Establishing a Bayesian Prior for PIT Tag Detection Probability at Sullivan Juvenile Bypass Facility

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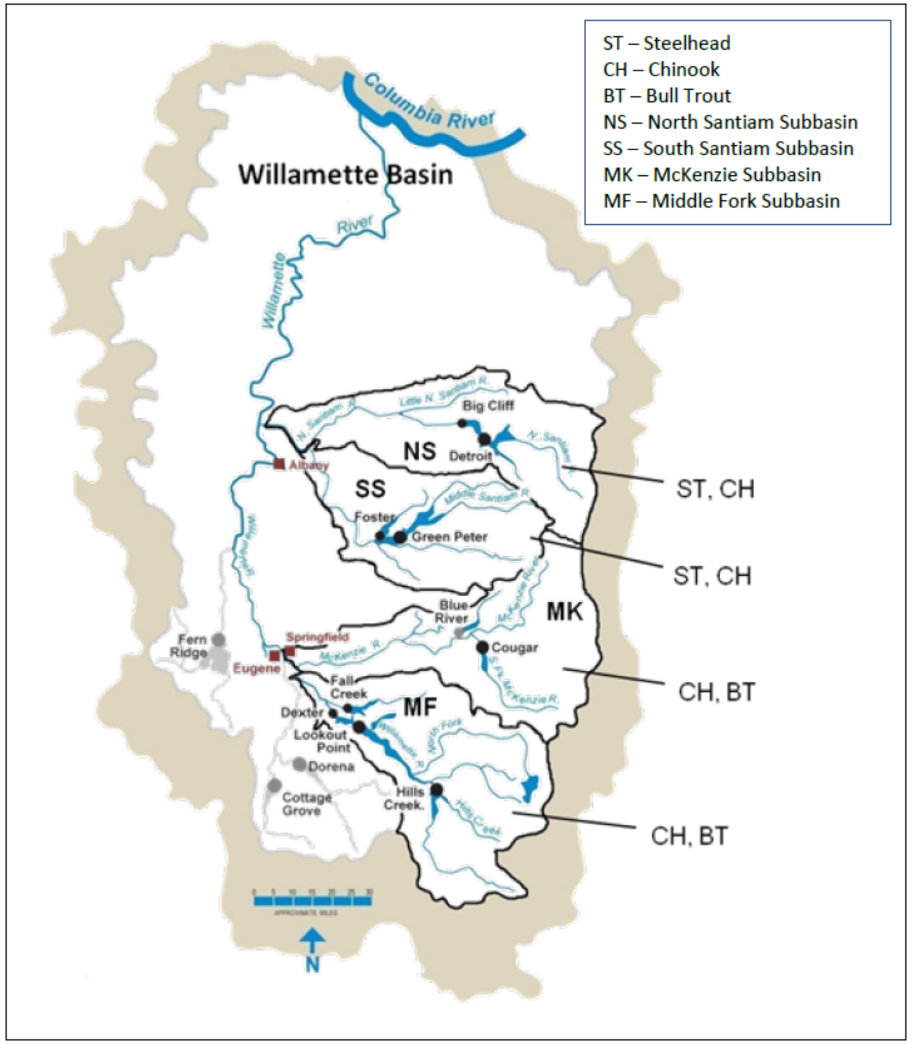
UBC
Integrated Passage Assessment

Integrated Passage Assessment (IPA) Model

- Evaluate dam passage options in Willamette sub-basins
  - Spring Chinook salmon (*Oncorhynchus tshawytscha*)
  - Winter steelhead (*O. mykiss*)
- Integrates model features for above and below dam processes
- Survival rates key to understanding passage
  - e.g. downstream survival, smolt-adult survival
- Use Bayesian framework to incorporate uncertainty into survival rate estimates from PIT tag data analysis



Integrated Passage Assessment

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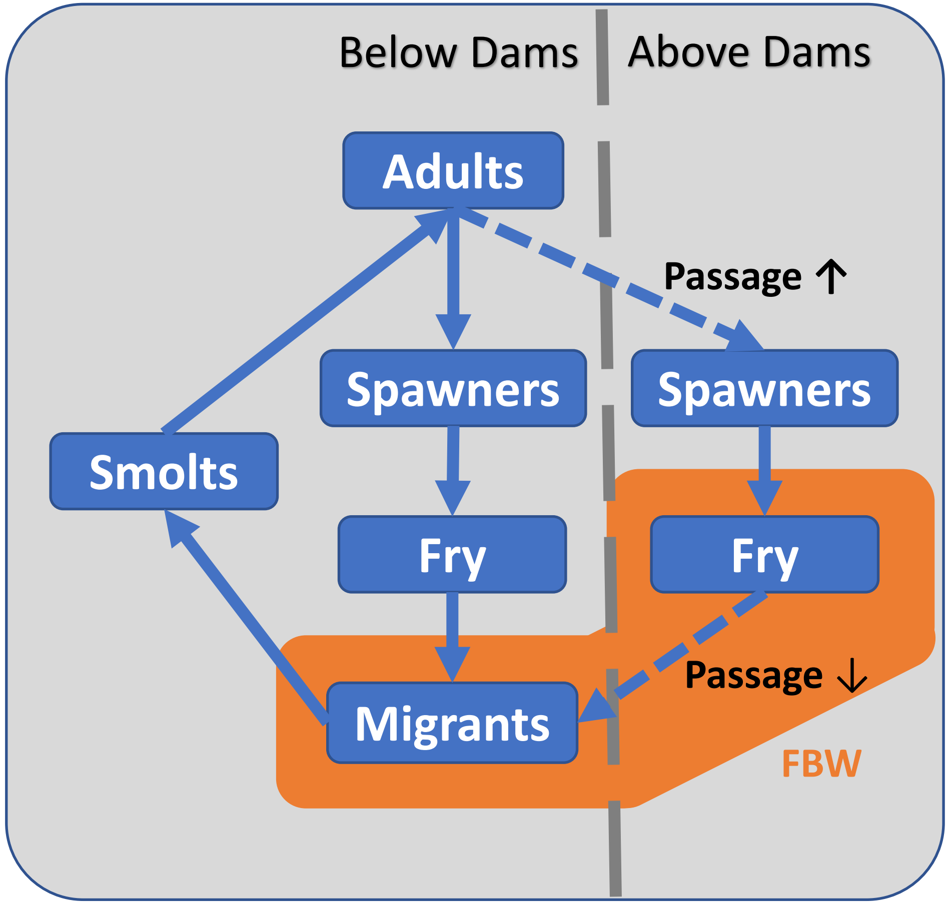

Generalized IPA Model for Willamette Spring Chinook Salmon

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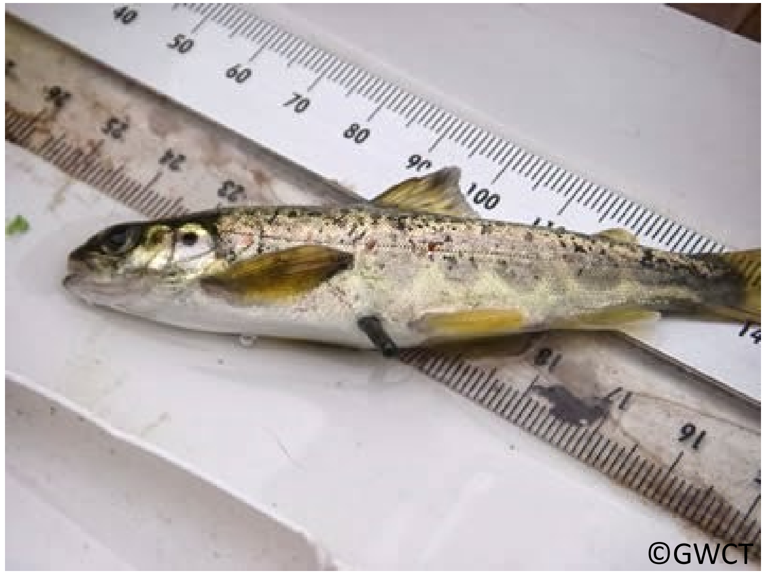
Willamette PIT Tag Data

- Multiple PIT tag studies performed in Willamette sub-basins
  - Chinook salmon and steelhead
  - HO above/below dam paired releases (>>10k fish)
  - NO captured releases (1k fish)
- Central data repository via PTAGIS
- Analysis problems can occur with too few detections

PTAGIS



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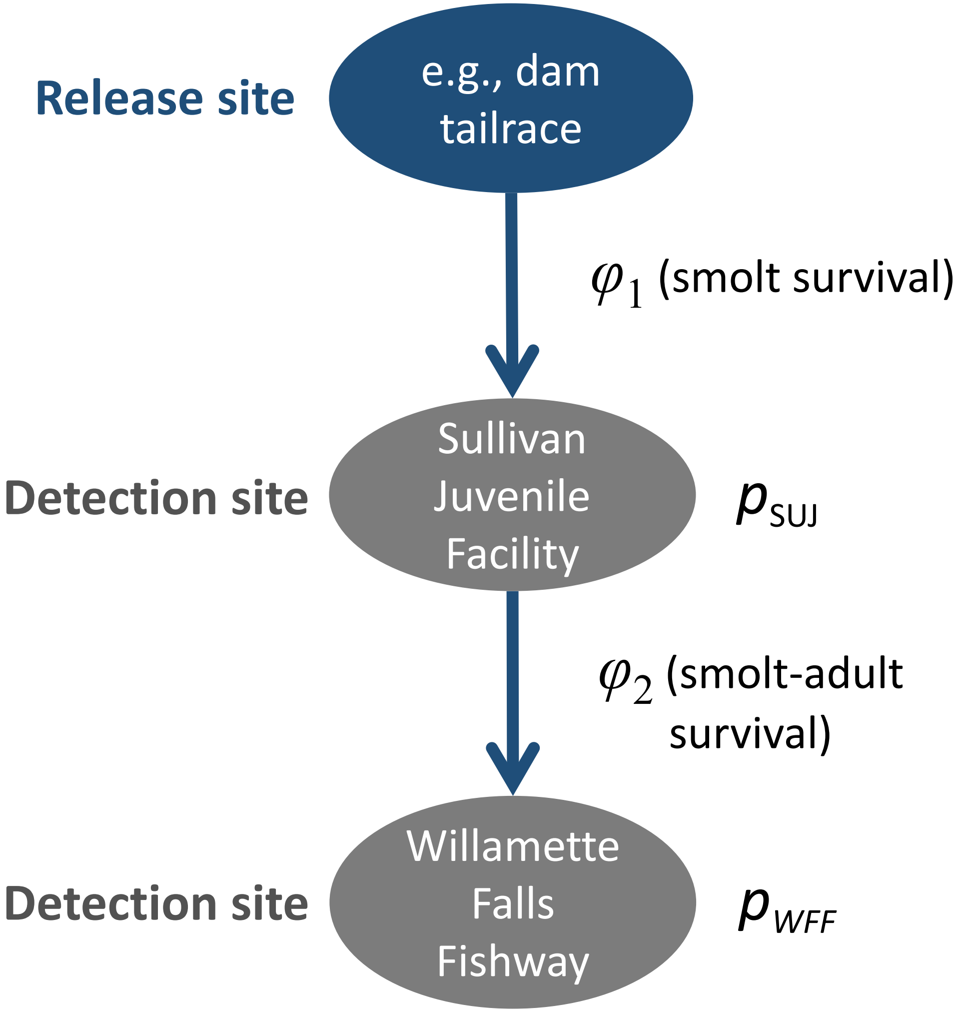
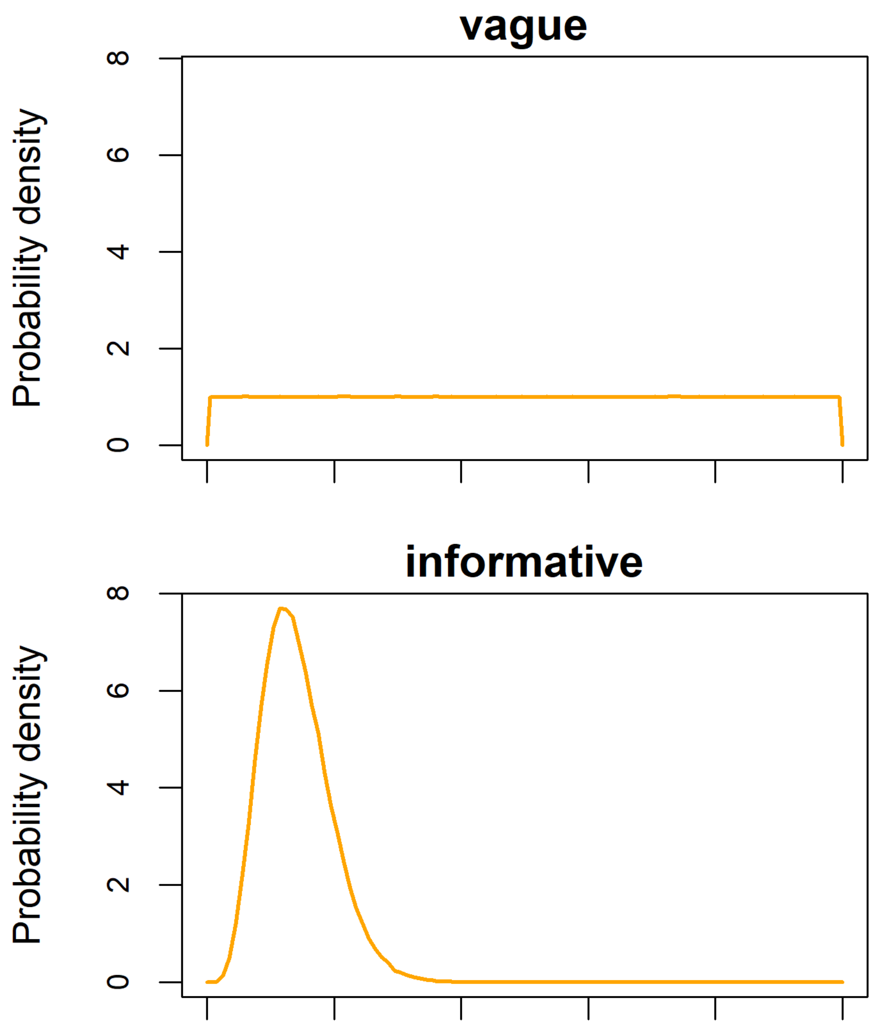
PIT Tag Survival Analysis

- Bayesian Cormack-Jolly-Seber (CJS) Model
- Survival rate (φ) between release and detection locations modelled by adjusting number of detections at each location for probability of detection (p)
- Few fish detected at a location can be due to low survival or low detection probability
- Important to understand detection probability



Bayesian priors

- Reduce uncertainty in model parameter estimates by incorporating knowledge via ‘informative’ priors
- Summarise what is known about parameter values from data or expert judgement
  - e.g. known that detection probability at Willamette Falls Fishway is close to 1



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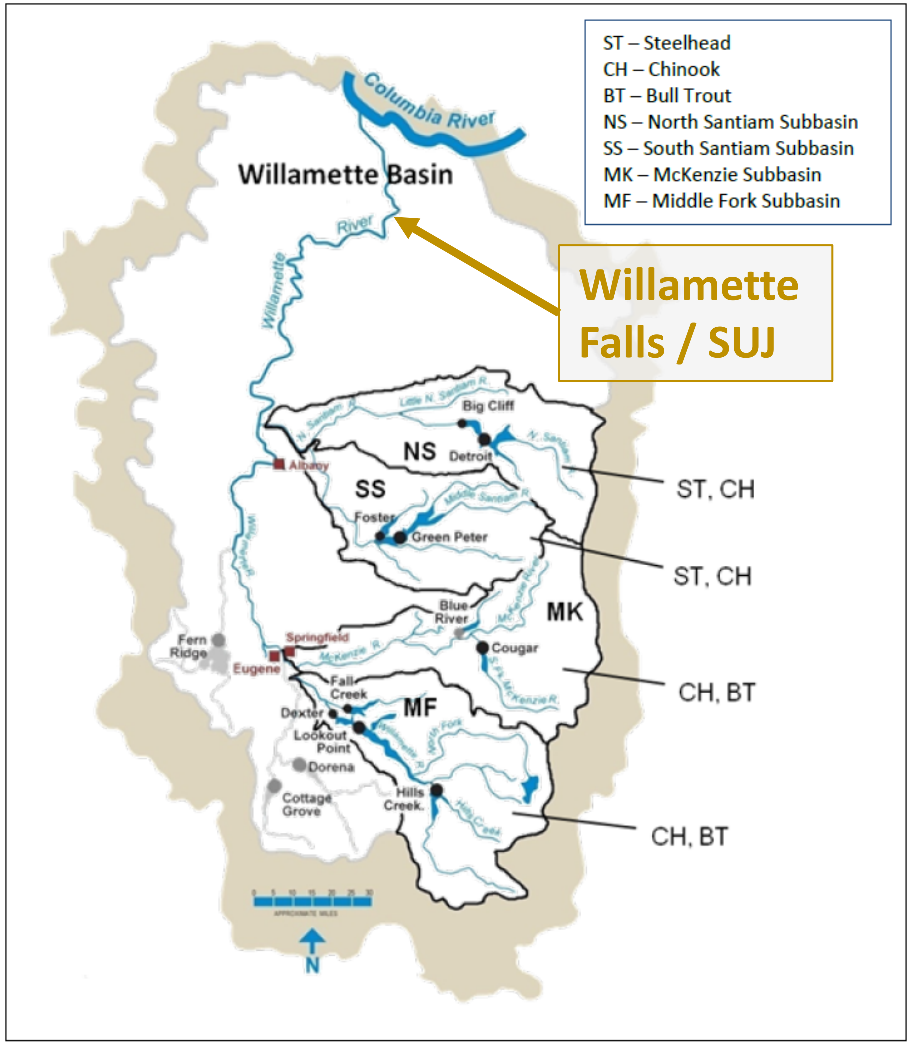
Bayesian priors

- Reduce uncertainty in model parameter estimates by incorporating knowledge via 'informative' priors
- Summarise what is known about parameter values from data or expert judgement
  - e.g. known that detection probability at Willamette Falls Fishway is close to 1
- Established a prior for *p* at Sullivan Juvenile Fish Bypass Facility (SUJ)



PIT tag detection studies at Willamette Falls

- Karchesky & Pyper (2009) fish guidance efficiency
- Karchesky et al. (2010) double-tagged fish (acoustic + PIT)
  - 267 smolts released 5 rkm upstream, 232 passed Falls, 23 detected
- Schroeder et al. (2016) flow adjustment to estimate daily number of migrants
  - Expanded tag detections to adjust for flow

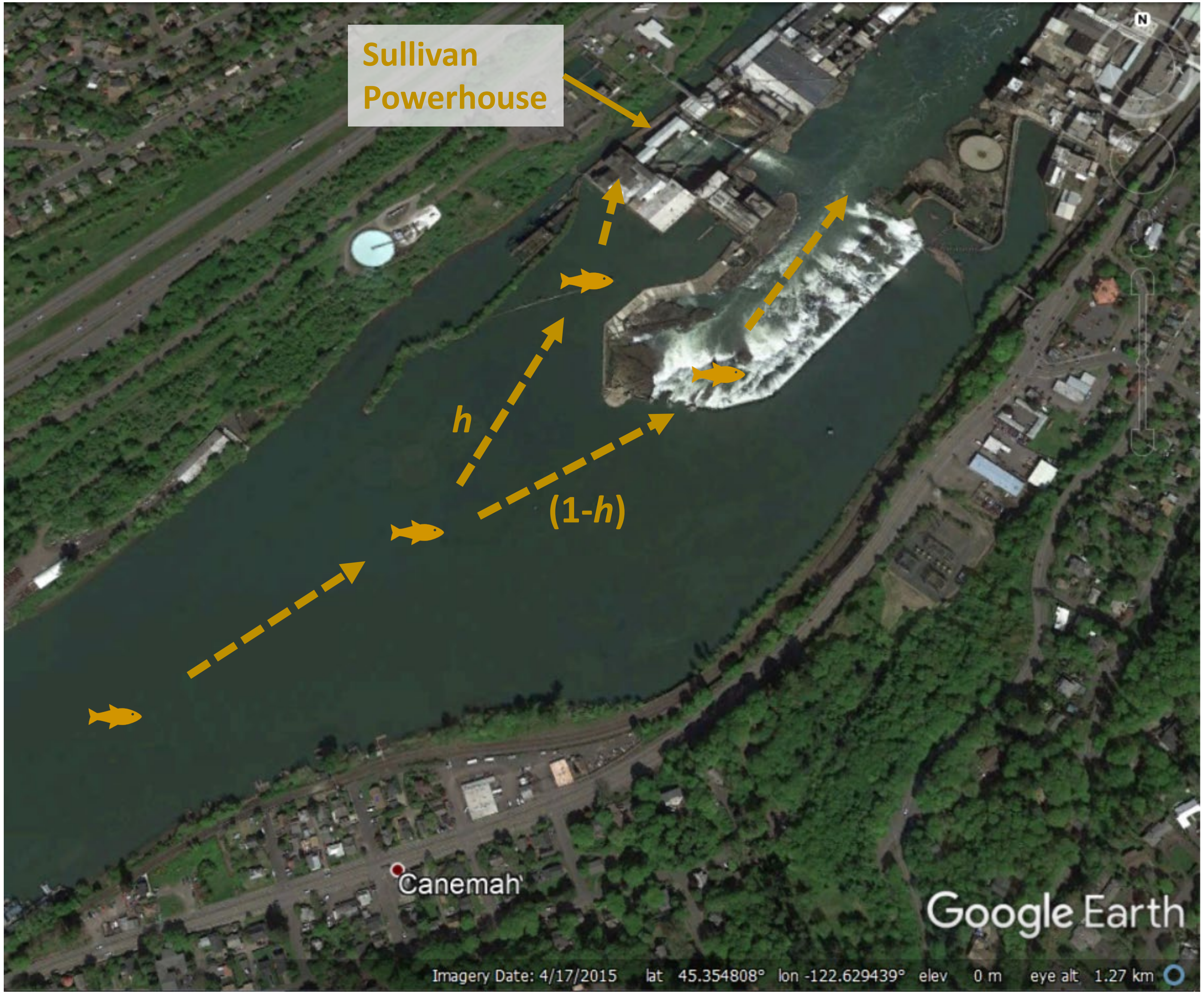
$$ET = \frac{T}{[(I/Q)P_\mathrm{r}E_\mathrm{G}E_\mathrm{A}]}$$

  - Not suitable as need detection histories

Relative passage P_r	Discharge cfs
1.0	<15,000
0.8	15,000-25,000
0.5	25,000-40,000
0.3	40,000-60,000
0.2	>60,000

Willamette Falls

- Several components to detection probability
- Migrating smolts have passage choice
  - Falls
  - Hydro powerhouse
- Proportion *h* pass via powerhouse



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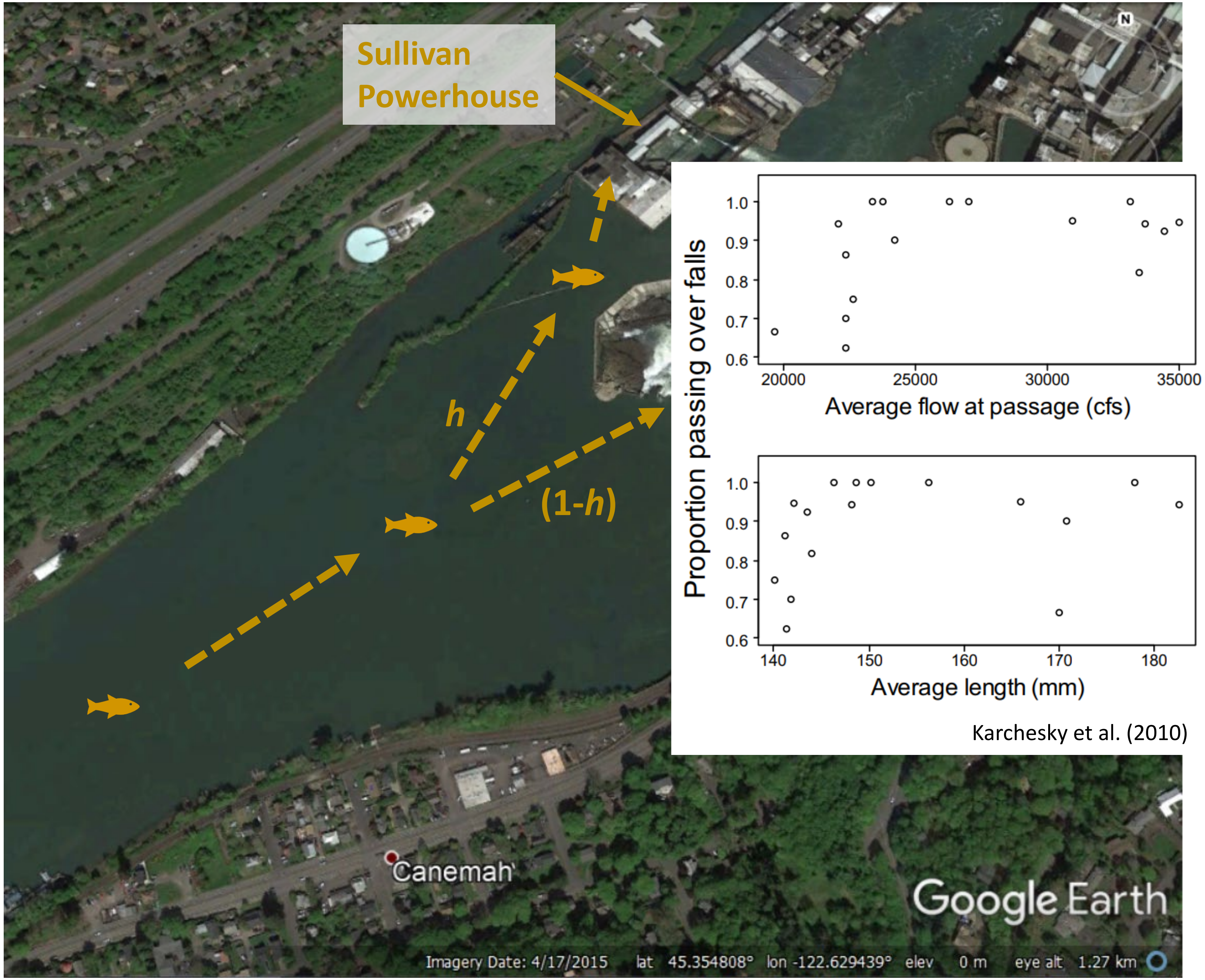
Willamette Falls

- Several components to detection probability
- Migrating smolts have passage choice
  - Falls
  - Hydro powerhouse
- Proportion *h* pass via powerhouse
- Effects of discharge and fish length



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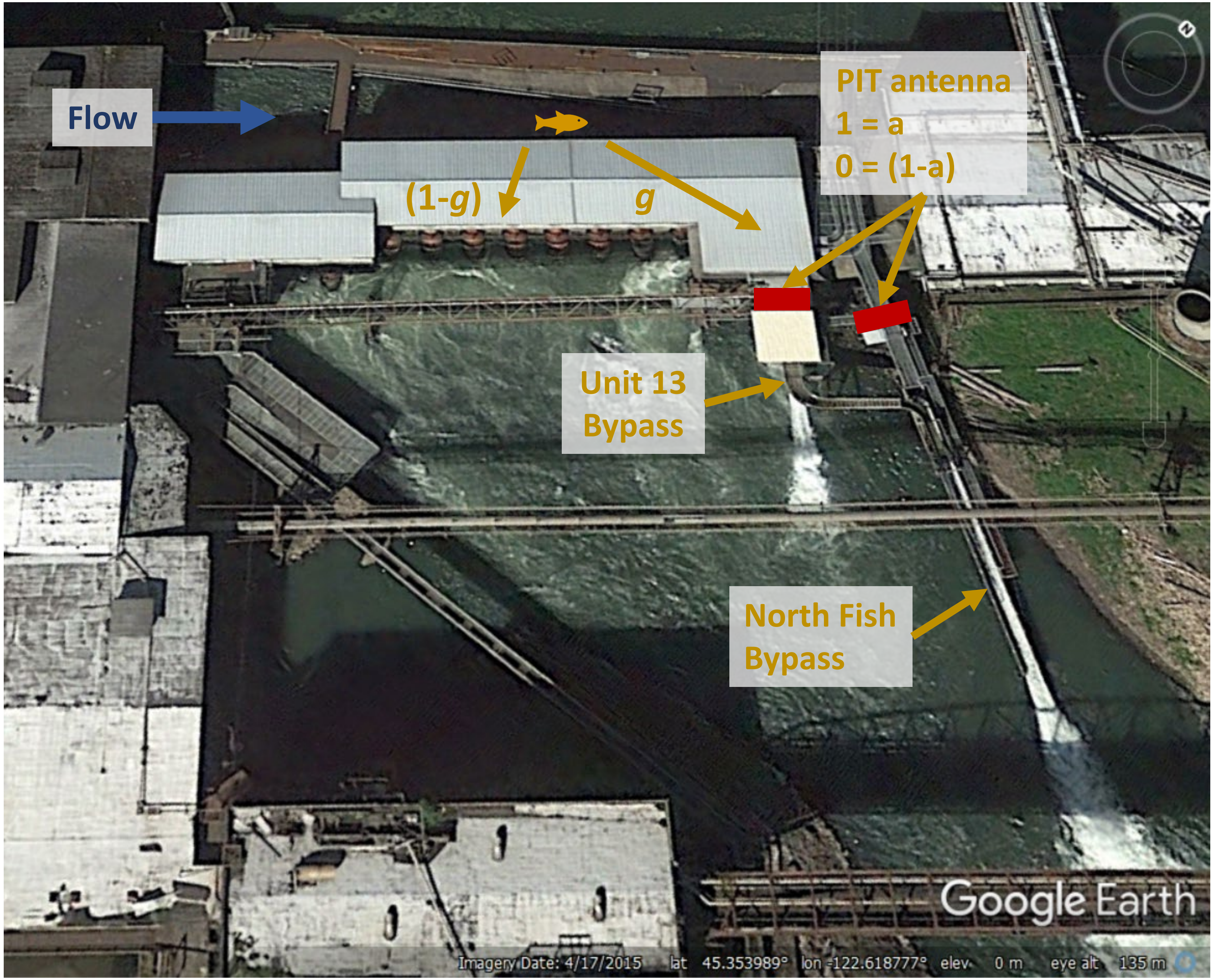
Sullivan Powerhouse

- 13 units
- 6,000 cfs capacity
- Juvenile Bypass Facility
  - Unit 13 Eicher screen
  - North Fish Bypass
- Fish guided to bypasses with efficiency *g*
- PIT antenna detect fish with efficiency *a*



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Components of detection probability at SUJ

- Parameterised using data from double-tagged fish telemetry studies with releases directly upstream of Willamette Falls
- Proportion of smolts passing through the powerhouse, *h*

  $$h \sim Uniform(0.01, 0.37)$$

- Fish guidance efficiency for smolts to pass through bypass, *g*

  $$g \sim Uniform(0.77, 1.0)$$

- Bypass antenna detection efficiency for PIT tags, *a*

  $$a \sim Uniform(0.7, 0.93)$$

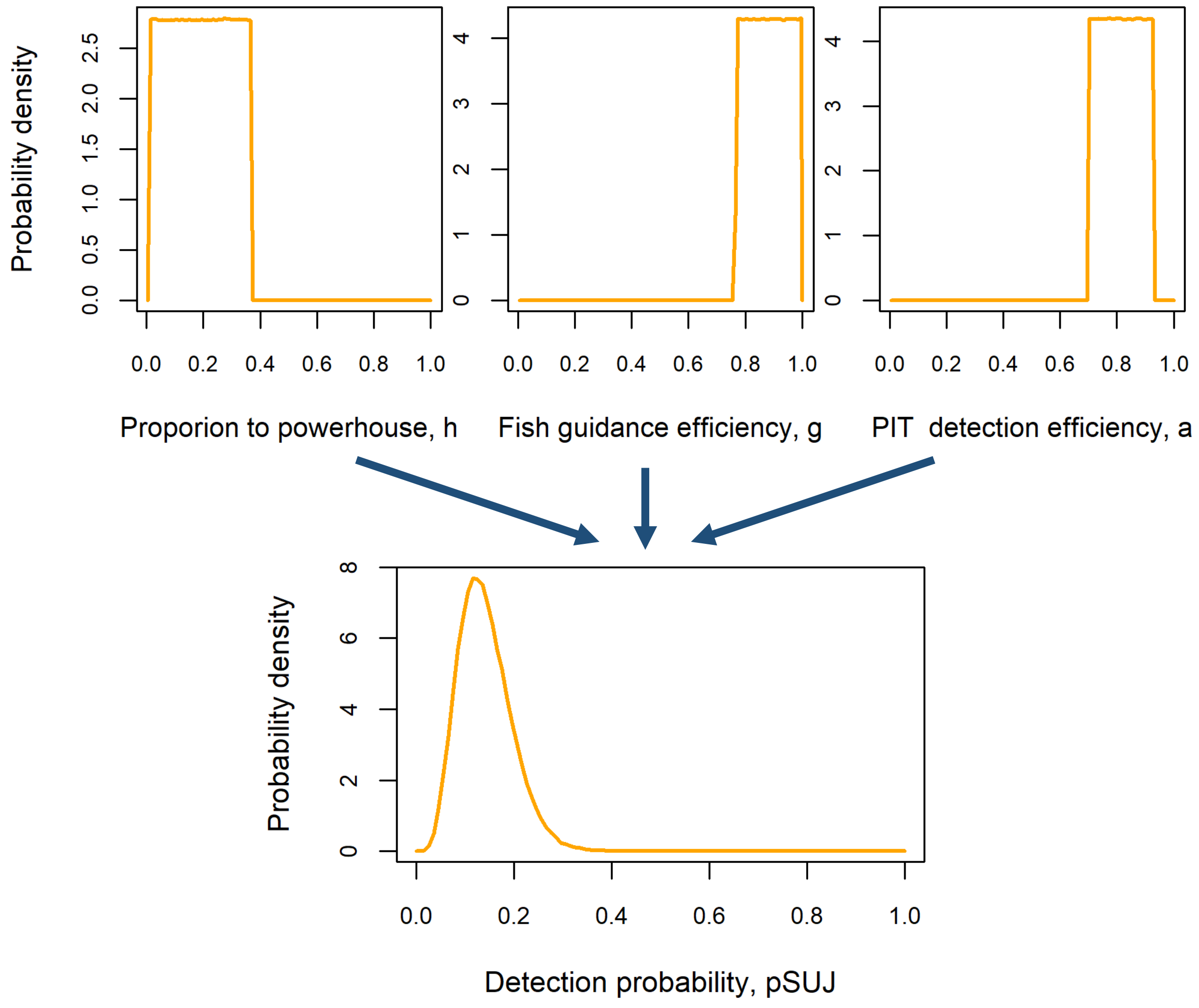
- Detection probability, $p_{\mathrm{SUJ}} = h \times g \times a$

References: Karchesky & Pyper (2009); Karchesky et al. (2010) ; Schroeder et al. (2016); Skalski et al. (2000)

Specification of a mechanistic prior for p_{SUJ}

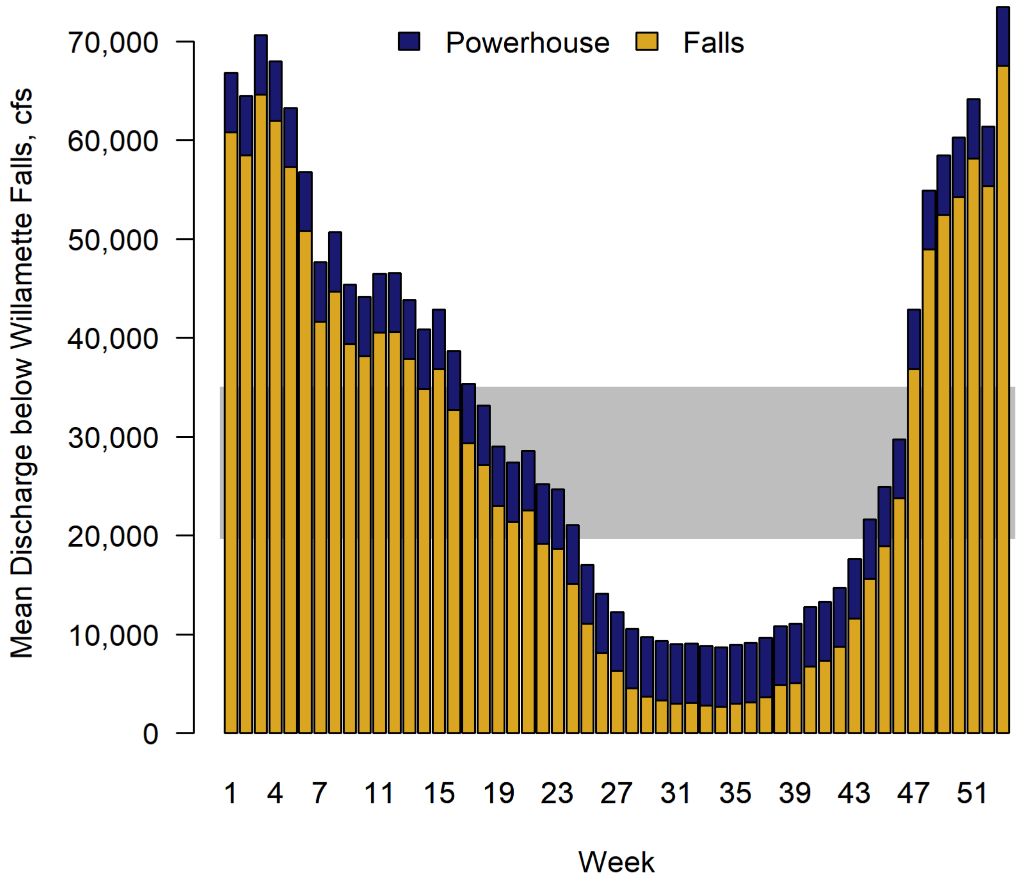
- Monte Carlo simulation (*n*=5,000) drew uncorrelated values from the distributions of *h*, *g*, and *a*
- Resulted in a probability distribution for *p* with a mean of 0.136 and a CV of 0.561
- Specified by a beta distribution for use as a prior in Bayesian CJS models

$$p_{\mathrm{SUJ}} \sim Beta(5.76, 35.28)$$



What to do about varying discharge?

- Karchesky et al. (2010) data used obtained when discharge ranged from 20-35Kcfs
- PIT tagged fish may pass Willamette Falls during periods when discharge is outside of this range
  - Potentially reduces applicability of prior
  - e.g. expect higher *p* when discharge lower
- If data available, further refinements to prior could incorporate effects of discharge



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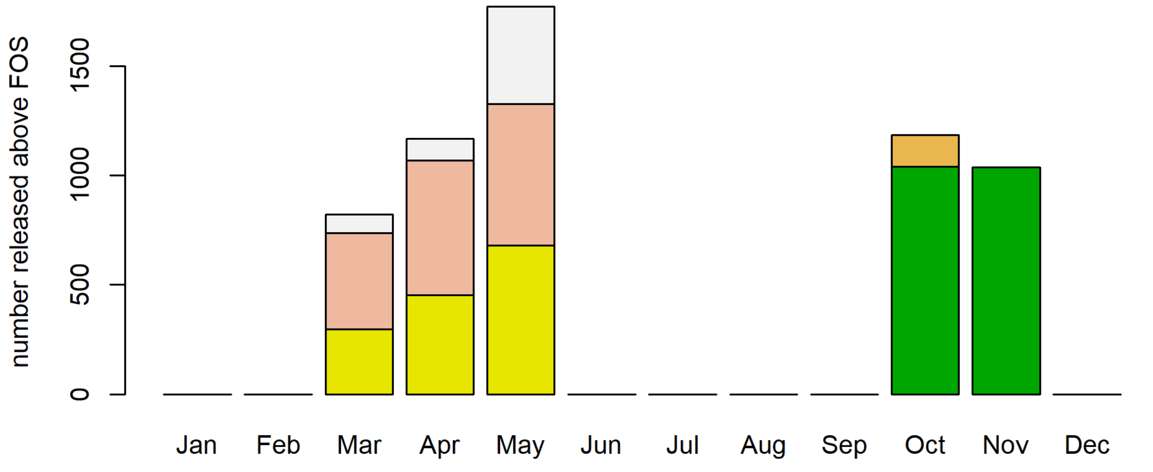
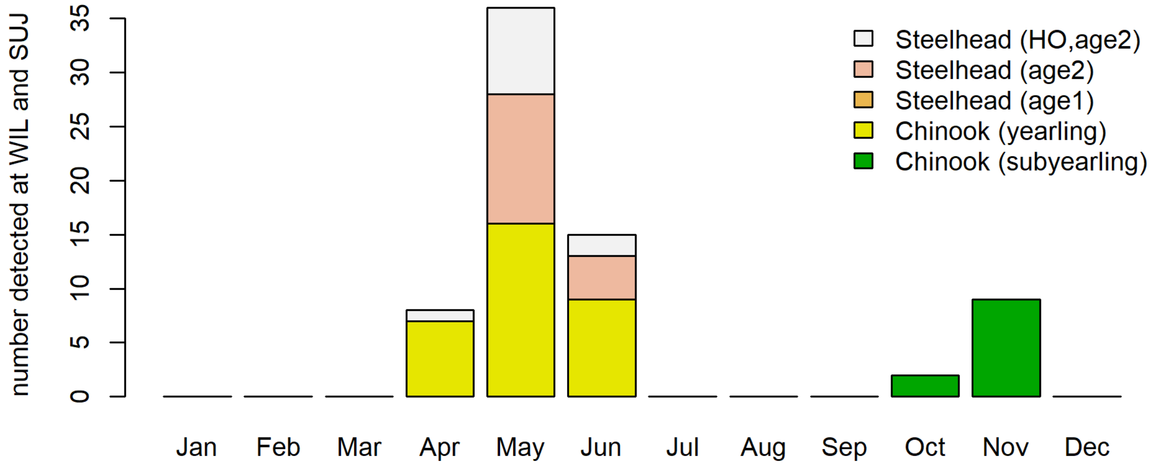
Supporting telemetry studies

- PNNL released acoustic + PIT-tagged fish at Foster Dam in 2016/2018
- Telemetry array upstream of Willamette Falls
  - Mean time release to array = 11.6 days
  - Of fish reaching array, 43/940 chinook salmon + 27/230 steelhead detected at SUJ
  - Mean time array to SUJ = 14 hr
- Calculated *p* in each month by adjusting number detected at array for estimated losses before Falls

$$p_m = N_{\mathrm{SUJ},m} / N_{\mathrm{adj.array},m}$$



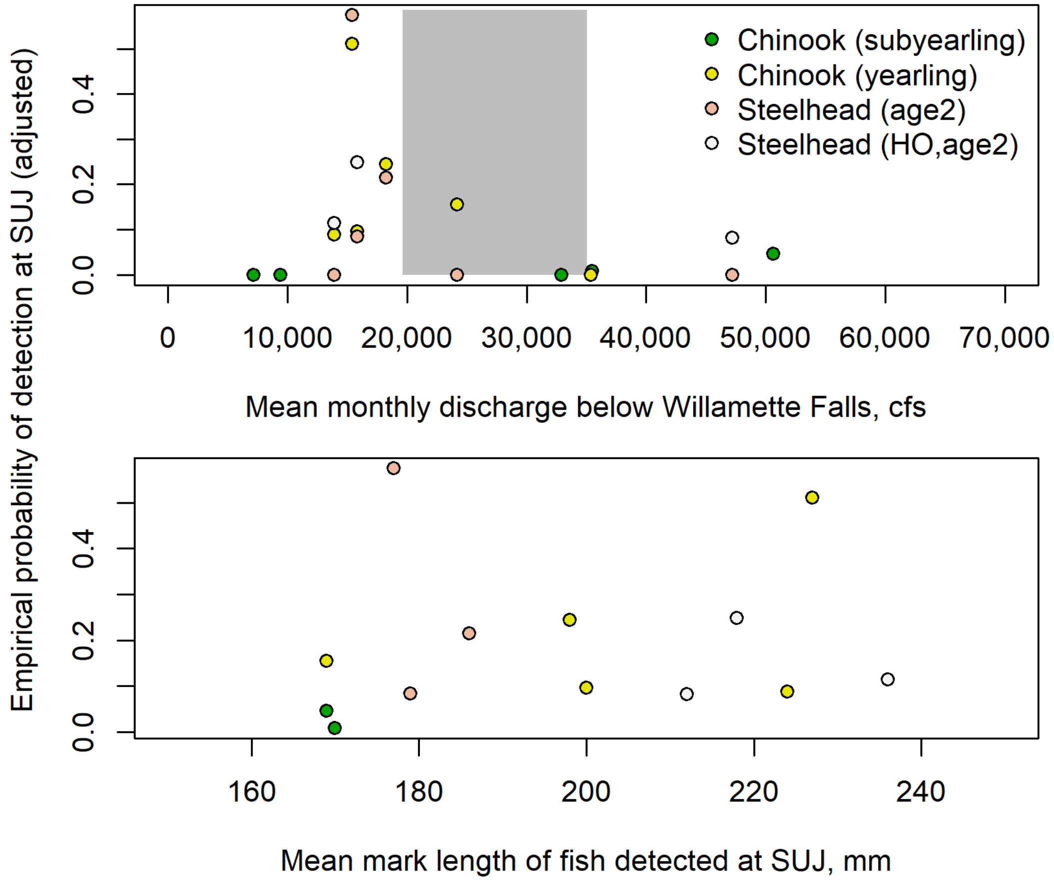


Integrated Passage Assessment

References: Hughes et al. (2017); Liss et al. (2020)

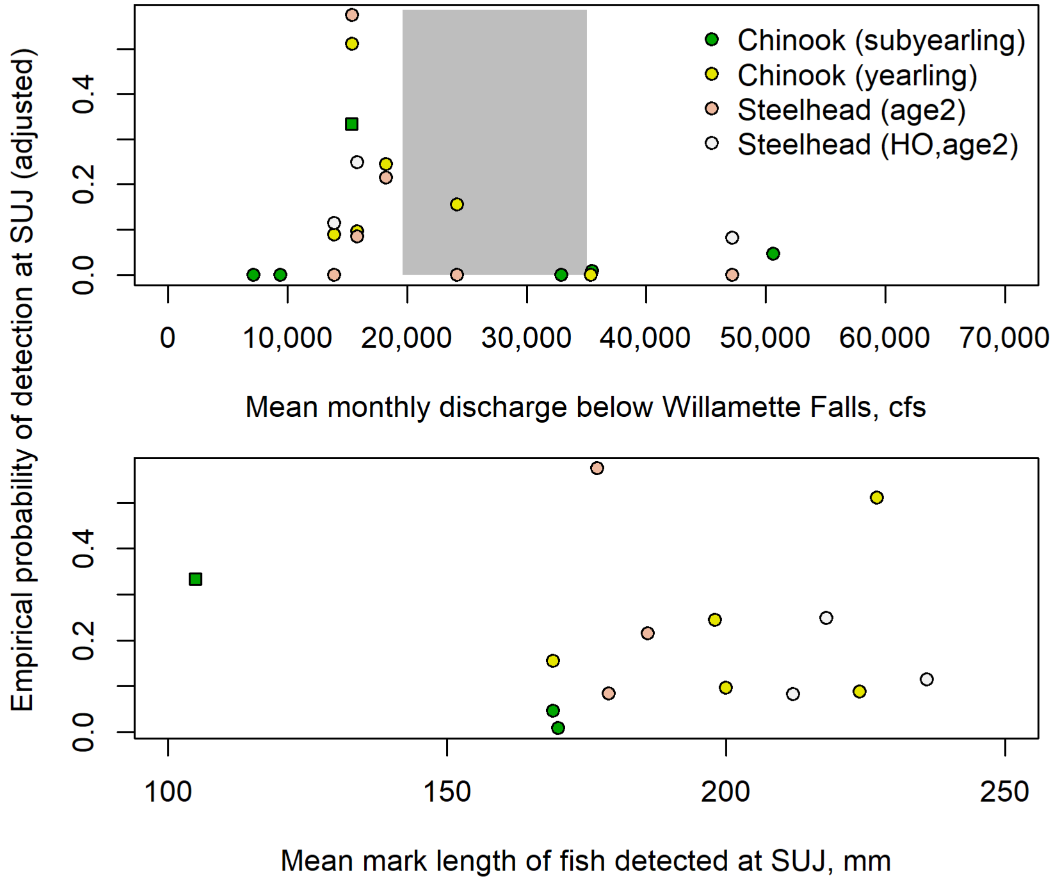
Supporting telemetry studies

- Examined relationships between empirical detection probability in each month and discharge, length
- Chinook salmon mean $p = 0.096$
- Steelhead mean $p = 0.147$
- Consistent with p_{SUJ} prior mean as 85-90% of fish went undetected at SUJ
- Wider range of mean monthly discharge suggests p is higher below 20,000 cfs



Supporting telemetry studies

- Recently obtained USGS data on double-tagged Chinook salmon releases at Detroit and Cougar Dams in 2011-15
  - Telemetry array in Portland 2014-15
- Data from 2014 Detroit release gives estimate of p = 0.333
- Supports that p is higher below 20,000 cfs



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References: Kock et al. (2015)

Future steps

- Although low sample sizes, possibility to use PNNL/USGS data to empirically update the mechanistic prior and account for 2-3 flow ranges
- Aim would be alternative priors for different release cohorts depending upon mean discharge when released cohort passed Willamette Falls

- Must remember this is a prior for Bayesian CJS model
  - Is there belief in it? Yes – supported by empirical data
  - If there is information in the PIT tag data, this will update the prior
  - Always evaluate the sensitivity of results to different specifications for priors

Acknowledgements

- Normandeau Associates, PNNL and USGS for undertaking detection/survival studies and for sharing data
- The Columbia Basin PIT Tag Information System (PTAGIS)