An Integrated Model for Estimating Pacific Lamprey Abundance and Passage at Willamette Falls

$$N = \frac{(C+1)(M+1)}{(R+1)} - 1$$

Steve Whitlock, Cyndi Baker, Jim Peterson

OSU

CONFEDERATED TRIBES OF WARM SPRINGS 1855

USGS science for a changing world

Obstacle and Opportunity

- Understanding passage rates and abundance is critical
- All barriers are different

Enumerating Fish at Passage Barriers

- Approaches
  - Census
  - Counting surveys
  - Mark-recapture

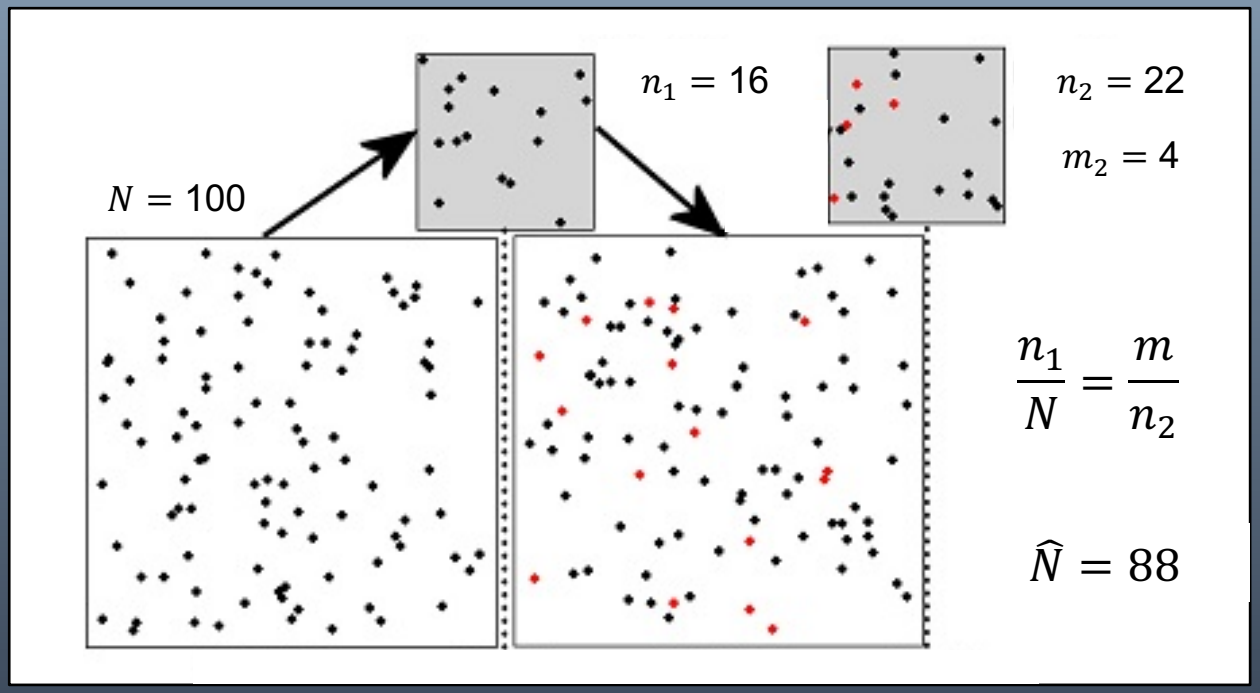
Lincoln Petersen(LP) Estimator

n_1 = # marked (1st pass)

n_2 = # examined (2nd pass)

m_2 = # recaptured (2nd pass)

TAGGED:UNTAGGED
=
OBSERVED:TOTAL



Lincoln Petersen(LP) Estimator

n_1 = # marked (1st pass)

n_2 = # examined (2nd pass)

m_2 = # recaptured (2nd pass)

TAGGED:UNTAGGED
=
OBSERVED:TOTAL

Lincoln Petersen (LP)

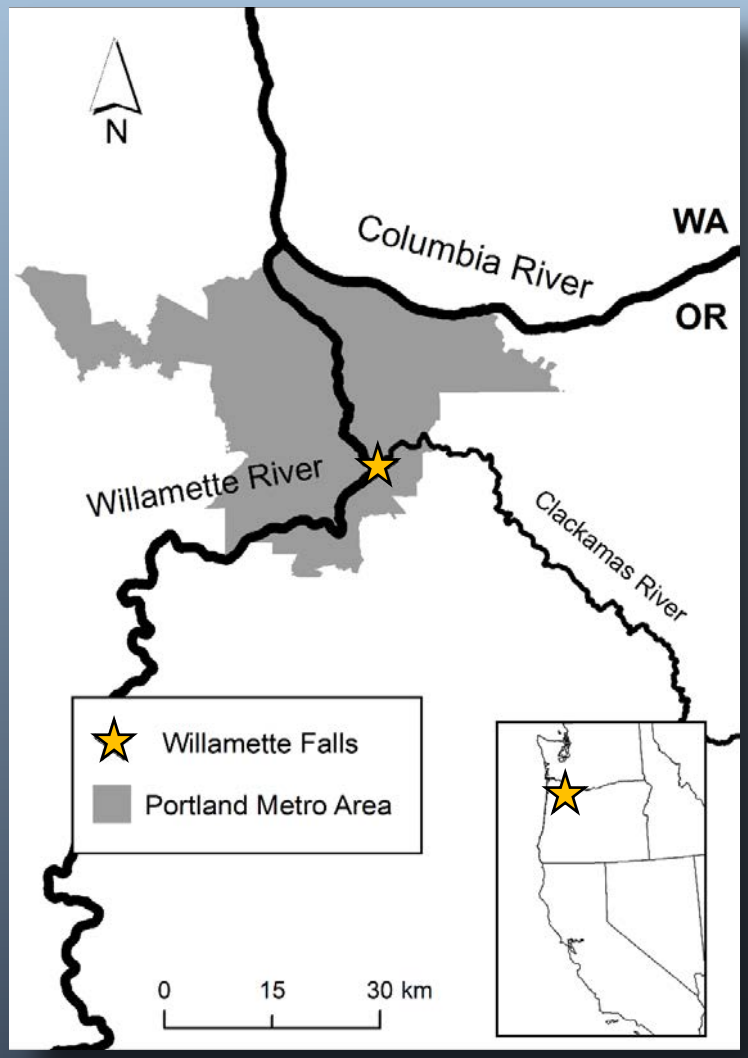
$$N = \frac{n_1 n_2}{m_2}$$

LP with Chapman's bias correction

$$N = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1$$

Pacific Lamprey at Willamette Falls

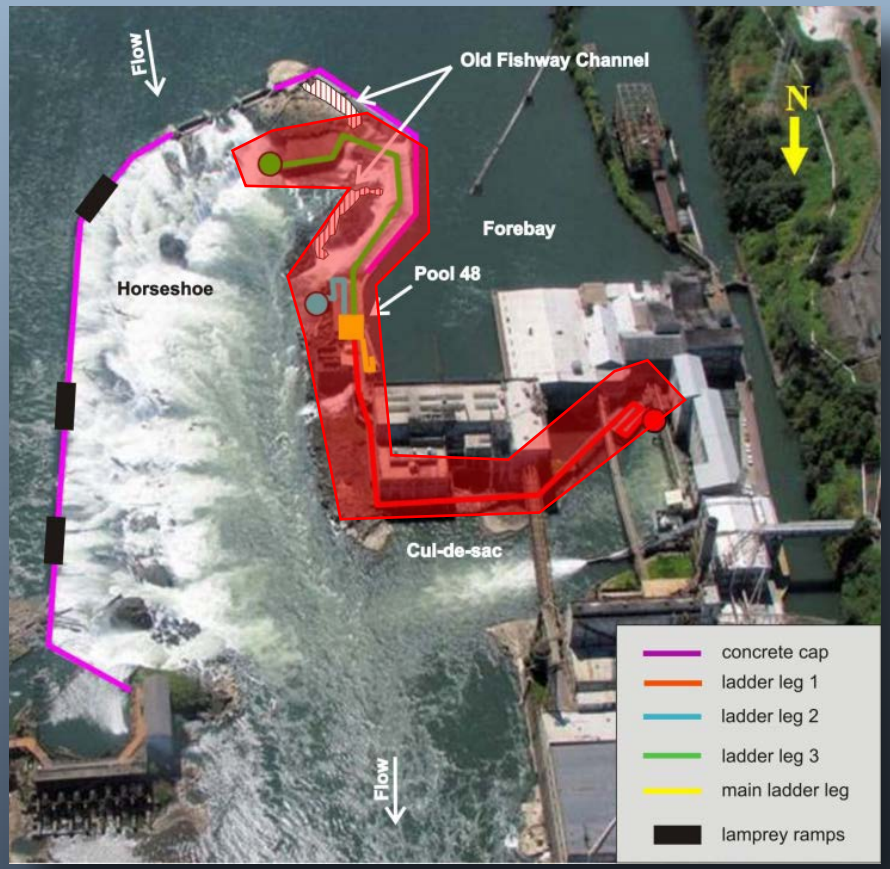
Willamette Falls
- Passage barrier
- Harvest location



Sampling at Willamette Falls

Willamette Falls
- Passage barrier
- Harvest location

- Tagging
  - Fish ladder PIT tag arrays
  - Captured and released ~2km downstream
- LP estimates



LP Estimates (2011-2018)

- Total abundance estimate:

$$N_{Total} = \frac{(\text{Tagged}+1) \cdot (\text{Inspected} + 1)}{(\text{Recaptures} + 1)} - 1$$

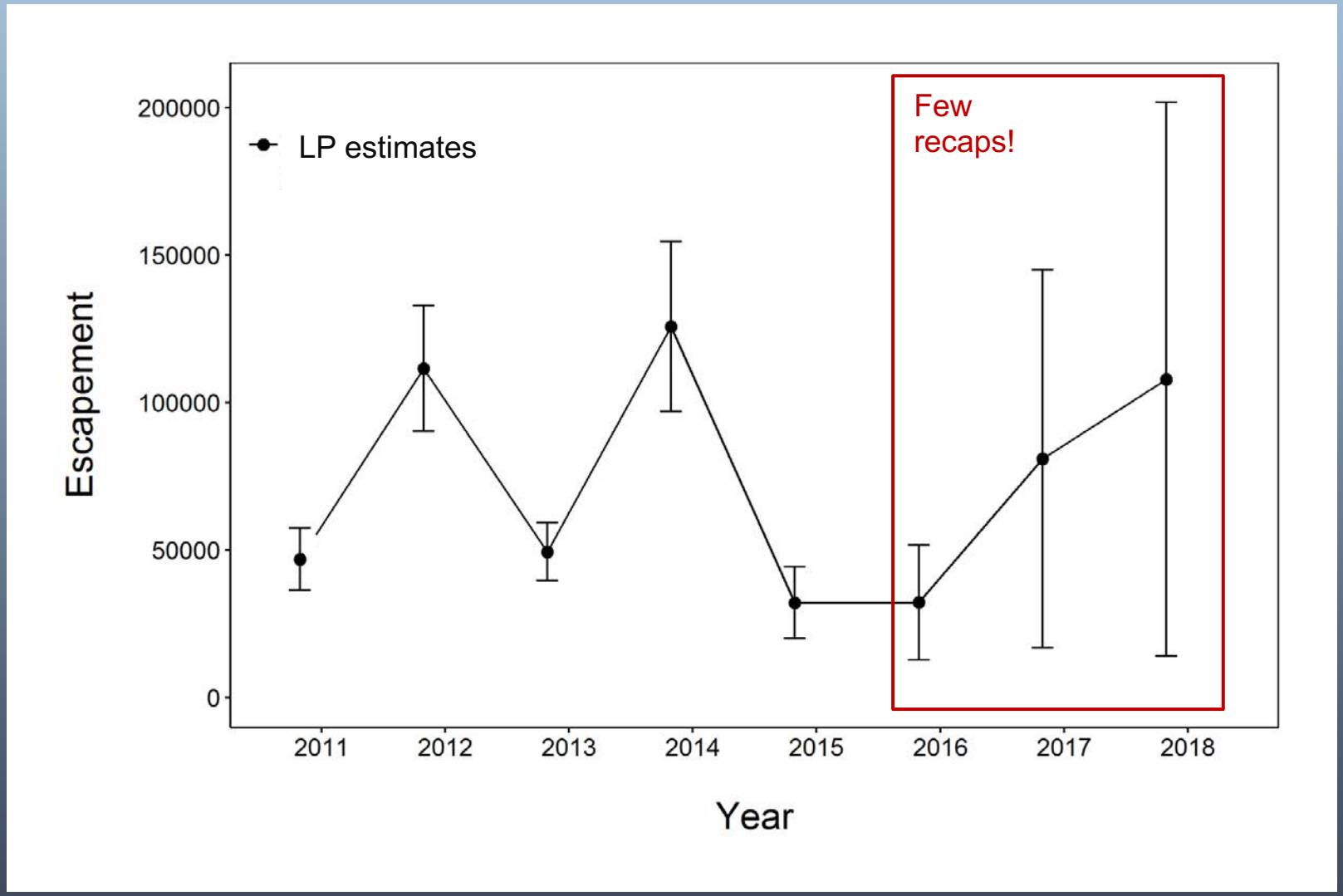
- Probability of return (R):

$$R = \frac{\text{Detected in the fish ladder}}{\text{Total tagged}}$$

- Escapement estimate:

$$N_{Escapement} = N_{Total} \times R$$

LP Estimates (2011-2018)



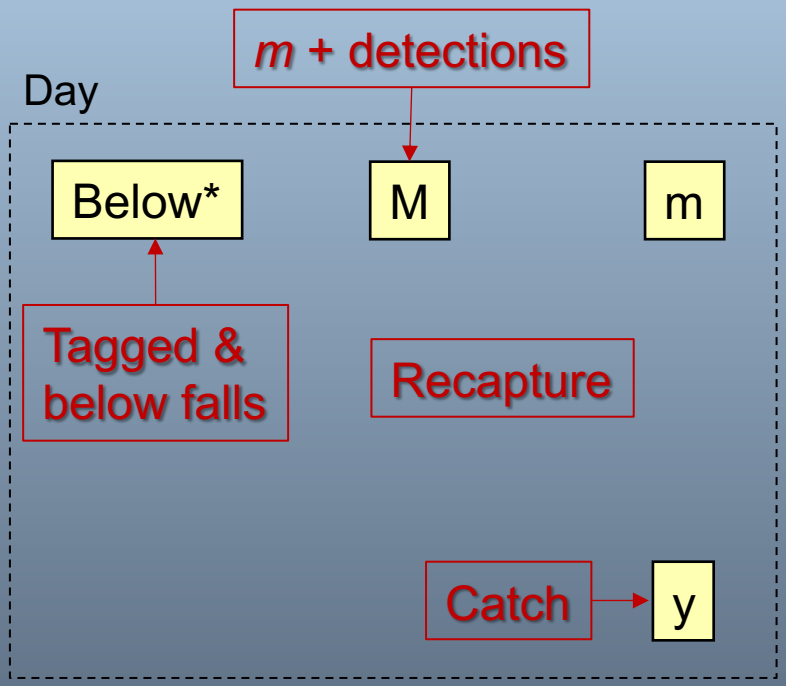
Research Questions

1) Can the precision of estimates be improved?
2) Is it possible to:
    a) Use additional data (daily detections)
    b) Make additional inferences (below-falls abundance)
    c) Incorporate environmental variables (temp, discharge)

Objectives

1) Create an alternative estimator using a model
   - Daily time step
2) Compare LP and model-based estimates
3) Examine outputs from the daily model

Daily Escapement Model



Daily Escapement Model

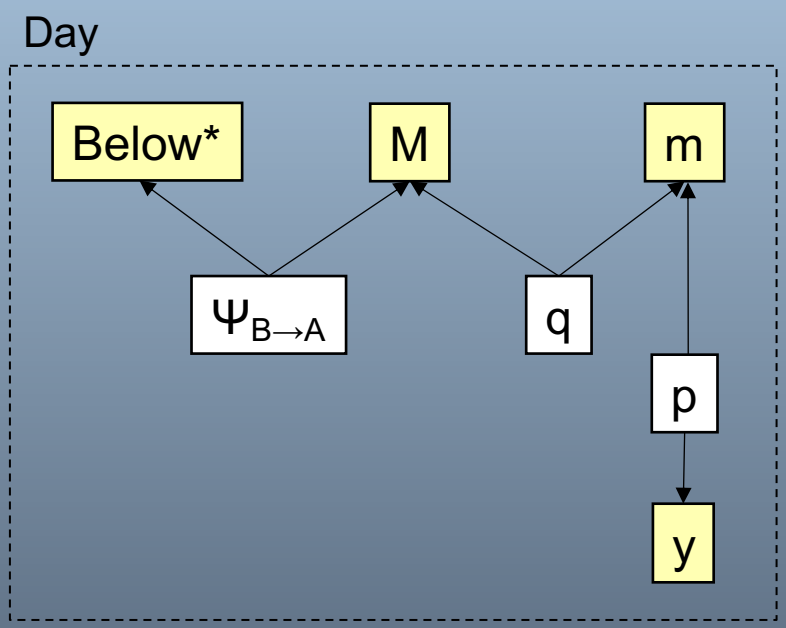
Daily estimates of probability of capture*(q)* and proportion tagged (*p*)

$$m_i \sim Bin(y_i\,, \boldsymbol{p_i})$$

$$m_i \sim Bin(M_i\,, \boldsymbol{q_i})$$

Daily estimates of passage probability

$$M_i \sim Bin\left(Below_i^*, \boldsymbol{\psi_{B\rightarrow A,i}}\right)$$



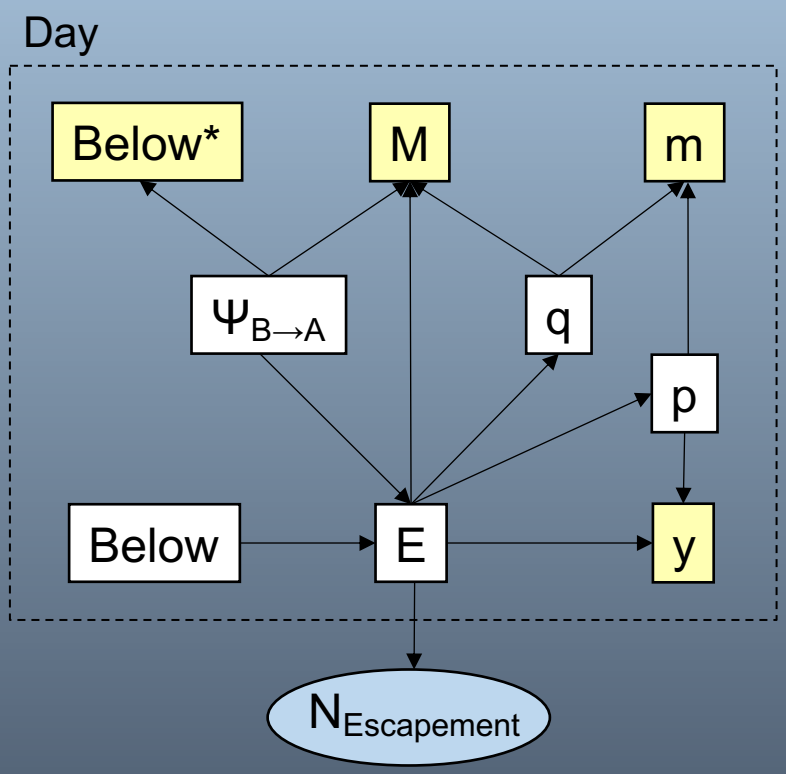
Daily Escapement Model

Two daily estimates of escapement

$$y_i \sim Binomial(\boldsymbol{E_i}, q_i)$$

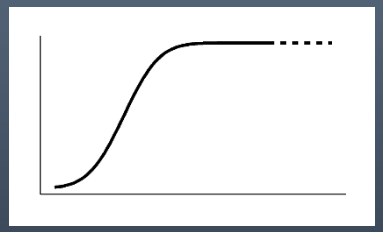
$$M_i \sim Binomial(\boldsymbol{E_i}, p_i)$$

Escapement is a function of passage and below-falls distribution



$$E_i \sim Binomial(\boldsymbol{Below_i}, \psi_{B\rightarrow A,i})$$

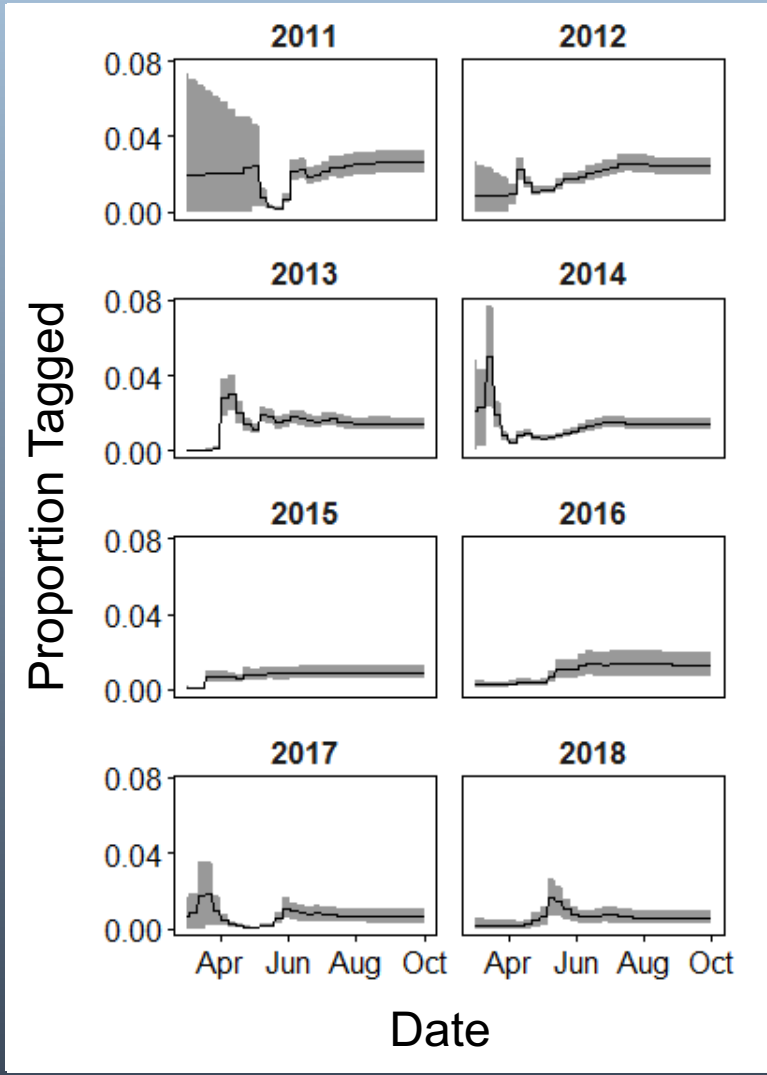
$$Below_i \sim \Phi(z)$$



Arrivals below falls

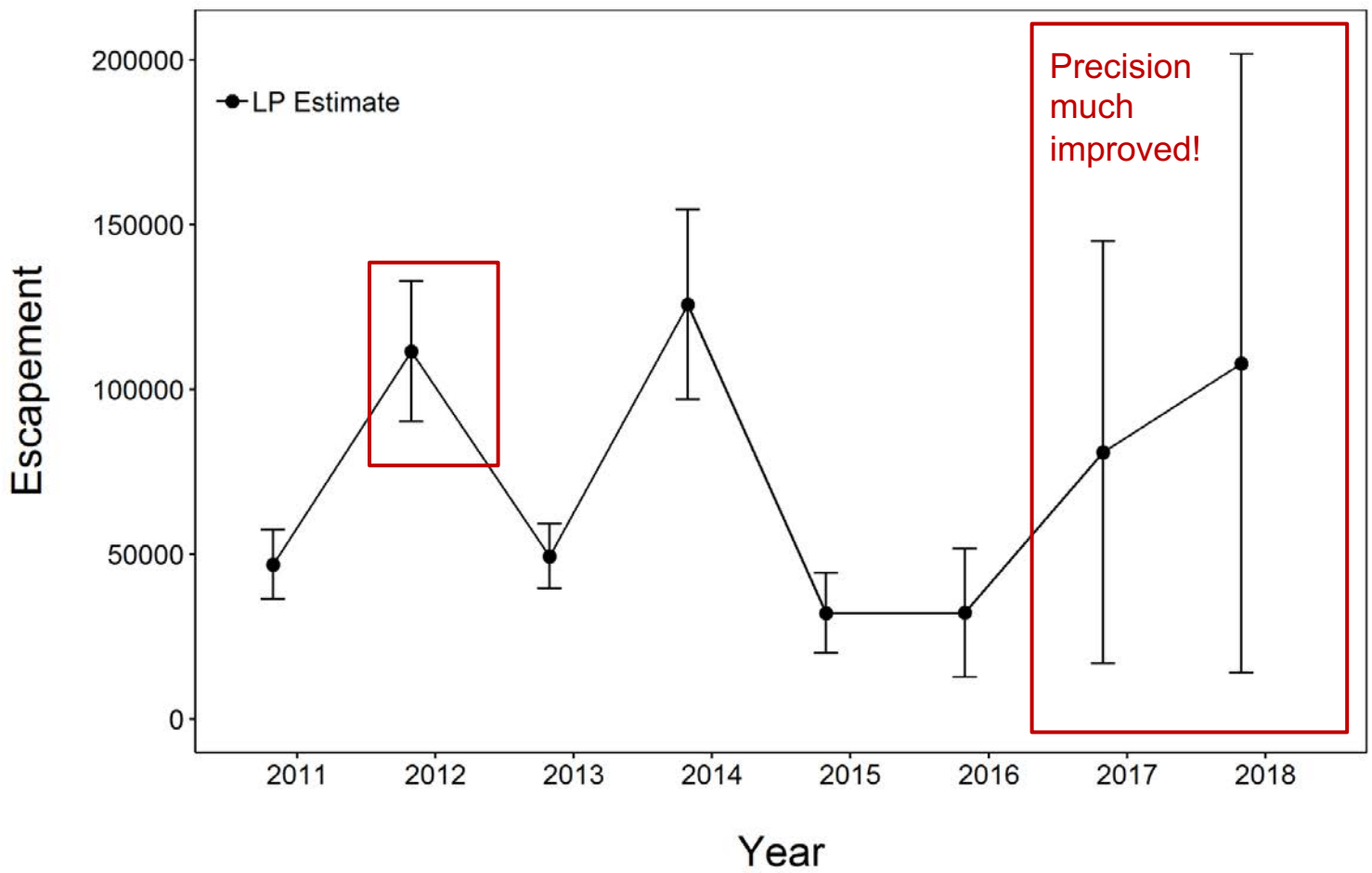
Model Fitting

- Passage probability based on:
  - Discharge, temperature, and stage, day of year
- Interpolation between sampling days
  - Splines
- Model fit using maximum likelihood estimation
  - Template Model Builder (TMB)

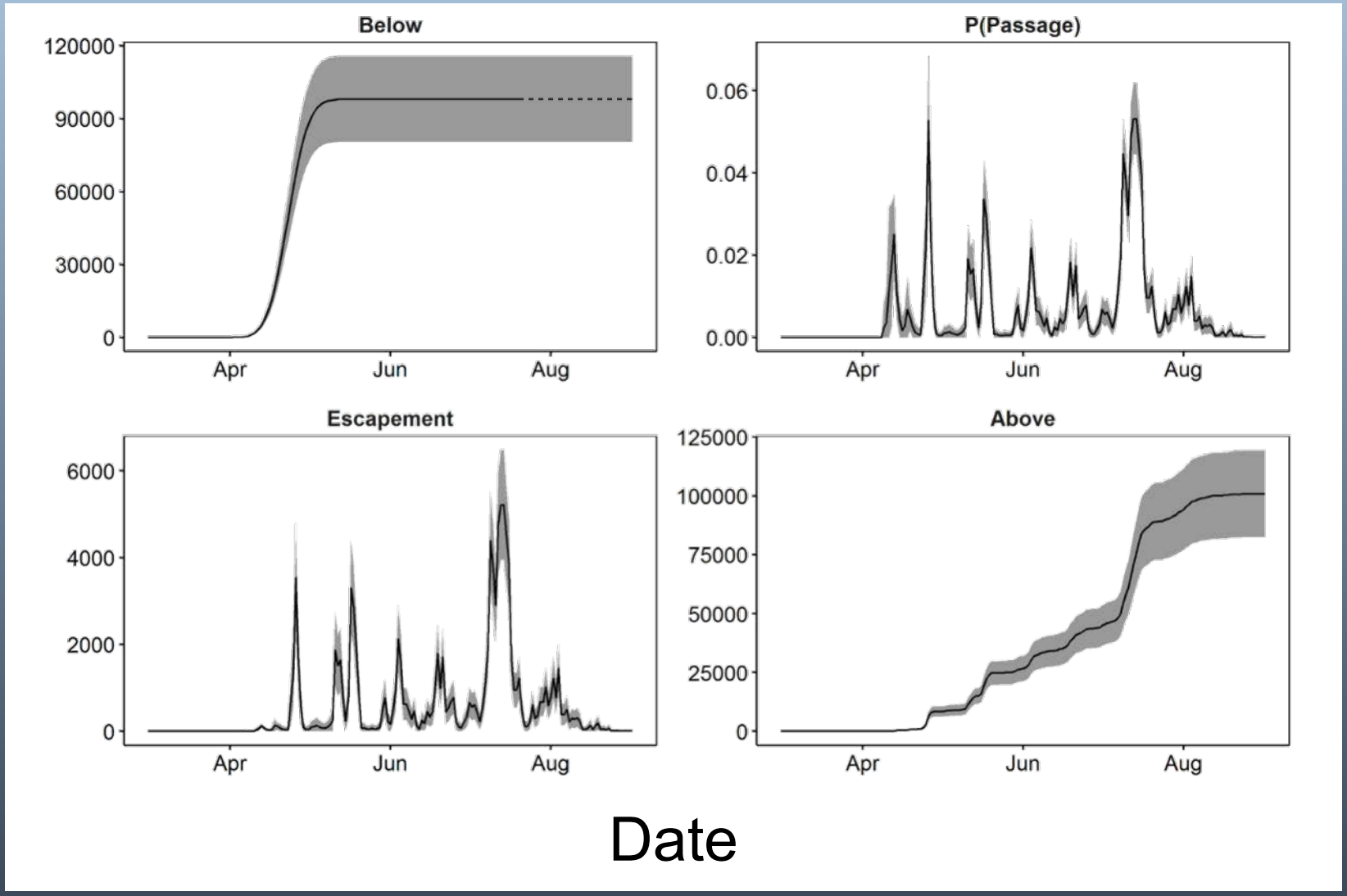


RESULTS

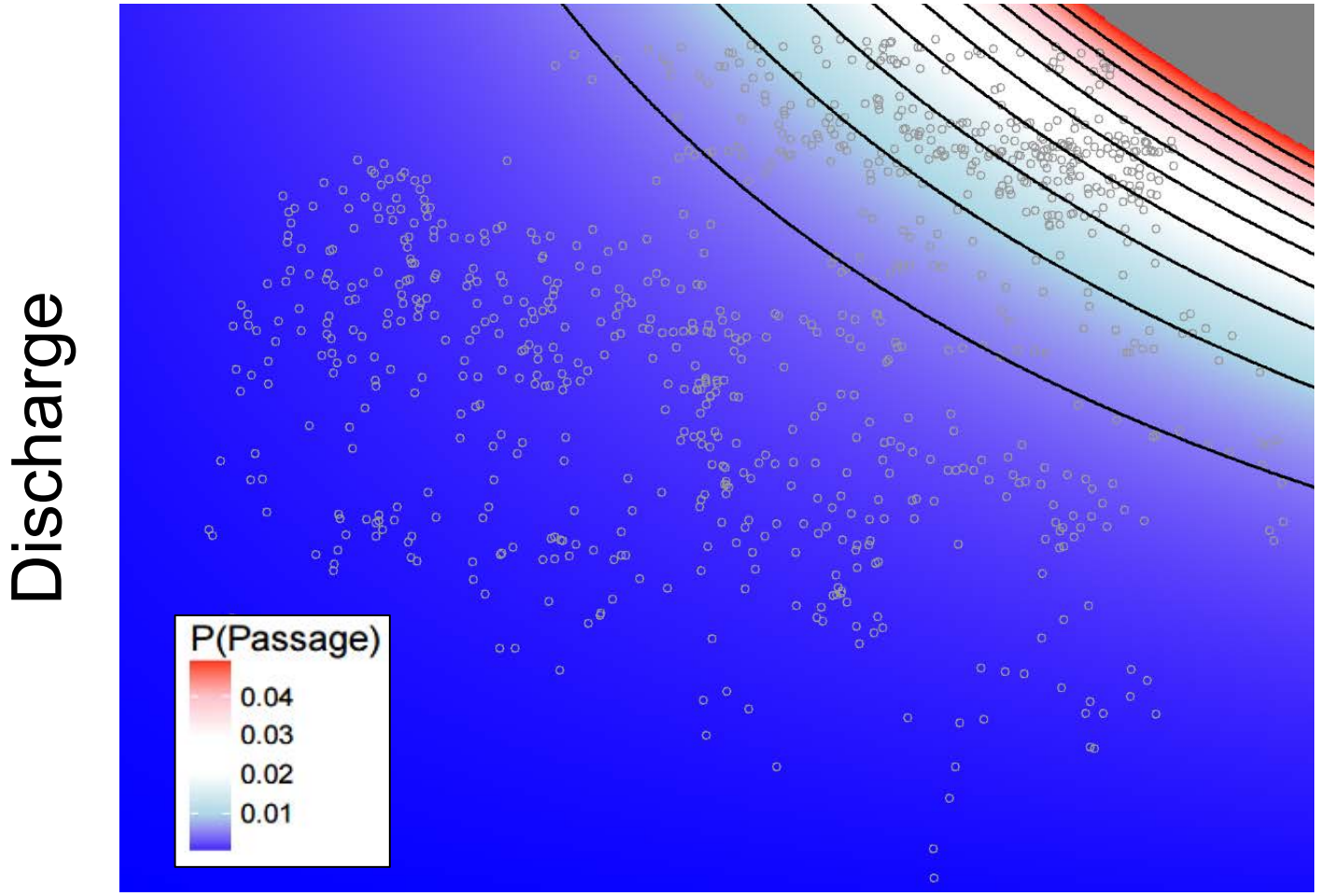
Estimates (2011-2018)



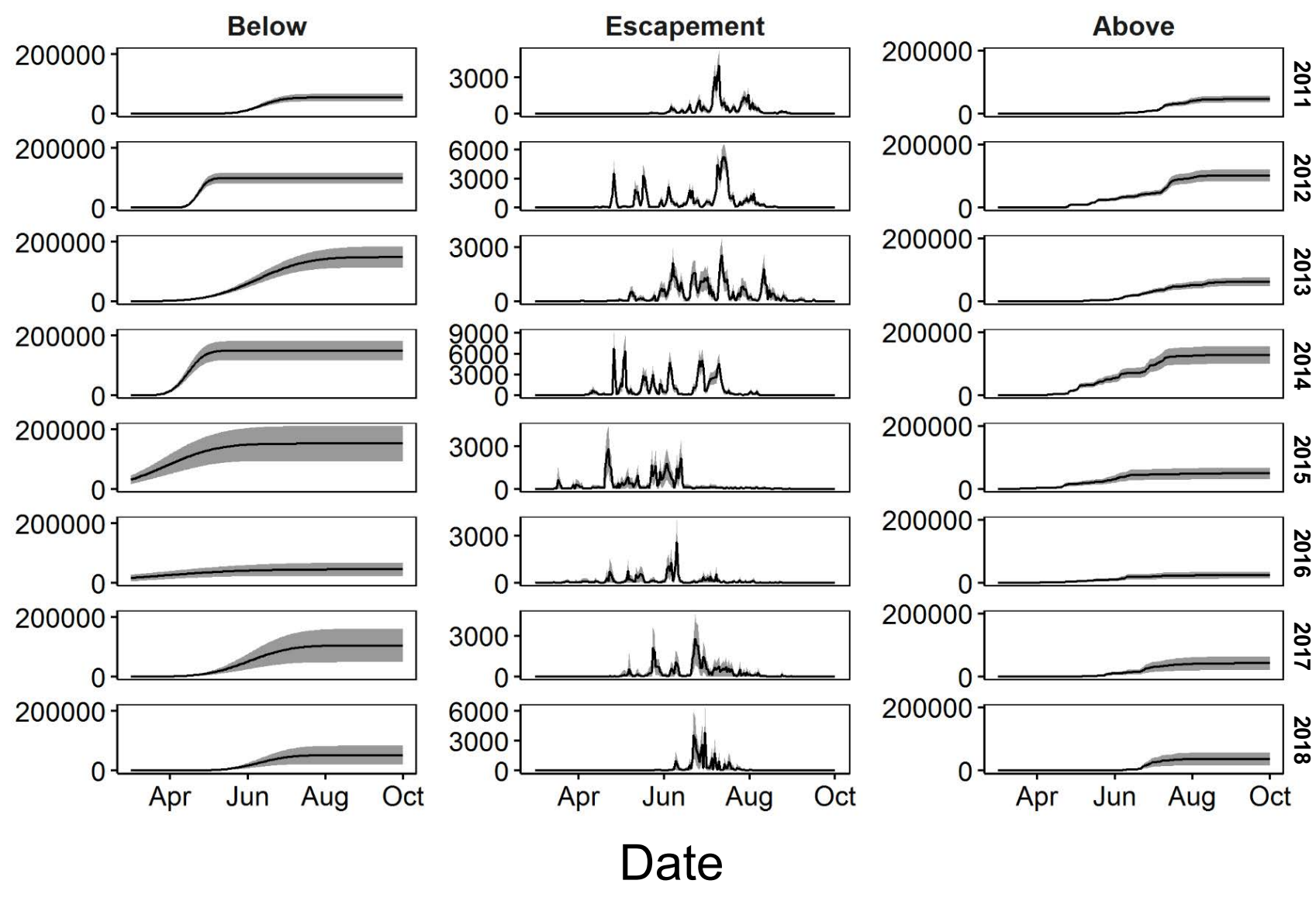
Daily Estimates (2012)



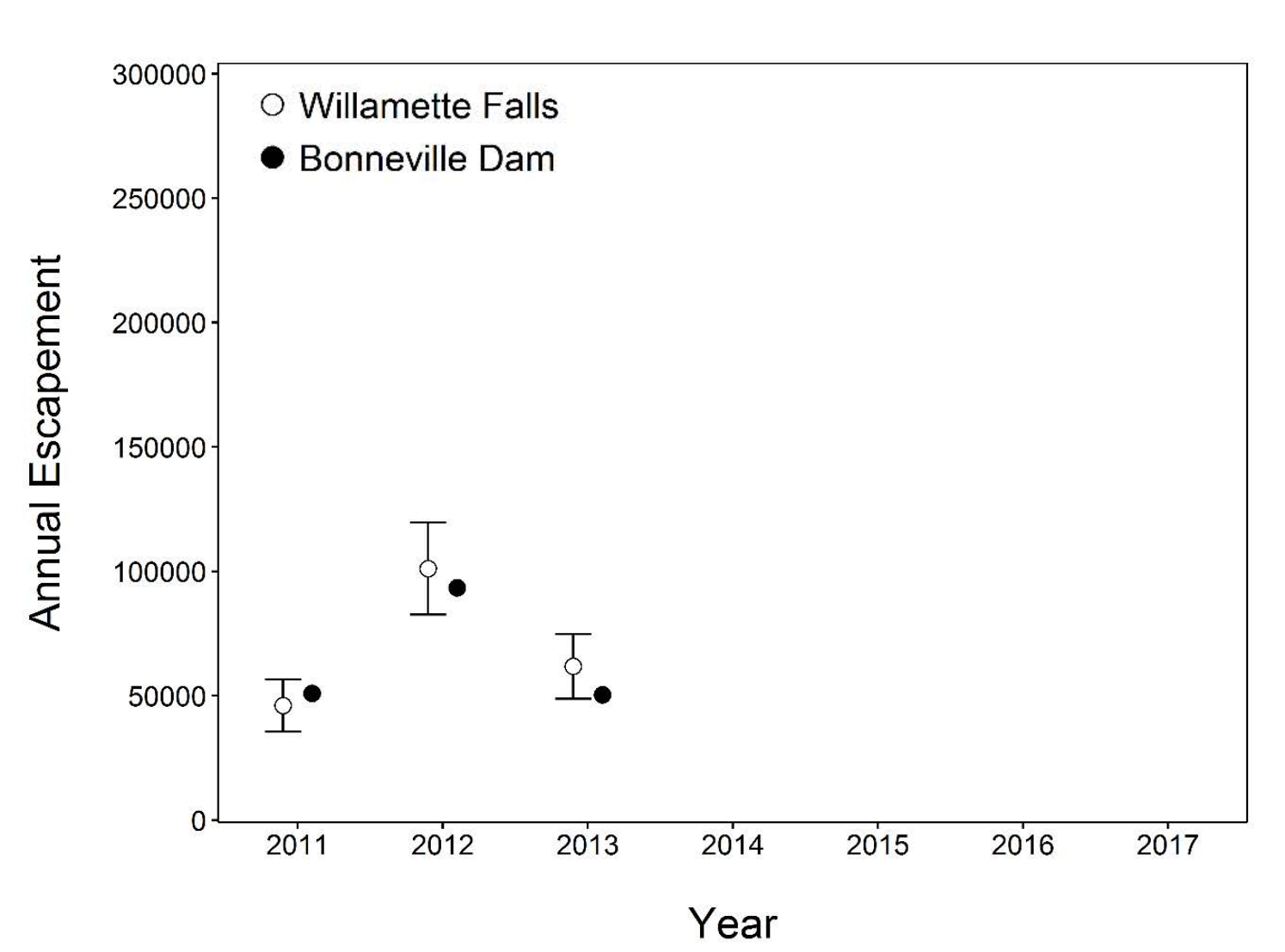
Temperature and Discharge Effects



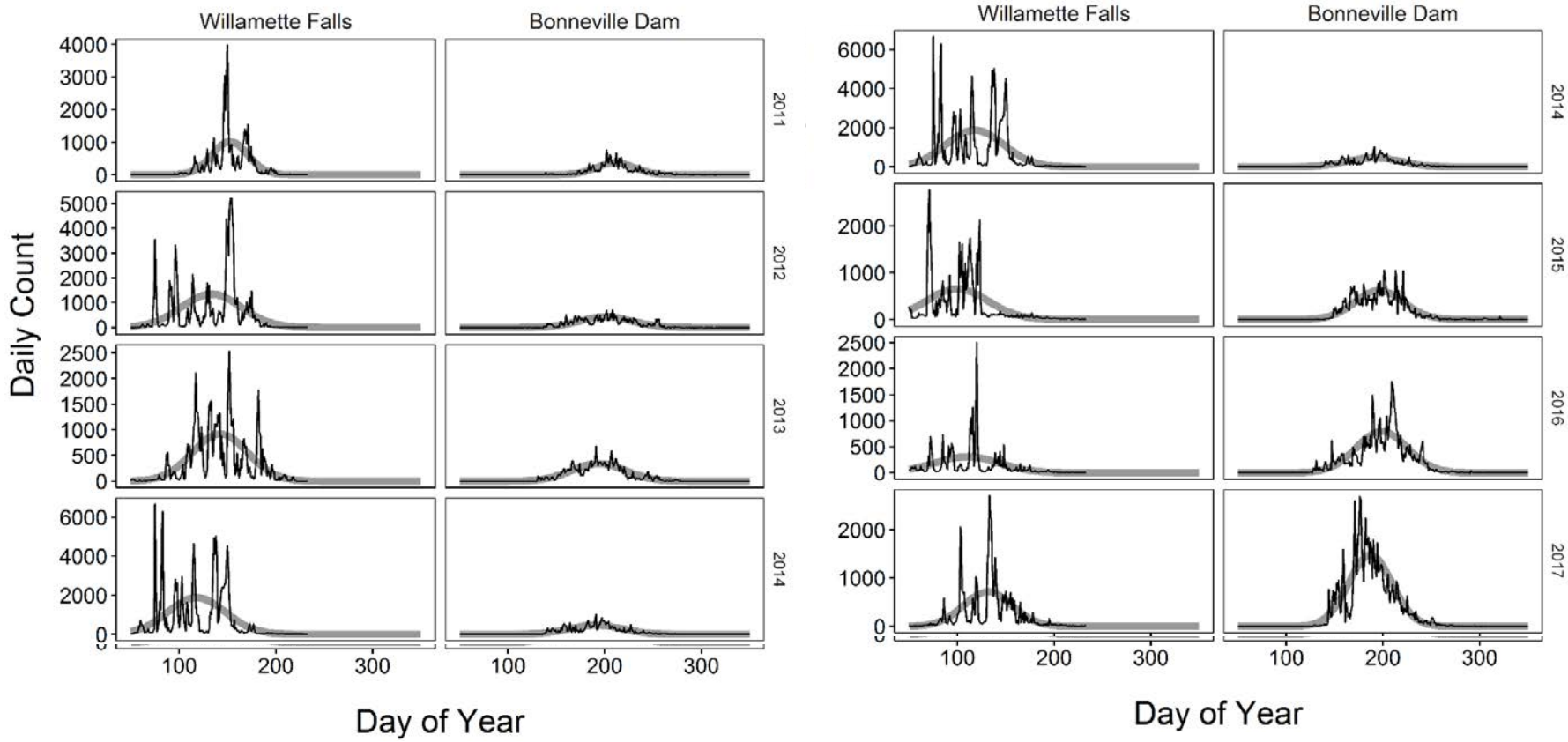
Daily Estimates (2011-2018)



Annual Estimates: Willamette Falls vs. Bonneville

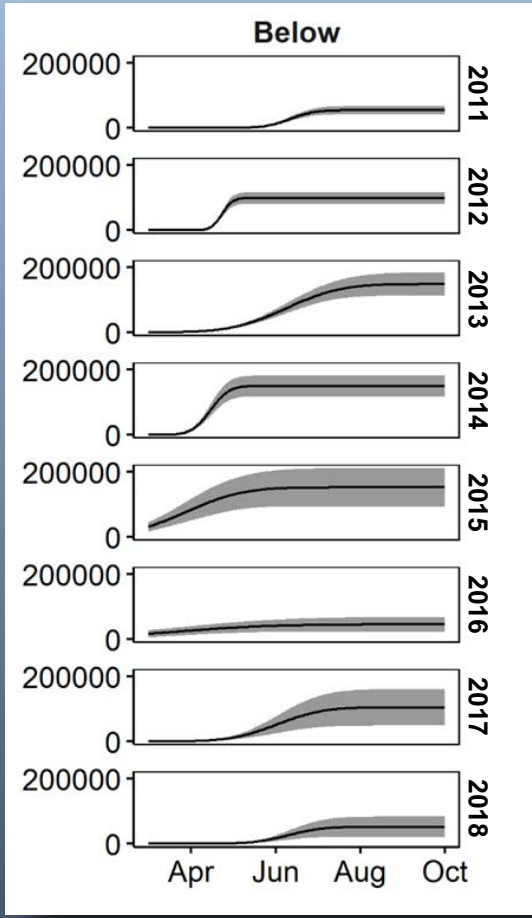


Daily Estimates: Willamette Falls vs. Bonneville



Conclusions

- Model-based estimator Improved precision
  - Accommodates low recapture rates
  - Borrows information
- Tailored model provided greater insight
  - Arrival below falls
  - Environmental relationships



Acknowledgements

Oregon State University

- Adam Duarte
- J. Tyrell Deweber

Portland General Electric

- Tim Shibahara

Warm Springs Tribe

- Carson Mcvay
- Research staff
- Field technicians

Funding

- Confederated Tribes of the Warm Springs Reservation
- Bonneville Power Administration

OSU

CONFEDERATED TRIBES OF WARM SPRINGS 1855

USGS science for a changing world