

# Incorporating spawn surveys in a semi-spatial stock-recruitment model

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Trevor Branch

University of Washington

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**SCHOOL OF AQUATIC AND FISHERY SCIENCES**

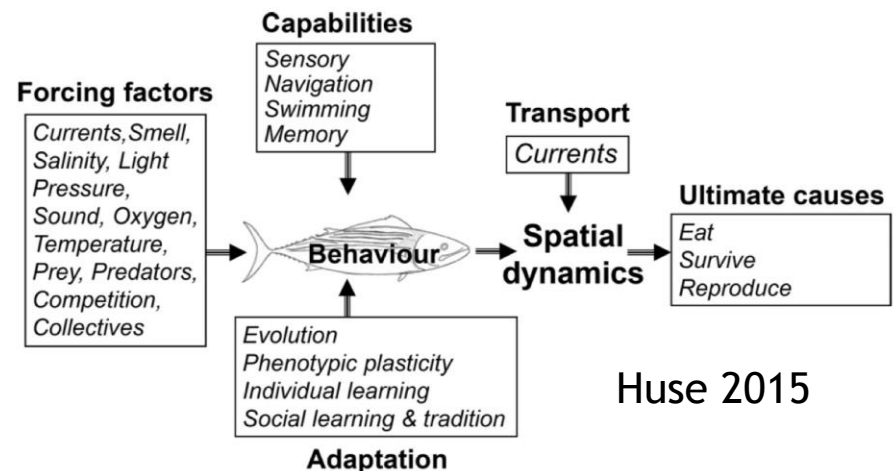


**CAPAM**

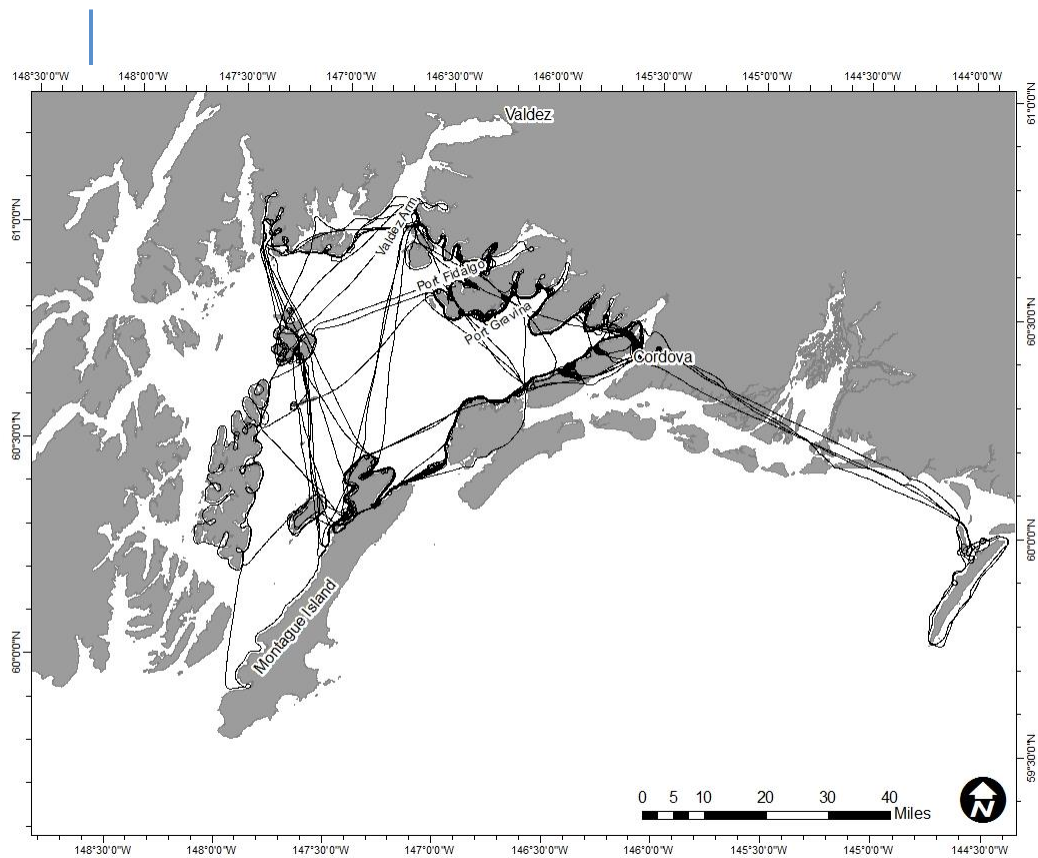
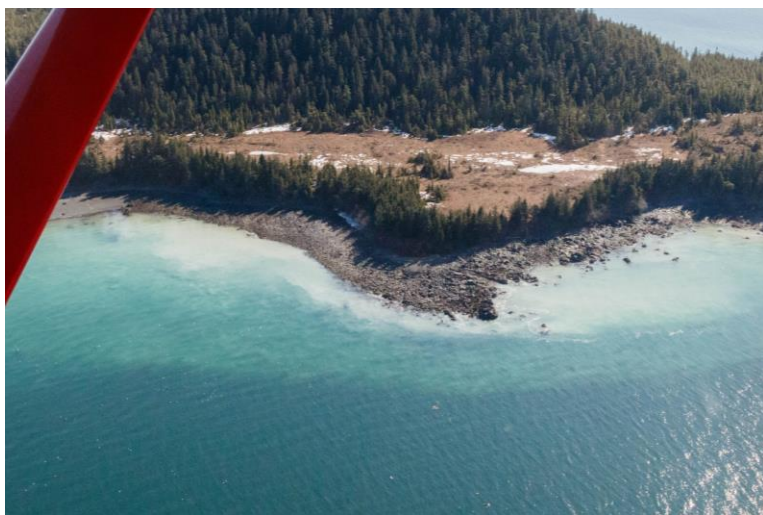
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# Herring spatial structure

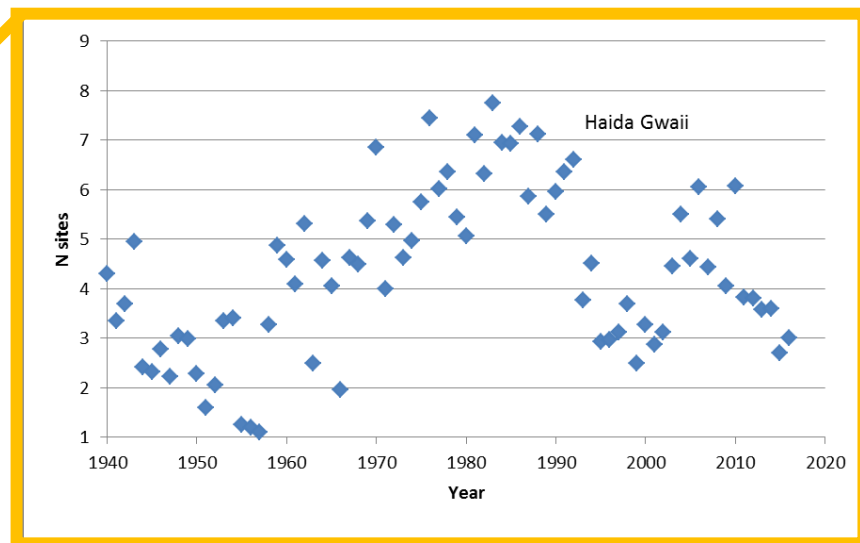
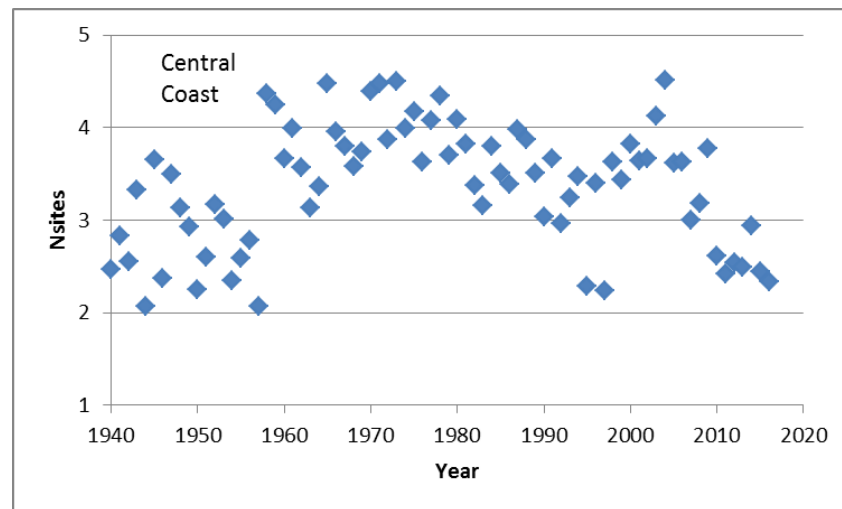
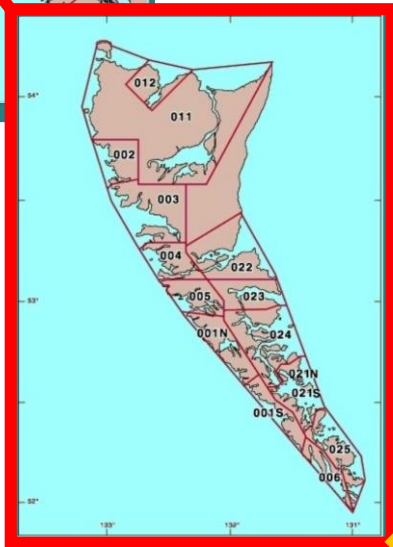
- Herring well known to spawn at various distinct sites & waves of different size (Haegele & Schweigert 1985)
- Systematic changes in spawn distribution over time noted for many herring stocks in Pacific and Atlantic (Hay et al. 2001; Hay et al. 2009)
- Spatial dynamics are the causes and effects of a complex suite of processes ultimately driving population dynamics

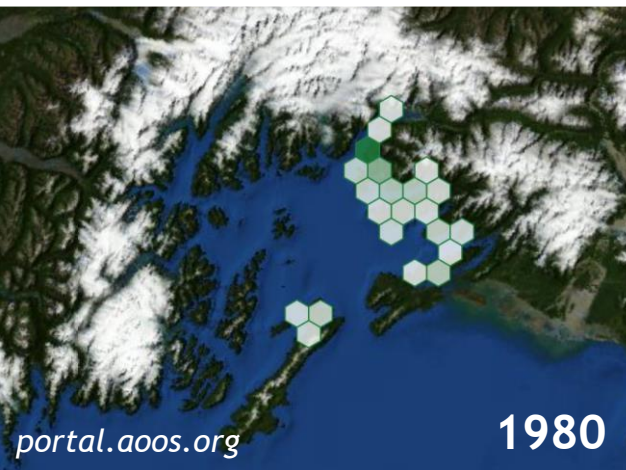
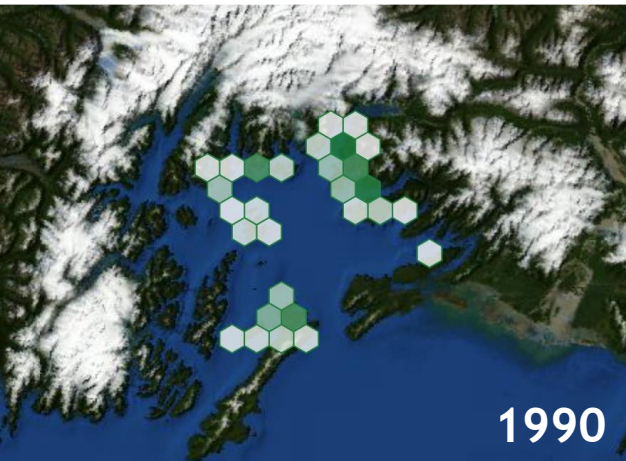
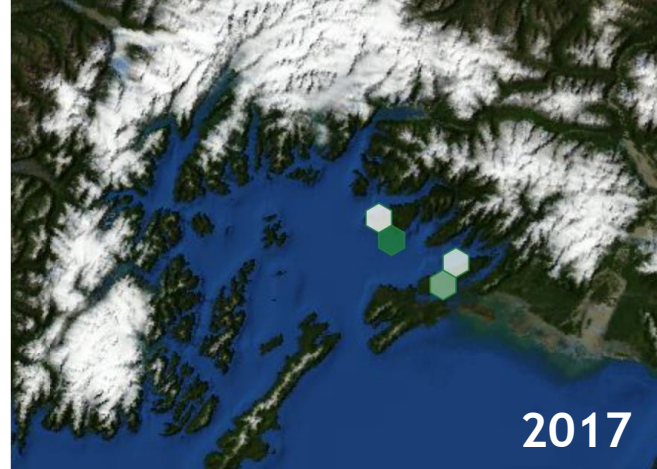
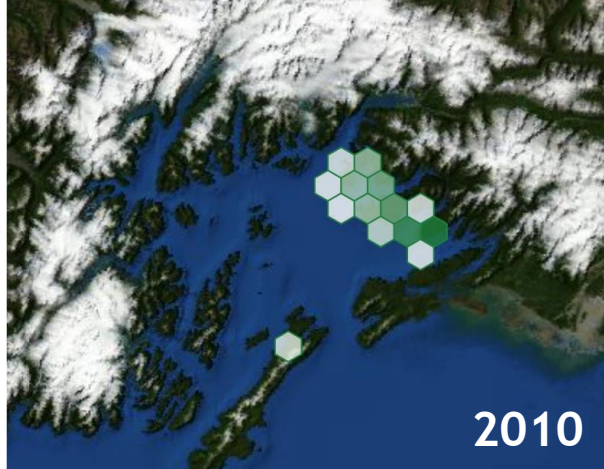
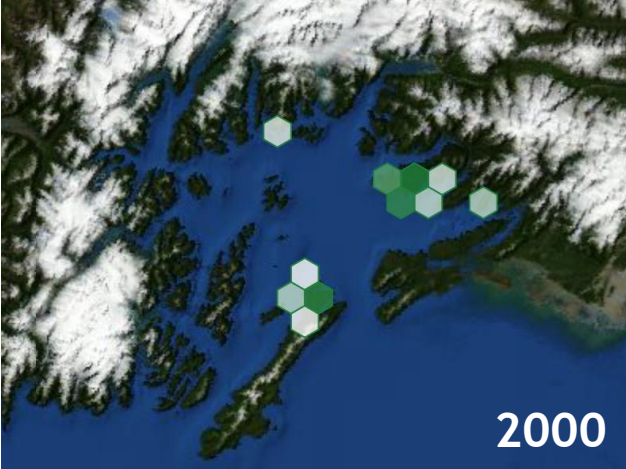


# Spawn surveys



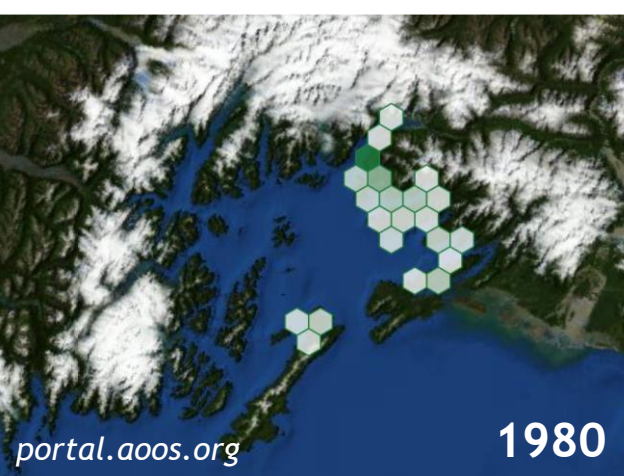
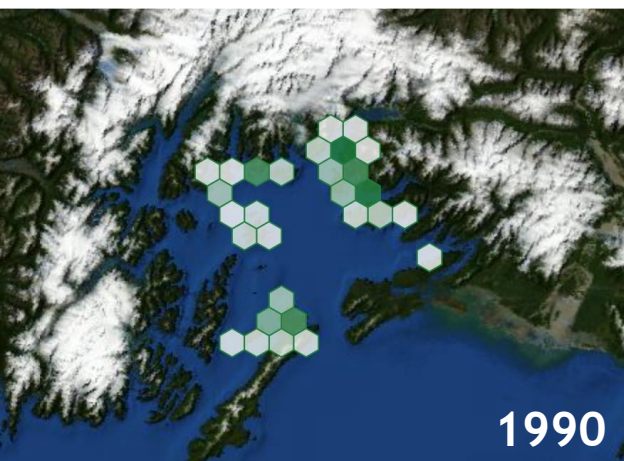
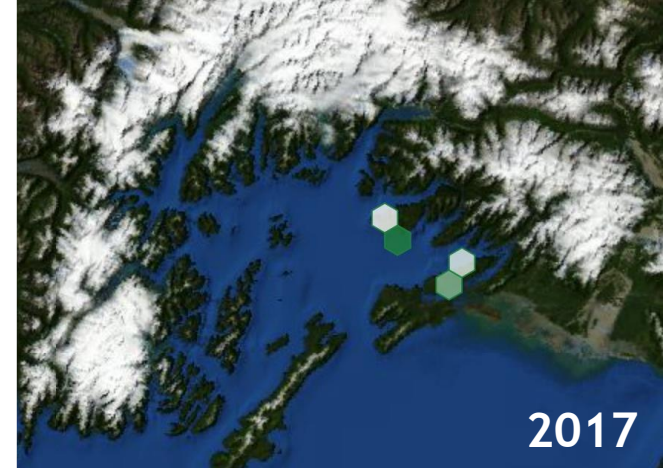
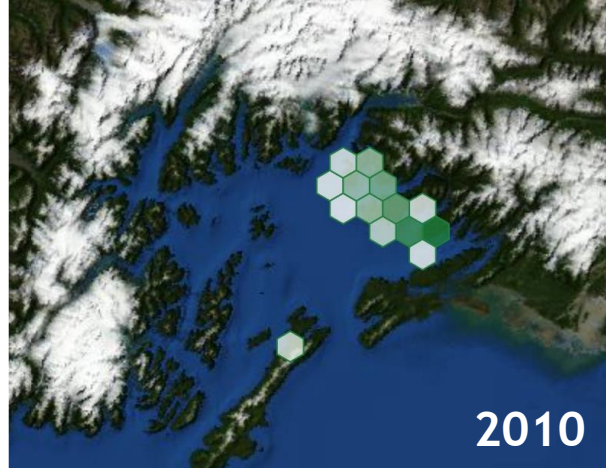
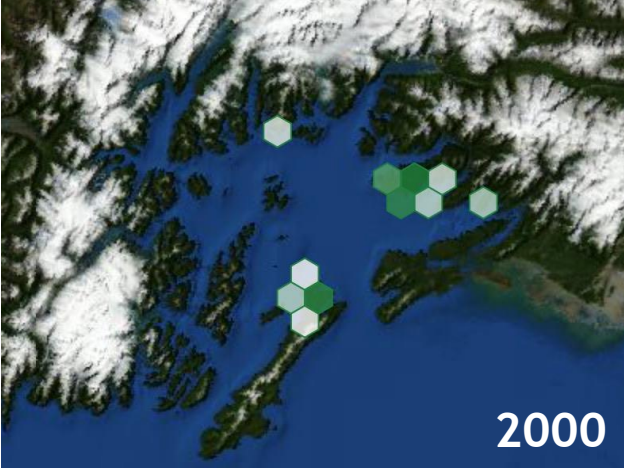
# BC Herring



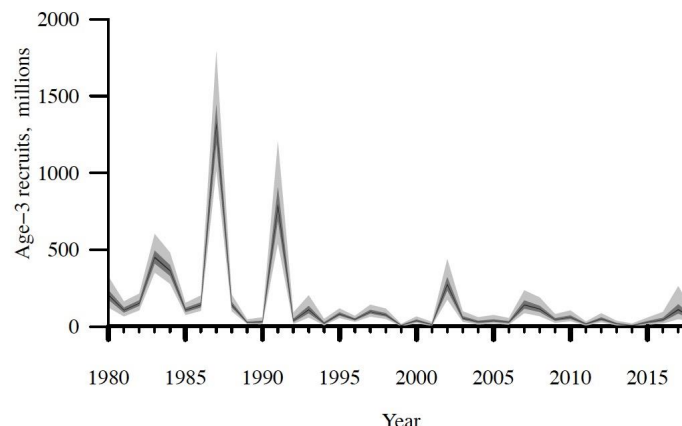
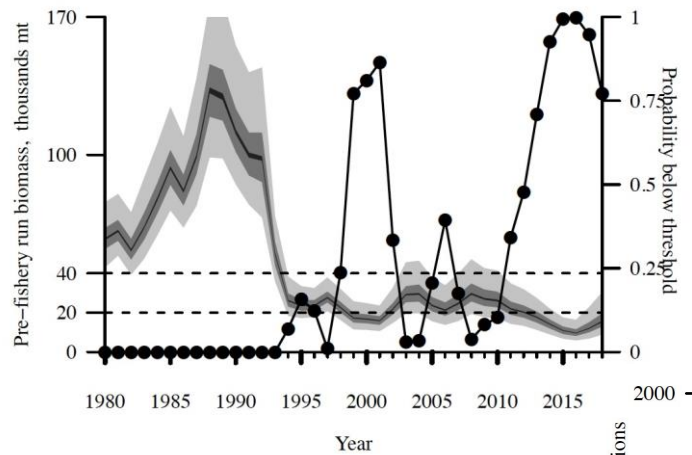


# Prince William Sound (PWS)





# Prince William Sound



# Motivation

- Issues related to stock assessment
  - Assuming  $R$  as a function of aggregate SSB
  - Stock-recruit parameters are time invariant
  - PWS herring assessment ignores stock-recruit - assumes  $R$  independent of SSB
- Hypothesis
  - Distributional changes explain some nonstationarity in recruitment relationship - improve predictions
- Approach
  - Derive SSR accounting for spatiotemporal variability
  - Simulation test new spatial SSR in a forecasting age-structured model
  - Practical Application: PWS Herring (TBD)

# Recruitment model

$$R_{tot} = R_1 + R_2 + R_3 + \dots R_N$$

$$B_{tot} = B_1 + B_2 + B_3 + \dots B_N$$

$$B_{tot} = p_1 B_{tot} + p_2 B_{tot} + p_3 B_{tot} + \dots p_N B_{tot}$$

N is hard to define though...



# Recruitment model

To simplify these sums:

$$N = 1/P \quad \text{or} \quad NP = 1$$

*where  $P$  = average (expected) proportion at each site  $i$*

Ricker stock-recruit applied locally  
at site  $i$ :

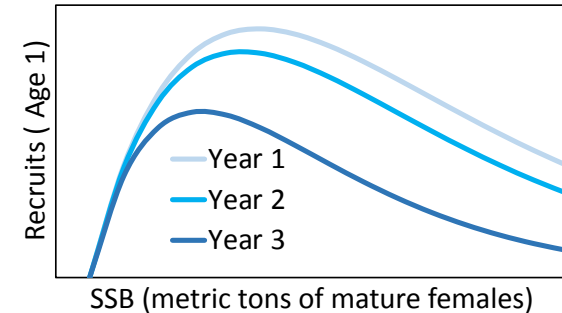
$$R_i = \alpha p_i B_{tot} e^{-\beta p_i B_{tot}}$$

$$R_{tot} = \sum_{i=1}^N \alpha p_i B_{tot} e^{-\beta p_i B_{tot}} \approx NP \alpha B_{tot} e^{-\beta P B_{tot}}$$

# Recruitment model

Since  $NP=1\dots$

$$NP\alpha B_{tot}e^{-\beta P B_{tot}} = \alpha B_{tot}e^{-\beta P B_{tot}} = R_{tot}$$



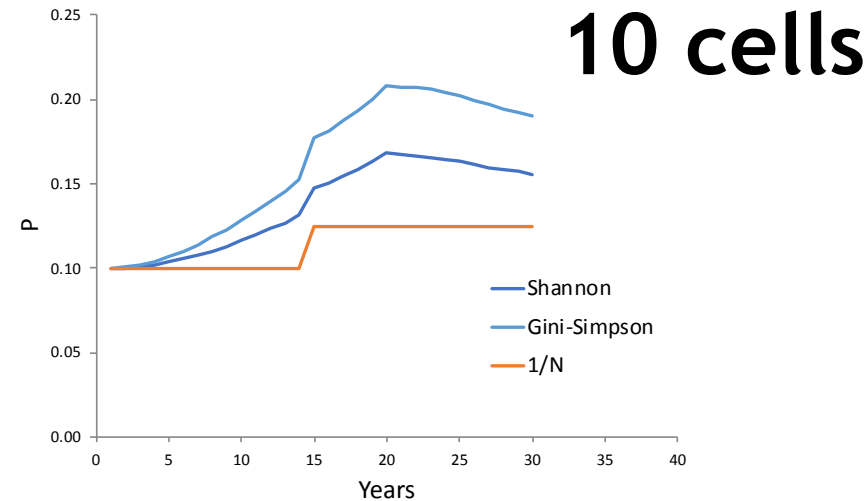
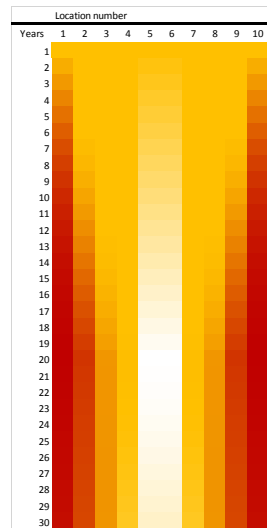
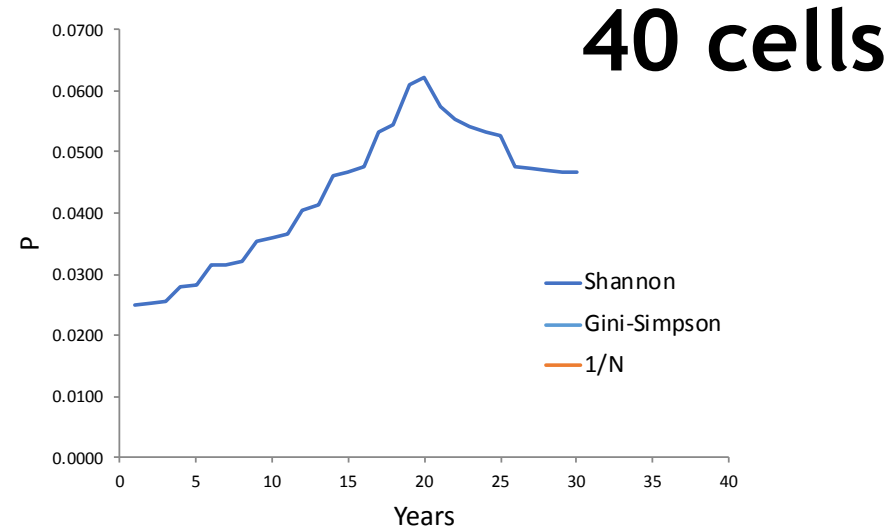
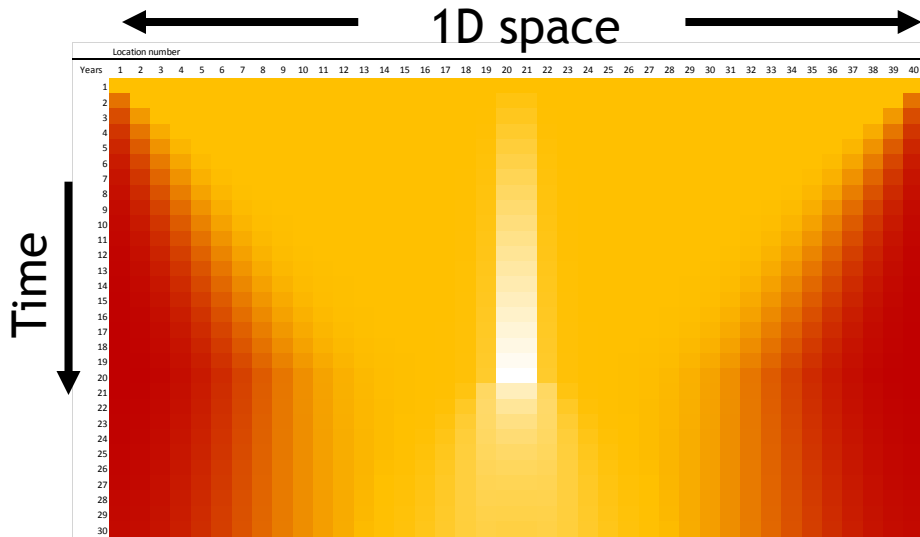
## Notes

- Identical to normal Ricker except for  $P$
- Interannual changes in  $P$
- $\beta$  are appropriately scaled
- Proportions  $p_i$  & thus sites are not explicitly accounted for - a summary statistic  $P$  describes them
- Not totally spatial, but “semi-spatial”

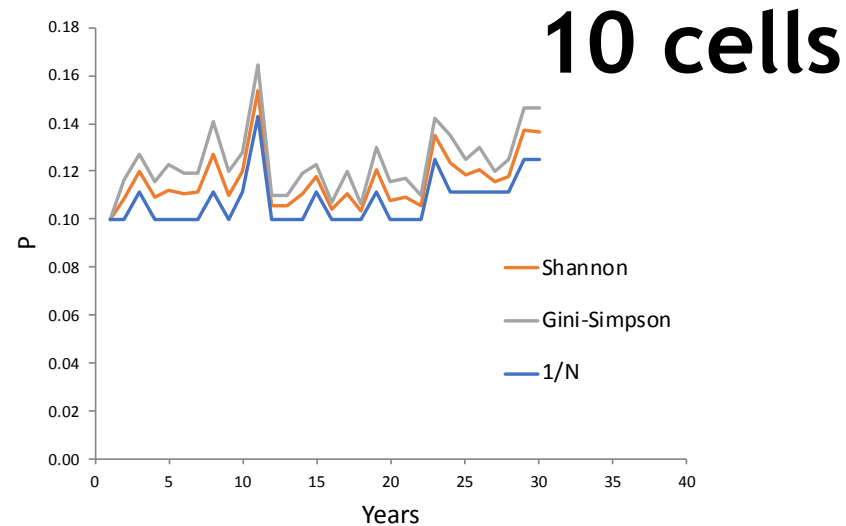
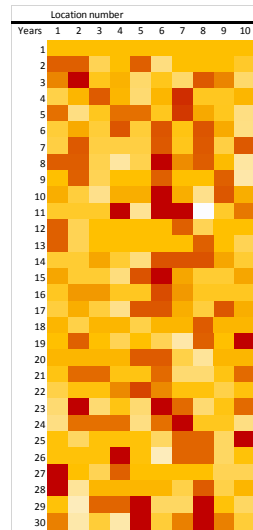
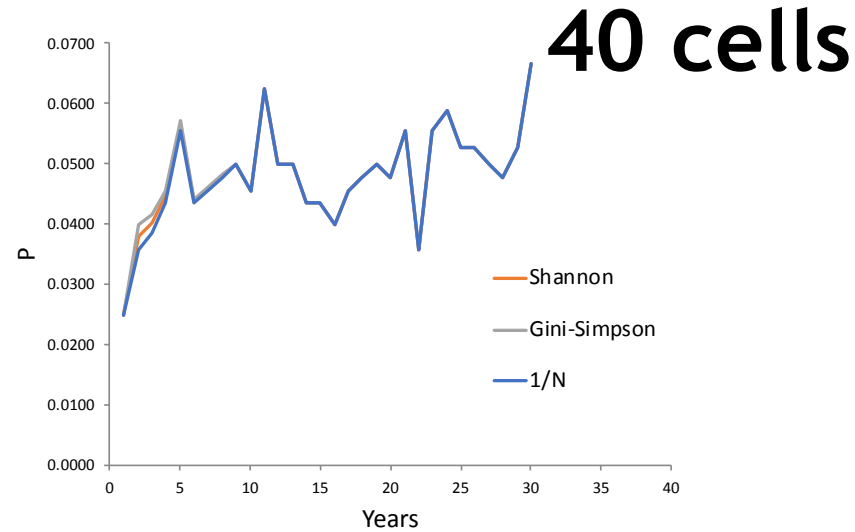
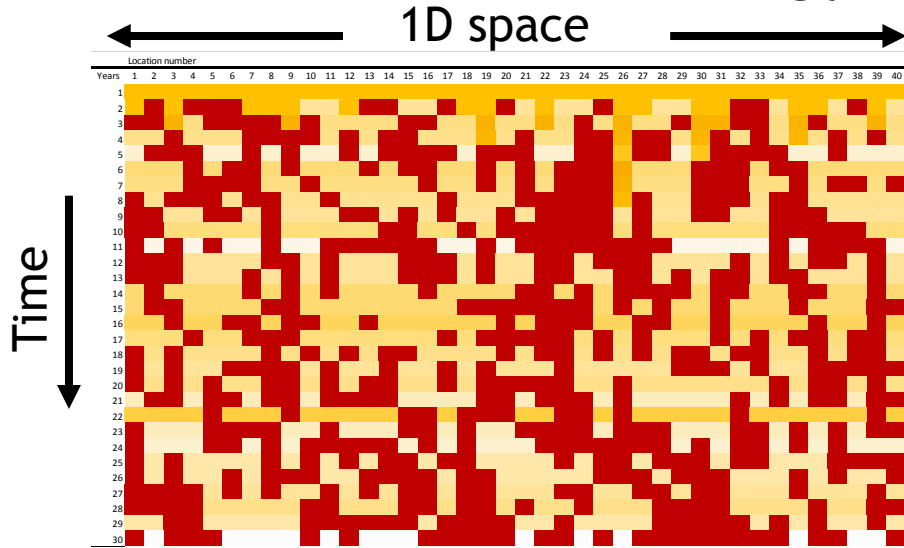
# P values

- P is expectation of all  $p_i$  , then P is identical to conventional diversity indices
- Calculating P
  1.  $1/N$  where N is a count of occupied sites
  2. Gini-Simpson index:  $\sum p_i^2$
  3. Shannon index:  $e^{\sum p_i \ln p_i}$
- $p_i$  obtained from surveys e.g. mapped milt observations in our case
- Time series of P values directly input into the estimation model (i.e. assumed without error)
- Relative changes in P matter, not the actual values
- **Issue: Defining spatial scale for calculating  $p_i$**

# 1D dispersion example: Contraction/expansion



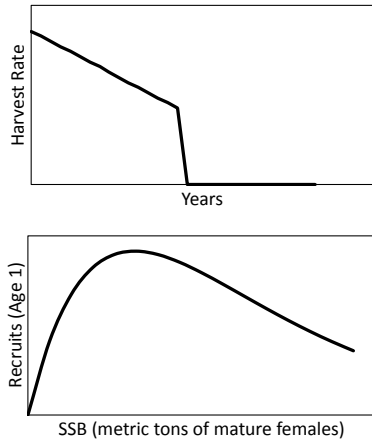
# 1D dispersion example: Random



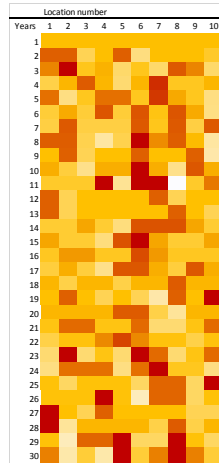
# Simulation initialization

# Operating model

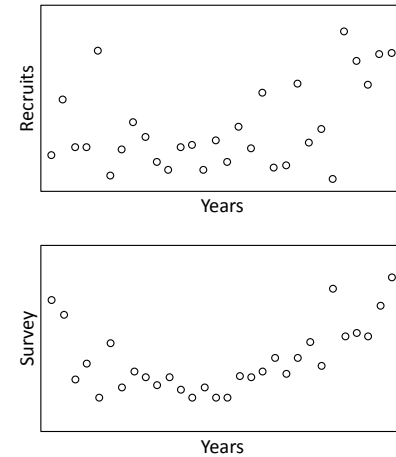
Fixed variables



Input biomass proportions over time

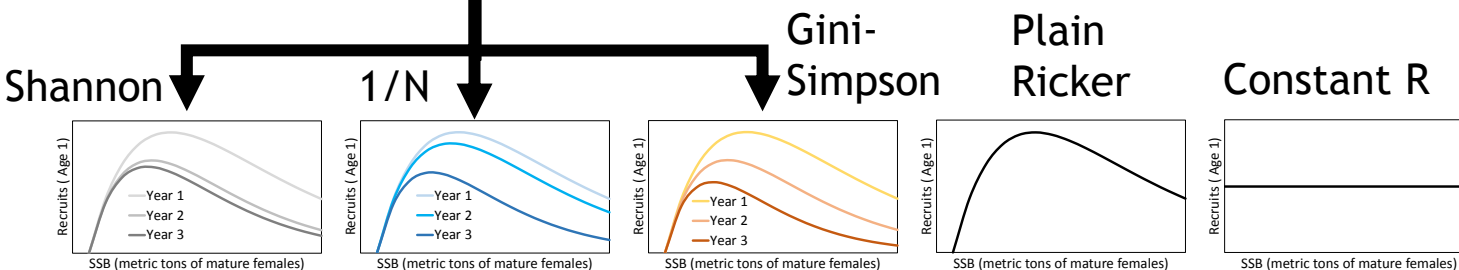


Add process & observation error



5 Estimation models

100 simulated data sets



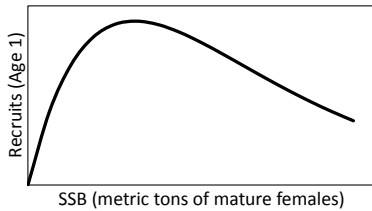
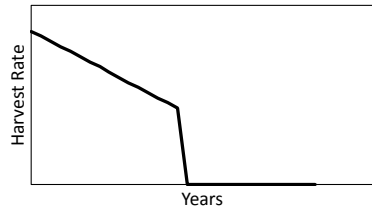
Set-up

# Simulation initialization

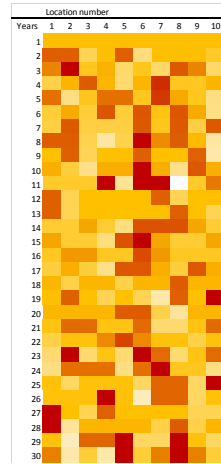
x6 scenarios

# Operating model

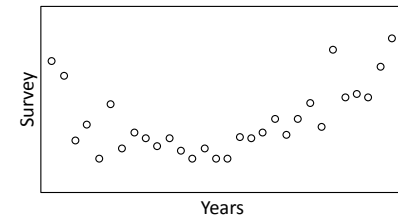
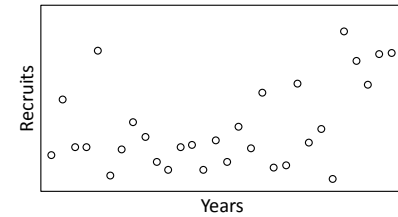
## Fixed variables



## Input biomass proportions over time

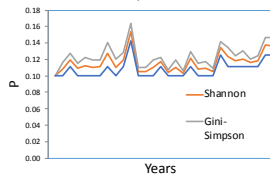


## Add process & observation error



## 5 Estimation models

100 simulated data sets



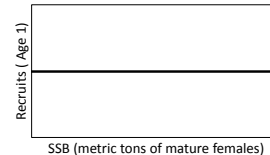
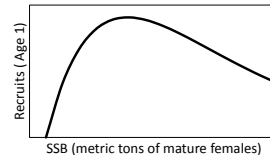
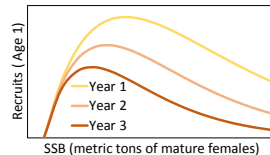
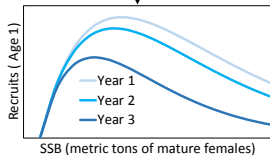
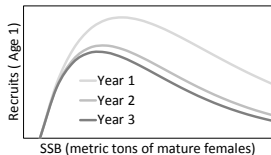
Shannon

1/N

Gini-Simpson

Plain Ricker

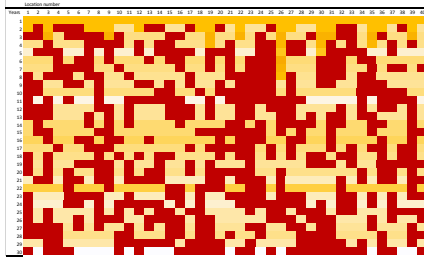
Constant R



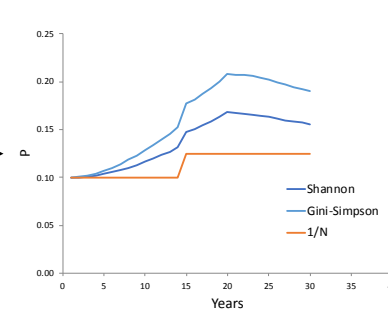
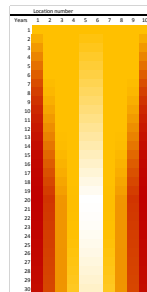
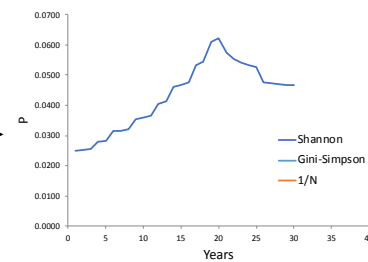
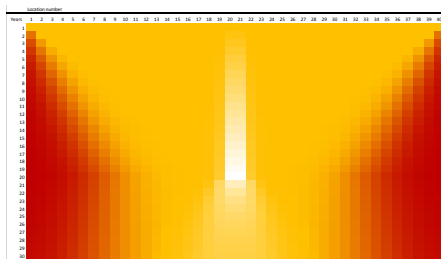
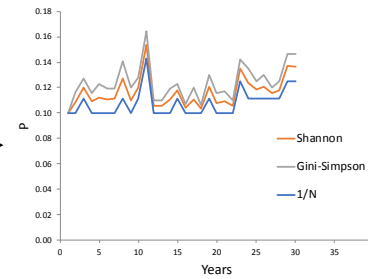
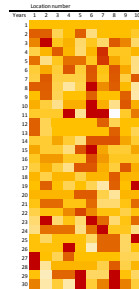
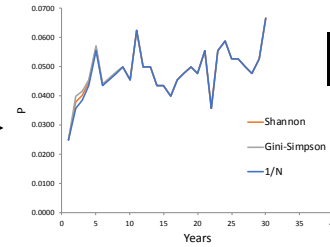
# Set-up

# 6 spatial scenarios

OM  
Input



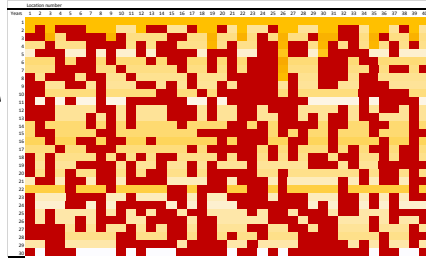
EM  
Input





# 6 spatial scenarios

OM  
Input



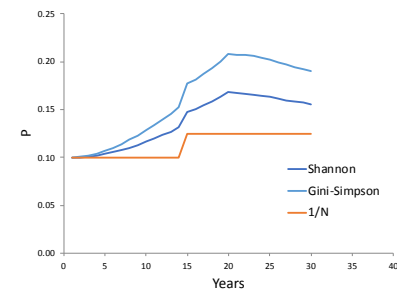
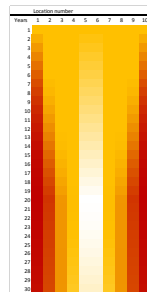
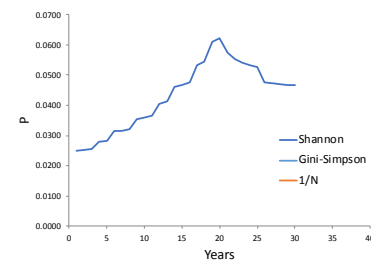
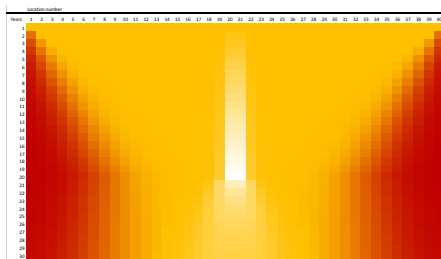
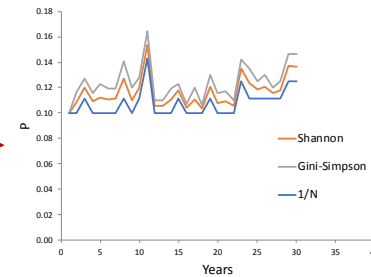
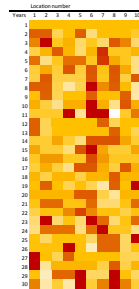
#1



EM  
Input

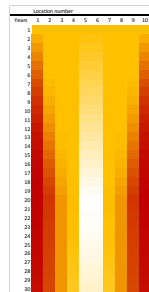
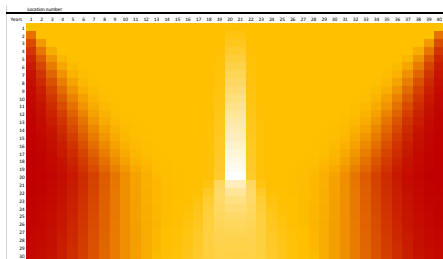
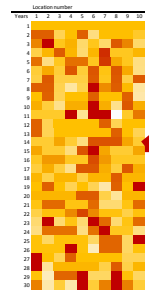
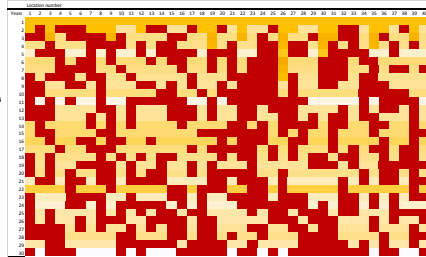


#2



# 6 spatial scenarios

OM  
Input



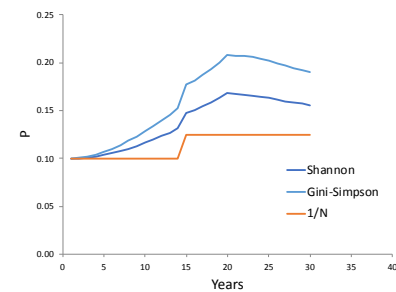
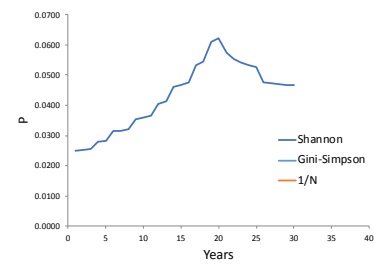
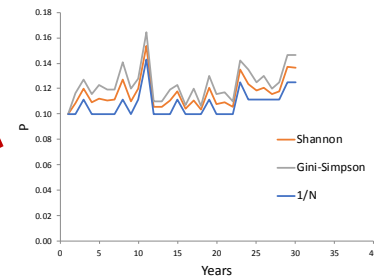
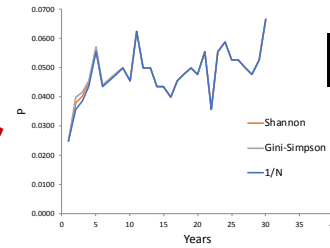
#1

#3

#4

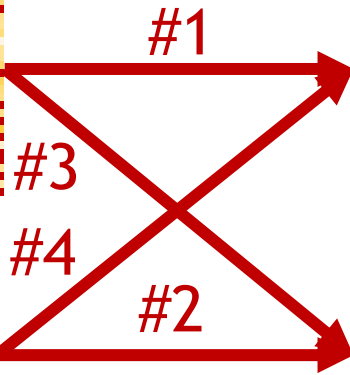
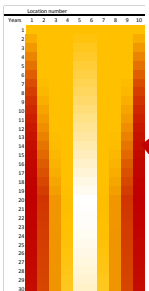
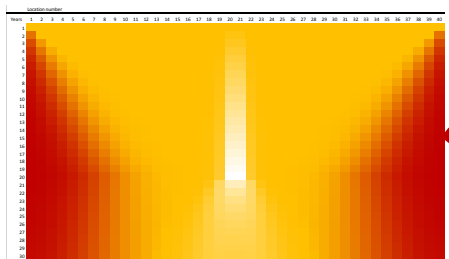
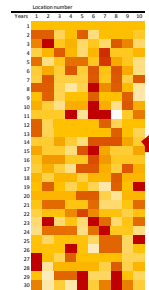
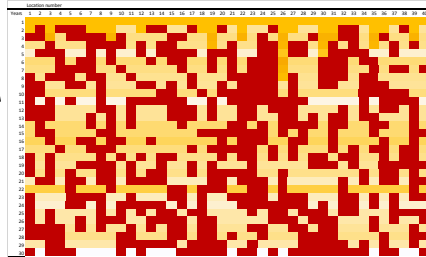
#2

EM  
Input

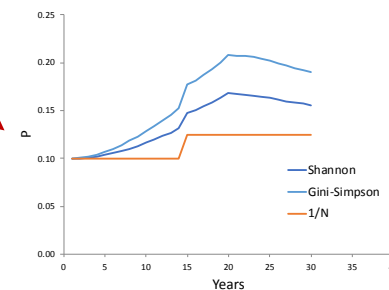
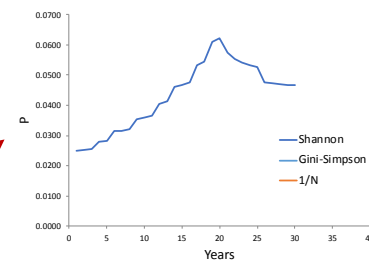
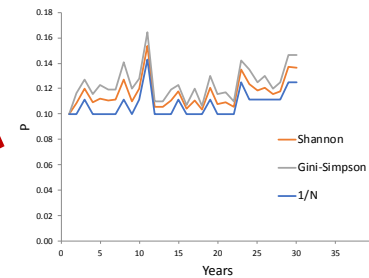


# 6 spatial scenarios

OM  
Input



EM  
Input



# Age-structured OM

- Data:
  - 30 years
  - Survey time series
  - Catch time series
  - Catch composition
- Assumed and/or time-invariant:
  - maturity-at-age (logistic)
  - weight-at-age
  - survey selectivity (logistic)
  - natural mortality (0.3)
  - survey error (0.2)

# Age-structured OM

- Parameters (number)
  - Fishing selectivity (2), survey catchability  $q$  (1), Ricker  $\alpha$  &  $\beta$  (2), initial numbers-at-age (N ages-1),  $\varepsilon_R$  (N years),  $\sigma_R=0.6$  &  $0.3$

$$\alpha B_{tot} e^{-\beta P B_{tot}} e^{\varepsilon_R - \sigma_R^2 / 2}$$

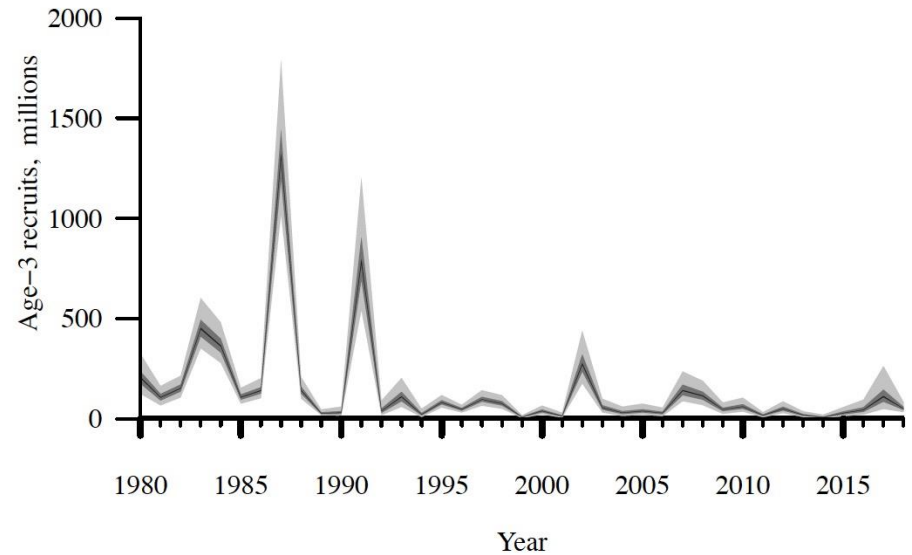
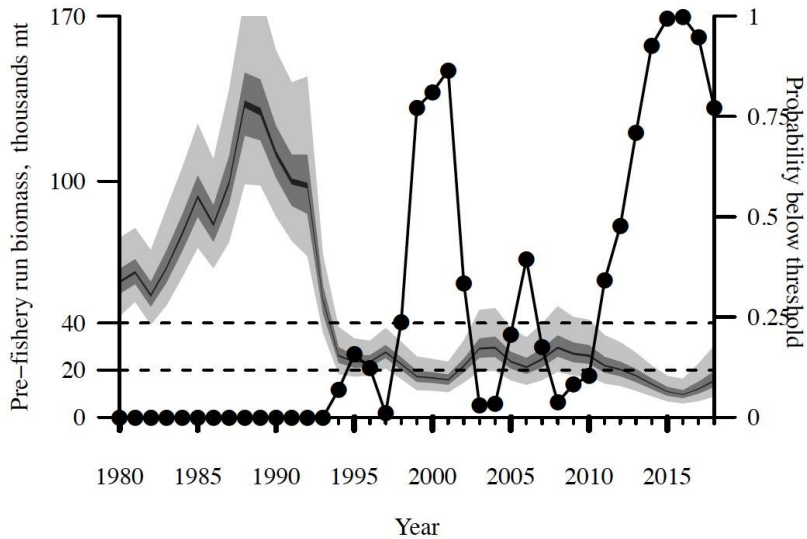
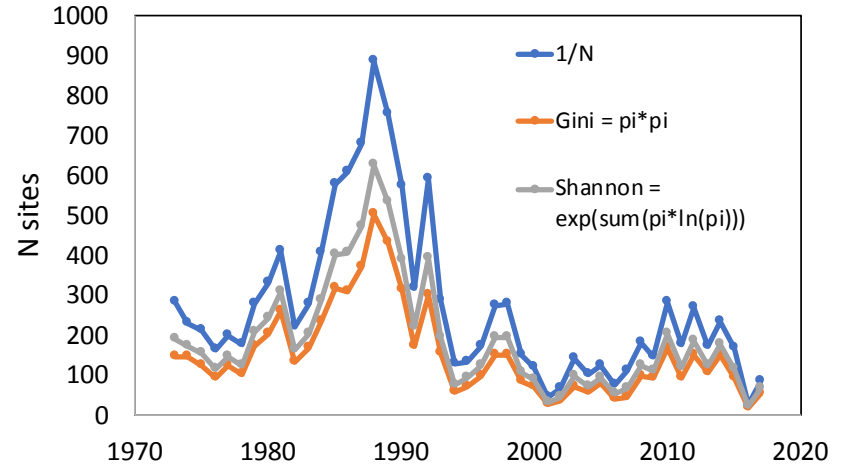
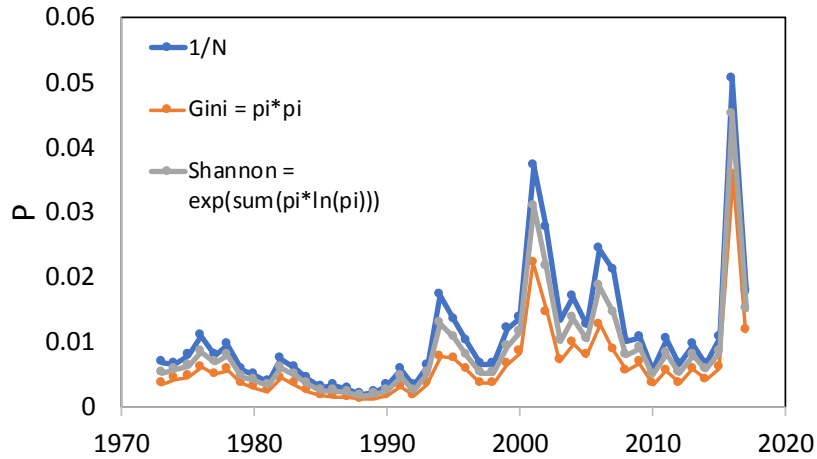
- Likelihood
  - Survey: Log-normal
  - Catch composition: Multinomial
  - $\varepsilon_R$ : random effects
- Models run in Template Model Builder (TMB)

# Next steps

- Everything's running
- Explore precision & accuracy of short/medium term predictions
  - Forecasting model
- Other configurations
  - Alternative stock-recruit forms
  - Impact on estimating static reference points ( $B_0$ )
- Investigate impact on uncertainty estimates
- Practical application: PWS stock assessment

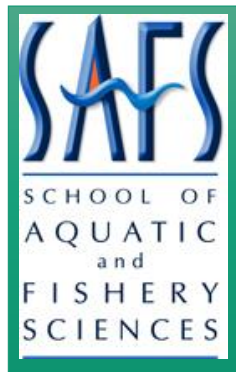
# Prince William Sound

$N \text{ sites} = 1/P$



# Acknowledgments

- Alec - posed the concept & analysis
- Dave - mapping, processing, & interpretation of milt data
- Trevor - design of current study







**Questions? Comments?**



# Scenarios

## Estimation Models

Shannon

Gini-Simpson

1/N

Plain Ricker

Constant R

#1

#2

#3

#4

#5

#6

alpha -

beta -

q -

SSE(nyr) -

max(R) -

CV(R) -

alpha -

beta -

q -

SSE(nyr) -

max(R) -

CV(R) -

alpha -

beta -

q -

SSE(nyr) -

max(R) -

CV(R) -

alpha -

beta -

q -

SSE(nyr) -

max(R) -

CV(R) -

beta -

q -

SSE(nyr) -

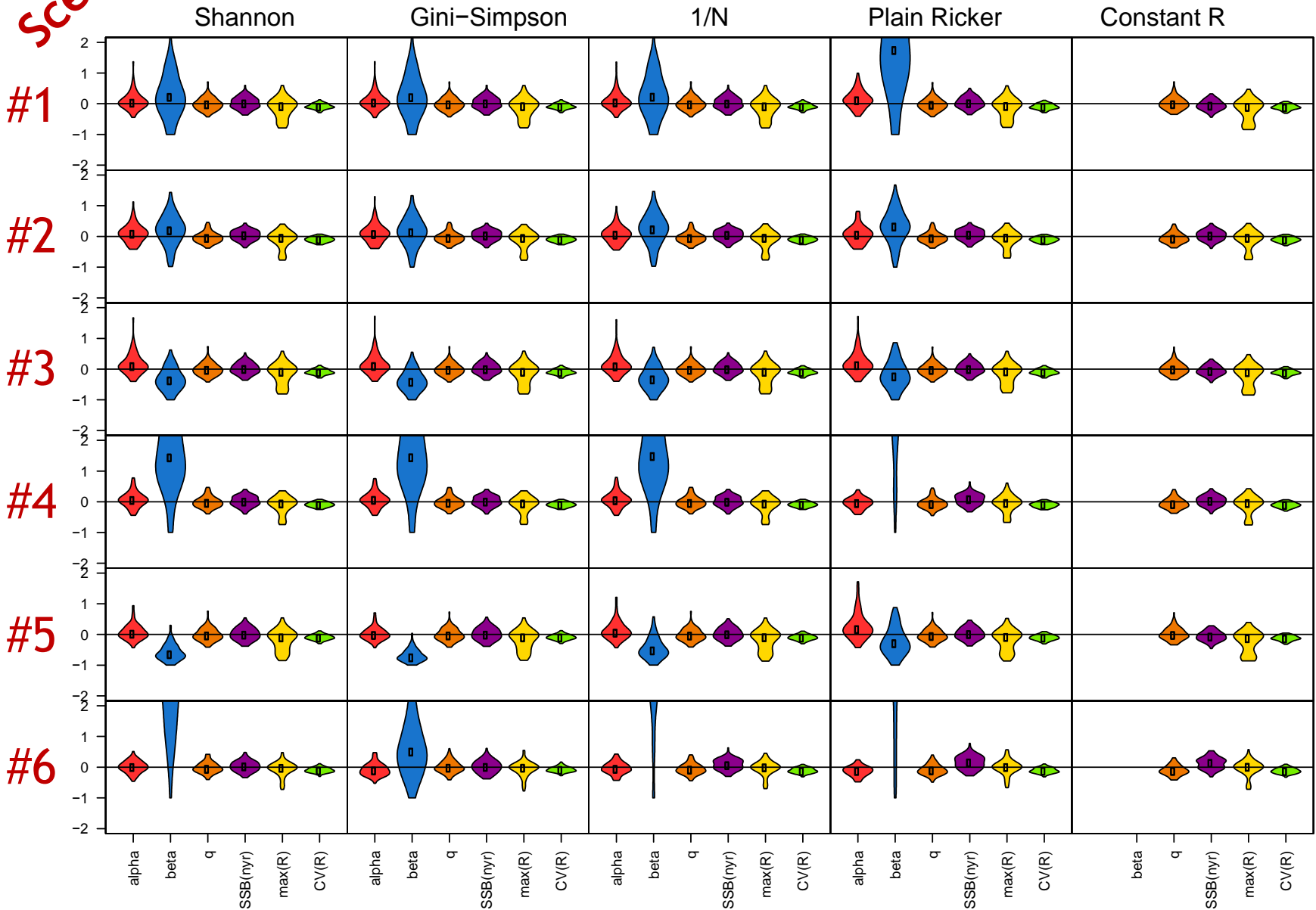
max(R) -

CV(R) -

Scenarios

# Estimation Models

Relative % Error



# Very preliminary, but

- The type of index used doesn't seem to matter
  - All 3 indices well track the relative trends in spatial (spatio-temporal) heterogeneity
- Spatial resolution at which P is calculated
  - EMs show Ricker parameters biased & imprecise in models where P indices are calculated at a finer resolution than the biomass proportions input in the OM