Developing an Integrated Population Model for the Western DPS Steller Sea Lions using Mark-Recapture and Aerial Survey Data

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UNIVERSITY of WASHINGTON

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Project Goals & Research Questions

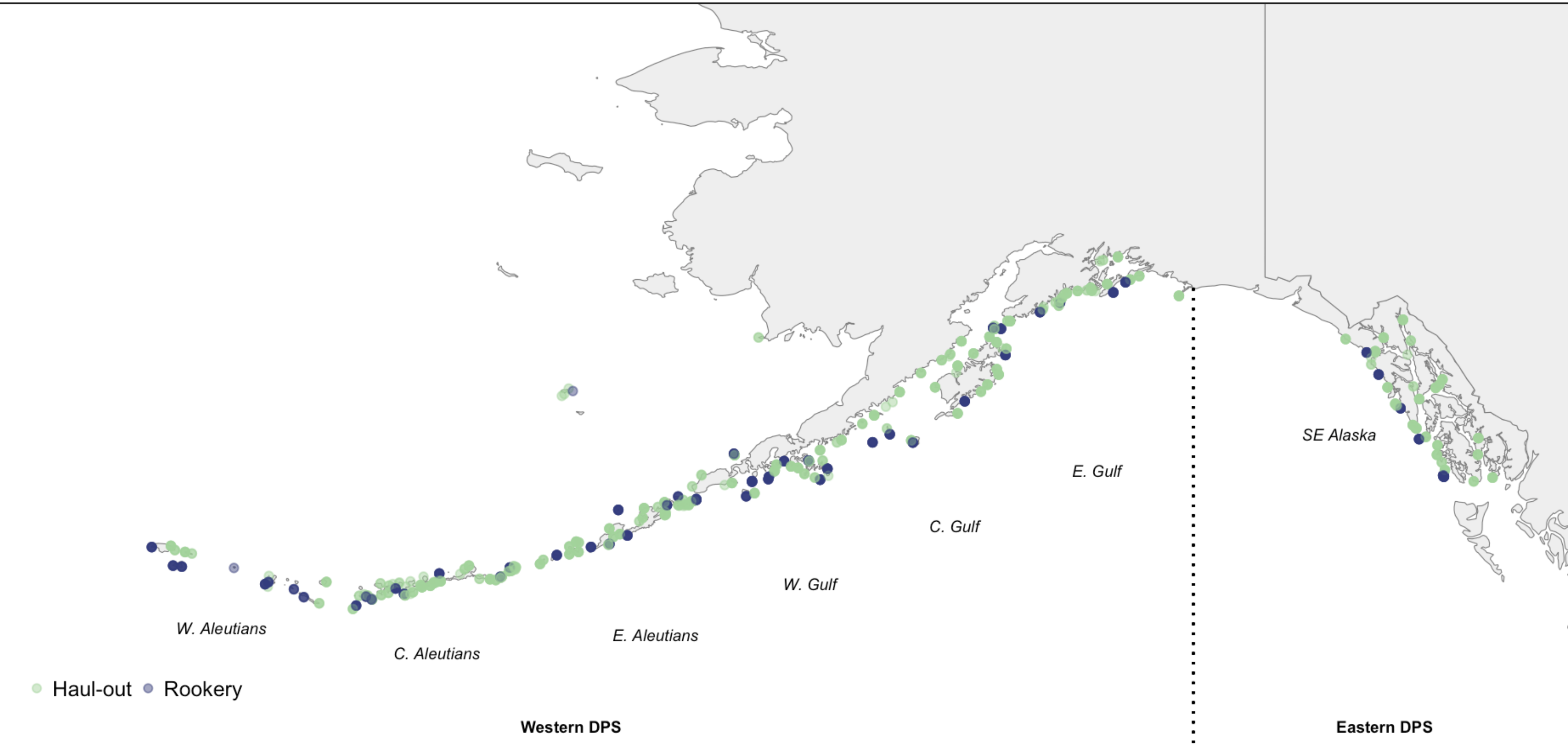
- *Ultimately…*
  - *Develop a Bayesian integrated population model for the western DPS*

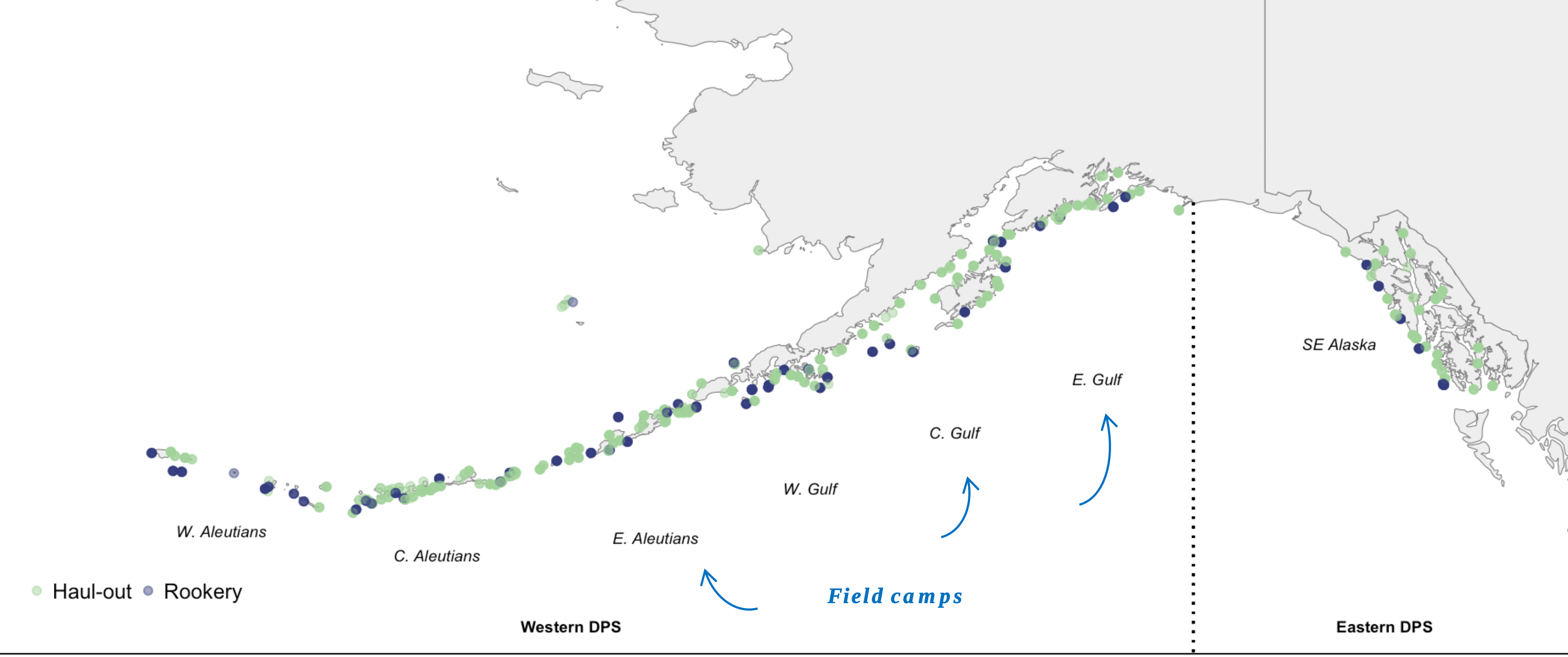
- *Why…?*
  - *IPMs can result in improved precision and reduced bias*
  - *Improved abundance estimates and insight into divergent recovery trends*

- *In the meantime…*
  - *Age-structured model to estimate survival, detection, and transition probabilities*
  - *Examine effects of individual characteristics and oceanographic conditions*
  - *Estimate pup abundance from aerial survey data using state-space mixture model*

Background

- *Populations declined throughout the 1970s-80s*
- *Populations listed under the ESA*
- *Eastern DPS recovering, western DPS still declining in some areas*



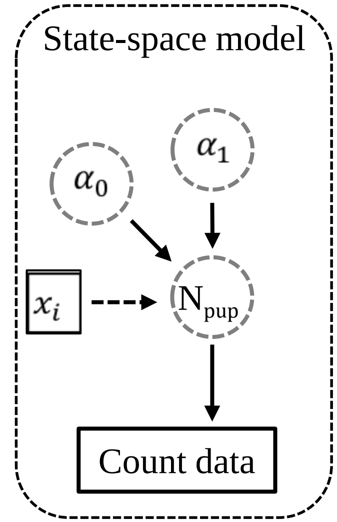


- *Many spatio-temporally specific demographic rates*
  - *Field camps and branding locations: data availability across regions*

- *Emphasis on abundance modeled against prey availability and ocean conditions*
  - *Lacking strong hypotheses about why these factors might affect abundance*

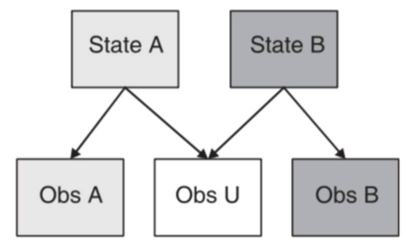
  → *Instead look at the effect of ocean conditions on demographic rates*

Model Development



- *Data integration for abundance estimation*
  - ✓ *Female-only model, 2000 - 2017*
  - ✓ *Counts from aerial surveys → pup abundance*
  - X *Proportion of non-pups present unknown*

- *Age-specific vital rates from mark-recapture data*
  - X *State uncertainty (female reproductive status)*



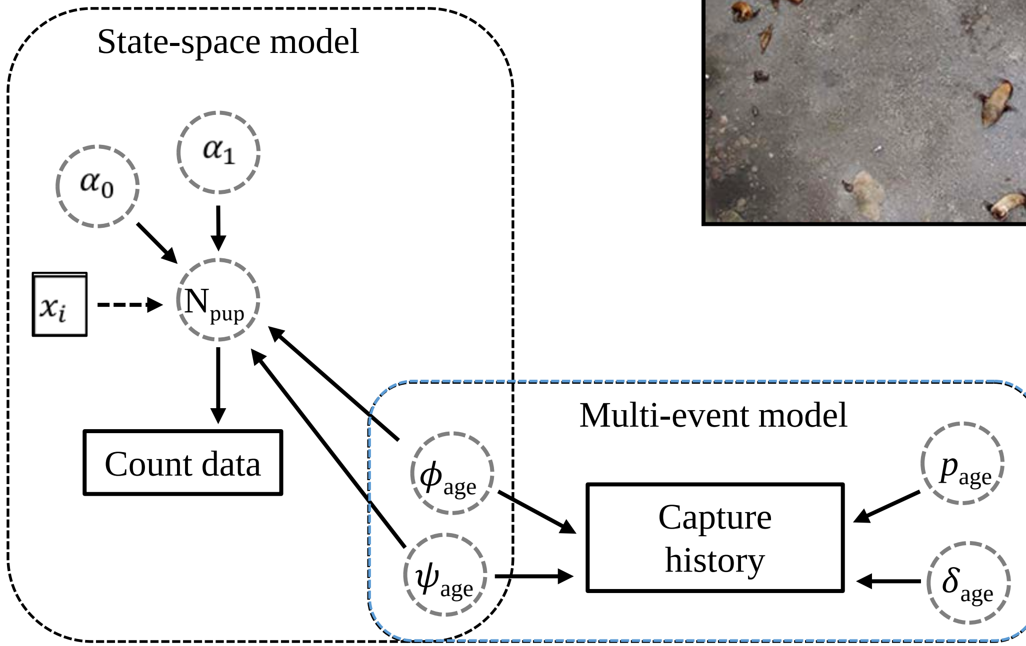
- *Multi-event model*
  - *Probabilistically link observations to true states*

  But! Variable probability of ascertaining reproductive status

  - *Robust design model?*
  - *Open JS model?*
  - *Add model states for resight location (e.g., rookery, haul-out)*
  - ✓ *CJS model with categorical variable for resight frequency*

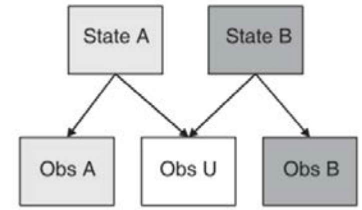
Model Framework ~ Integrated population model

$$N_i \sim Poisson(\lambda_i)$$
$$log(\lambda_i) = \alpha_0 + \alpha_1 * x_i$$
$$y_{i,j}|N_i \sim Binomial(N_i, p)$$



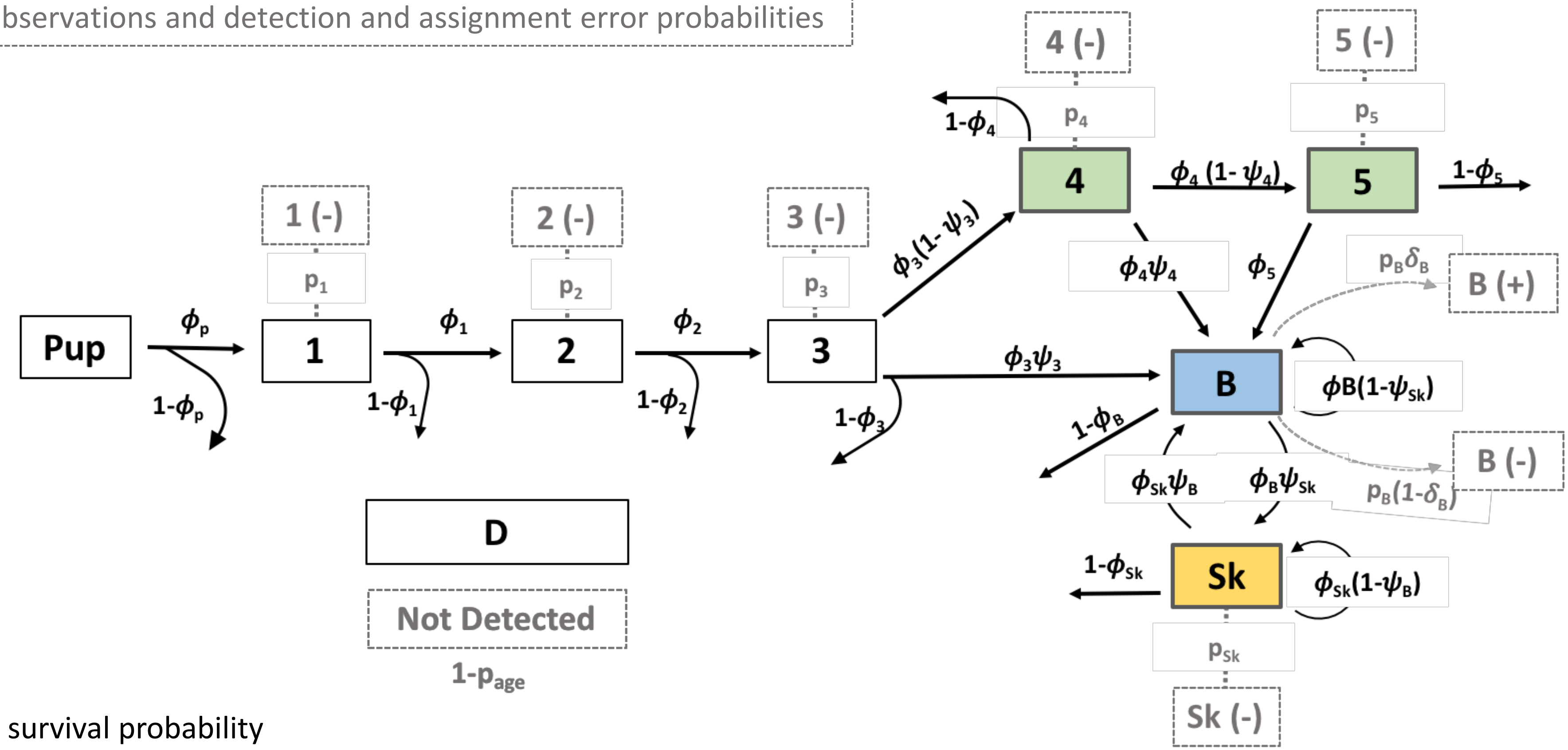
$$z_{i,t} \mid z_{i,t-1} \sim Categorical(\Omega_{z_{i,t-1},i,t-1})$$
$$y_{i,t} \mid z_{i,t} \sim Categorical(\Theta_{z_{i,t-1,i,t}})$$

Model Framework ~ multi-event model



States and survival and transition probabilities

Observations and detection and assignment error probabilities



ϕ: survival probability

ψ: transition probability

δ: ascertaining presence of pup when it is there

p: detection probability

p, B, Sk pre-breeder, breeder, skipper

(+/-) pup observation status

$$z_{i,t} \mid z_{i,t-1} \sim Categorical(\Omega_{z_{i,t-1},i,t-1})$$

$$y_{i,t} \mid z_{i,t} \sim Categorical(\Theta_{z_{i,t-1,i,t}})$$

Model Framework ~ Integrated population model

$N_i \sim Poisson(\lambda_i)$

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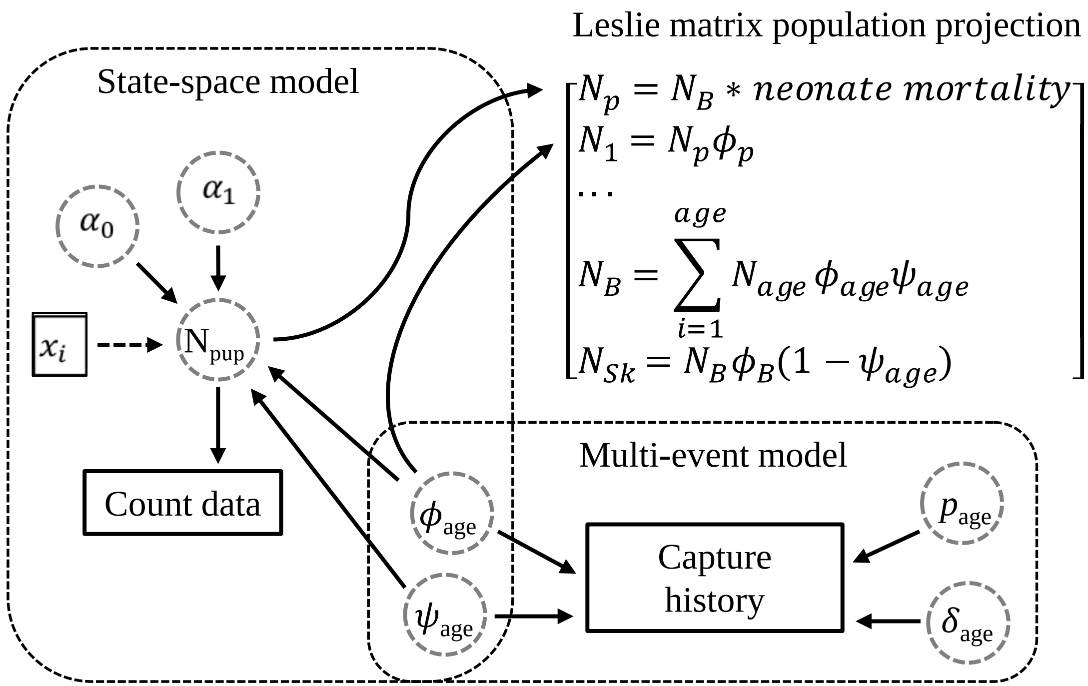
$y_{i,j} | N_i \sim Binomial(N_i, p)$



$z_{i,t} \mid z_{i,t-1} \sim Categorical(\Omega_{z_{i,t-1},i,t-1})$

$y_{i,t} \mid z_{i,t} \sim Categorical(\Theta_{z_{i,t-1,i,t}})$

CJS Model ~Variable Selection

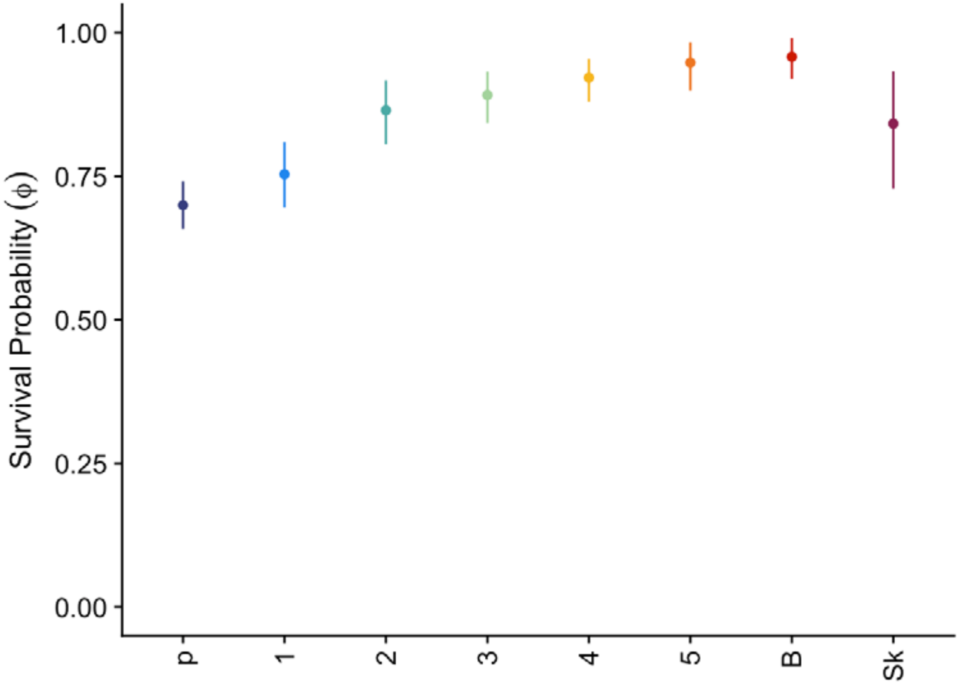
$\phi_{i,t,a} \sim \mu_a$	Intercept model
$\phi_{i,t,a} \sim \mu_a + \epsilon_{t,a}$	Random year effect
$\phi_{i,t,a} \sim \mu_a + \beta 1[region_i] + \epsilon_{t,a}$	Region + random year effect
$\phi_{i,t,a} \sim \mu_a + \beta 1[cohort_i] + \epsilon_{t,a}$	Cohort + random year effect
$\phi_{i,t,a} \sim \mu_a + \beta 1_a BMI_i + \epsilon_{t,a}$ $\psi_{i,t,a} \sim \mu_a + \beta 1_a MEI_t$	BMI + random year effect
$\phi_{i,t,a} \sim \mu_a + \beta 1_a MEI_t + \beta 2_a NOI_t + \beta 3_a BMI_i + \epsilon_t$ $\psi_{i,t,a} \sim \mu_a + \beta 1_a MEI_t + \beta 2_a BMI_i$	BMI + MEI + NOI + random year effect

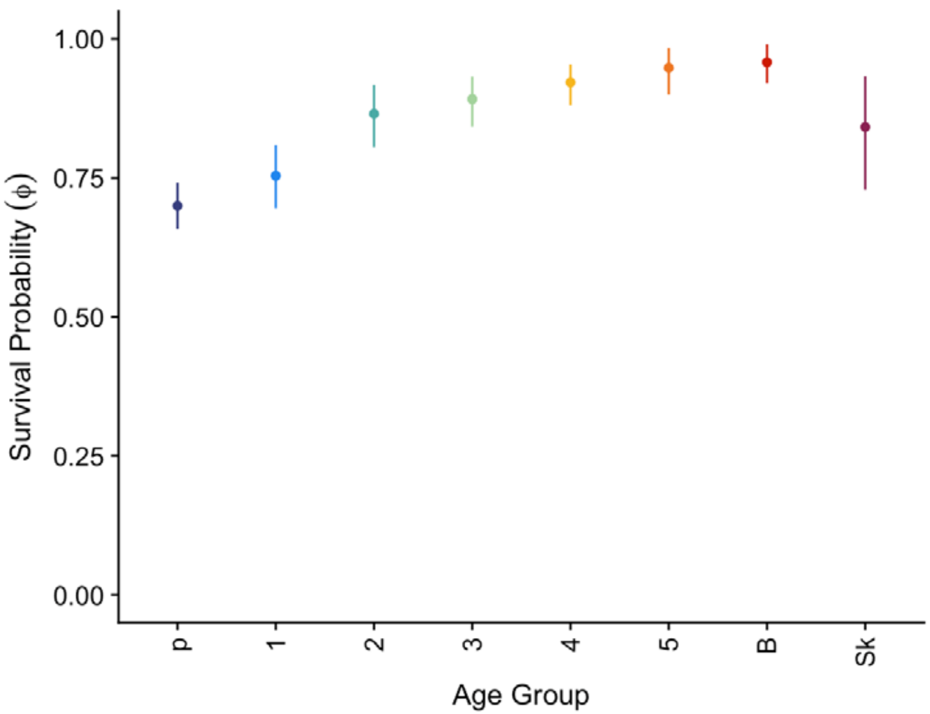
Flat uninformative priors: uniform(0, 1) normal(0, 0.001)

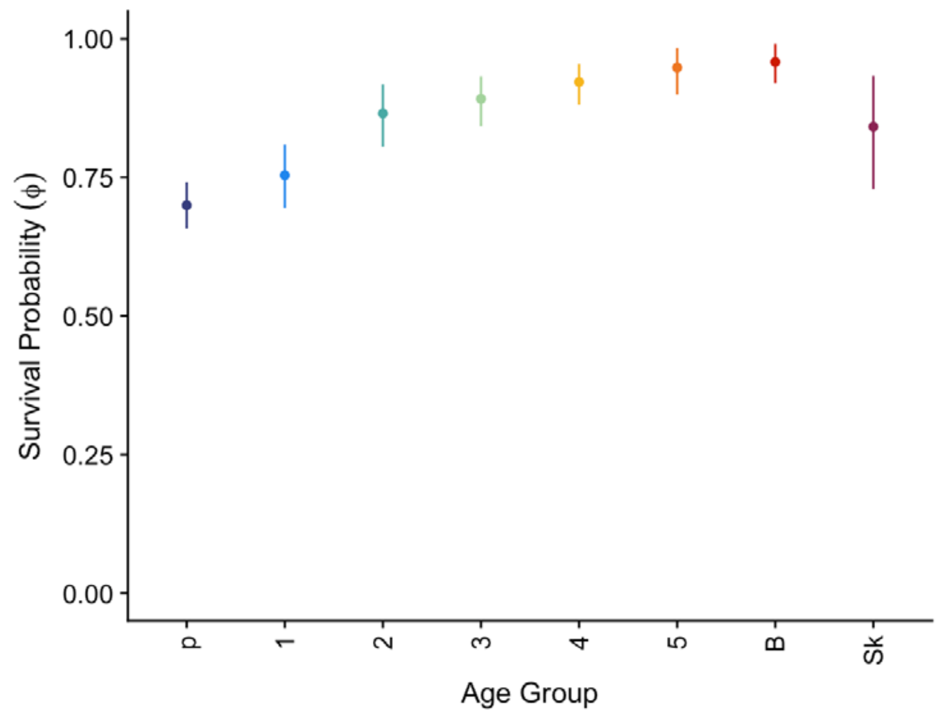
*Region*covariate interactions*

Intercept model

$$\phi_{i,a} \sim \mu_a$$

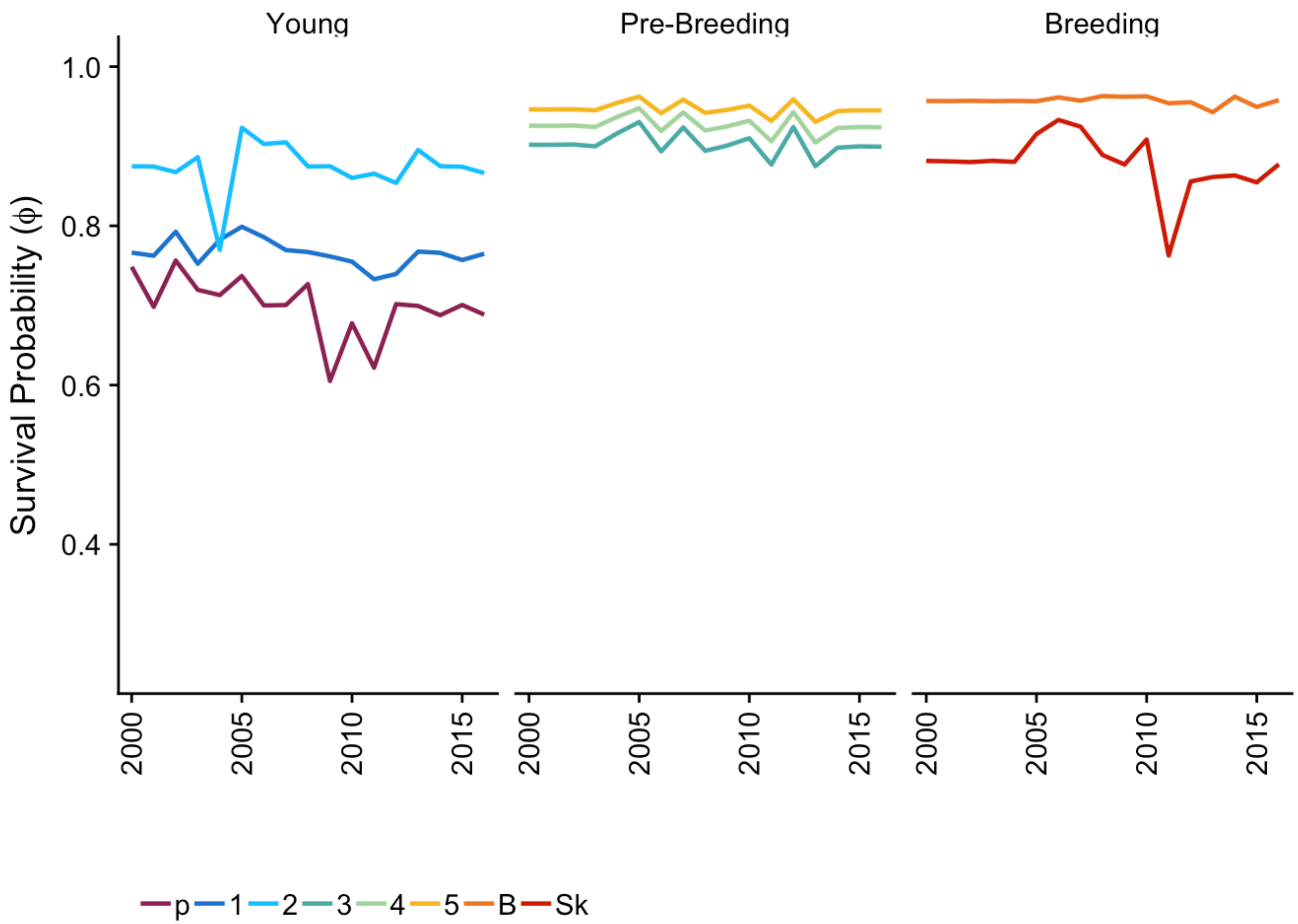






Random year effect

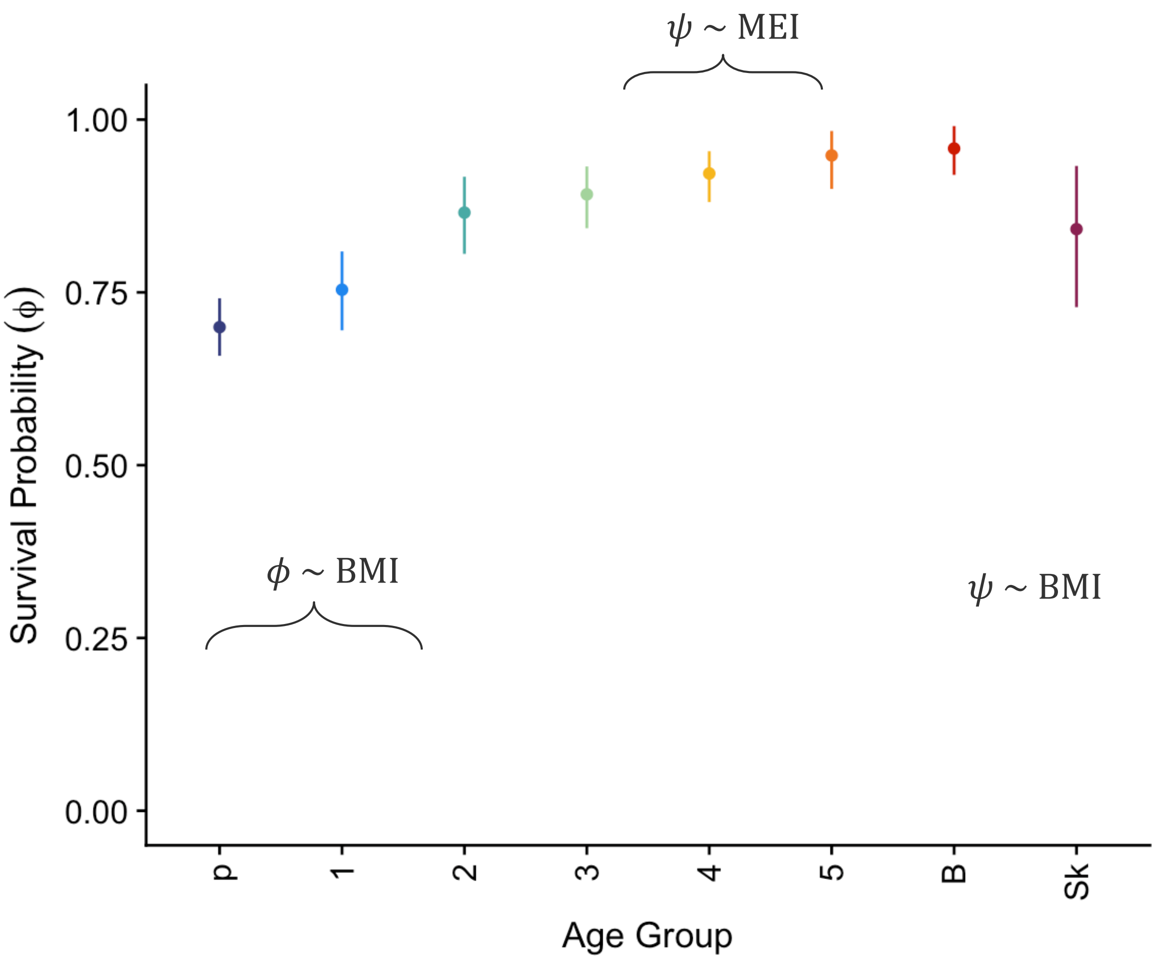
$$\phi_{i,t,a} \sim \mu_a + \epsilon_{t,a}$$



Effect of BMI on survival, BMI and MEI on breeding transition probability

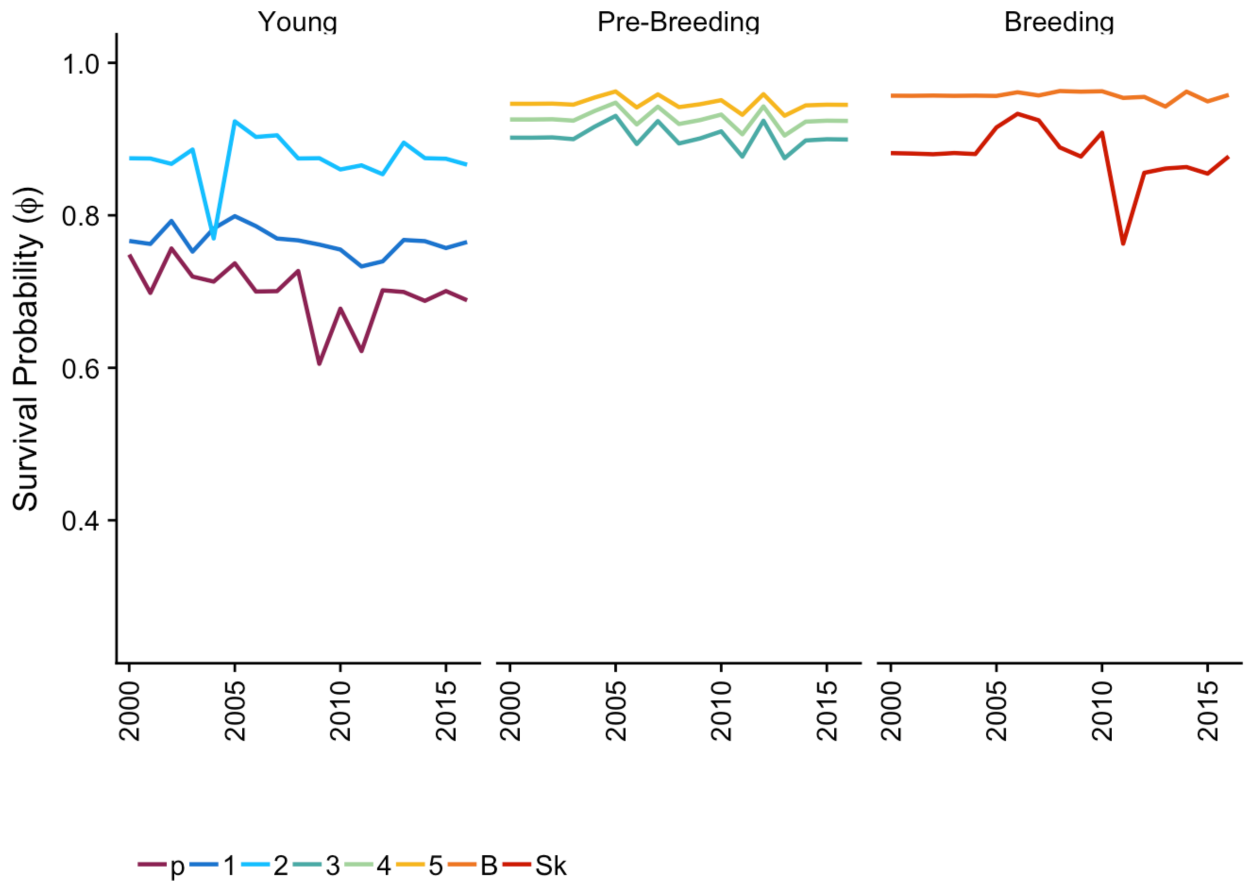
$$\phi_{i,t,a} \sim \mu_a + \beta 1_a BMI_i + \epsilon_t$$

$$\psi_{i,t,a} \sim \mu_a + \beta 1_a MEI_t + \beta 2_a BMI_i$$



Effect of MEI and NOI on survival

$$\phi_{i,t,a} \sim \mu_a + \beta 1_a MEI_t + \beta 2_a NOI_t + \epsilon_t$$



Summary & Next Steps…

- *Initial model runs*
  - *Reasonable survival estimates, increasing with age*
  - *Interesting patterns in breeding transition probability?*
  - *Maybe a small effect of BMI and ocean conditions*

- *Variable and model selection*
  - *More by-region interactions*
  - *Model averaging and selection (WAIC)*

- *Combined likelihoods for IPM*

Acknowledgements

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Questions? Feedback?

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