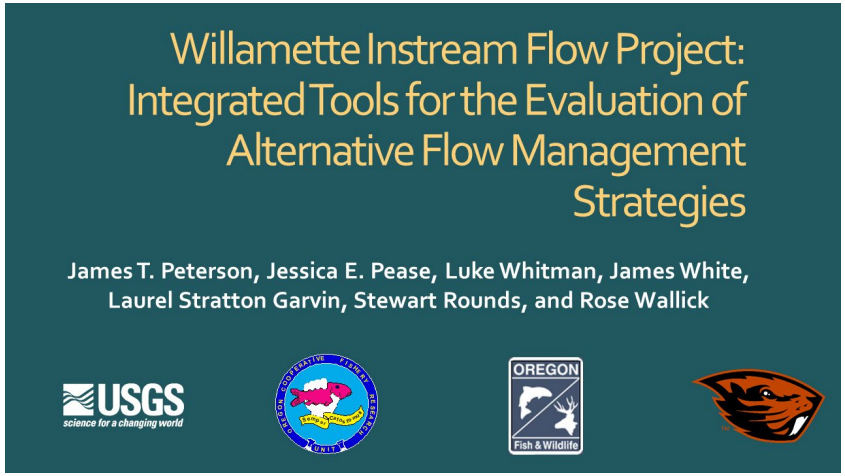
Shiny App


Individual Projects
Projects and Hydrograph
Storage
Salem BiOp
Redds Surviving to Swim-Up
Select Air Temperature Year:
Cool (2008)
Water Year category:
Abundant
Flow Scenario:
Historic Baseflow
Set Expected Run Size:
30000
Estimated Redds Surviving to Swim-Up
Number of Surviving Redds
7000
6000
5000
4000
3000
2000
1000
0
McKenzie
Middle Fork
North Santiam
South Santiam
how 10 entries
Search:
SpHab
names
criteria
1 1798504.478 McKenzie Narrow
2 1798504.478 Mckenzie Median
3 1812128.897 Mckenzie Broad
4 776351.190 Middle Fork Narrow
5 776351.190 Middle Fork Median

Next Steps

- Identify key uncertainties
- Include additional objectives
- Additional scenarios
- Shiny App Feedback – Tool Workshop
- Finding best flow regime to maximize adult equivalents

(Jim Presentation)



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Covariates for Chinook Model

- Survival (stratum specific)-
  - (for estuarine /ocean stratum: 2 models constant and cohort specific)
  - Peak discharge during a time interval
  - Average daily maximum temperature during a time interval
  - Proportion of days with ave daily temps > 20 C during a time interval
  - Cumulative number of days with ave daily temps > 20 C
  - Estimated body size
  - CPUE of smallmouth bass > 150 mm
  - Turbidity within a stratum
  - Peak cormorant and tern nesting counts at mouth of Columbia

Covariates for Chinook Model

- Movement (from river strata to WFD or below)
  - Cumulative degree days
  - Day of the year (+ quadratic term)
  - Estimated body size (group)
  - Change in average discharge from previous time interval
  - Average daily maximum temperature during a time interval
- Movement (from river strata to river strata)
  - Estimated body size (group)
  - Change in average discharge from previous time interval
  - Average daily maximum temperature within stratum that was left during a time interval
  - Average habitat availability within stratum that was left
  - Cohort size as indexed by redd counts
  - CPUE of small SMB (<100mm)

Covariates for Chinook Model

- Detection (p, stratum specific)
  - Ave discharge during sampling
  - Ave daily temperature during sampling
  - Ave turbidity when sampling
- Resight (R, stratum specific)
  - Ave discharge during interval
  - Ave daily temperature during interval
- Recovery
  - Peak cormorant and tern nesting counts at mouth of Columbia