Linking Northeast Pacific recruitment synchrony to environmental variability

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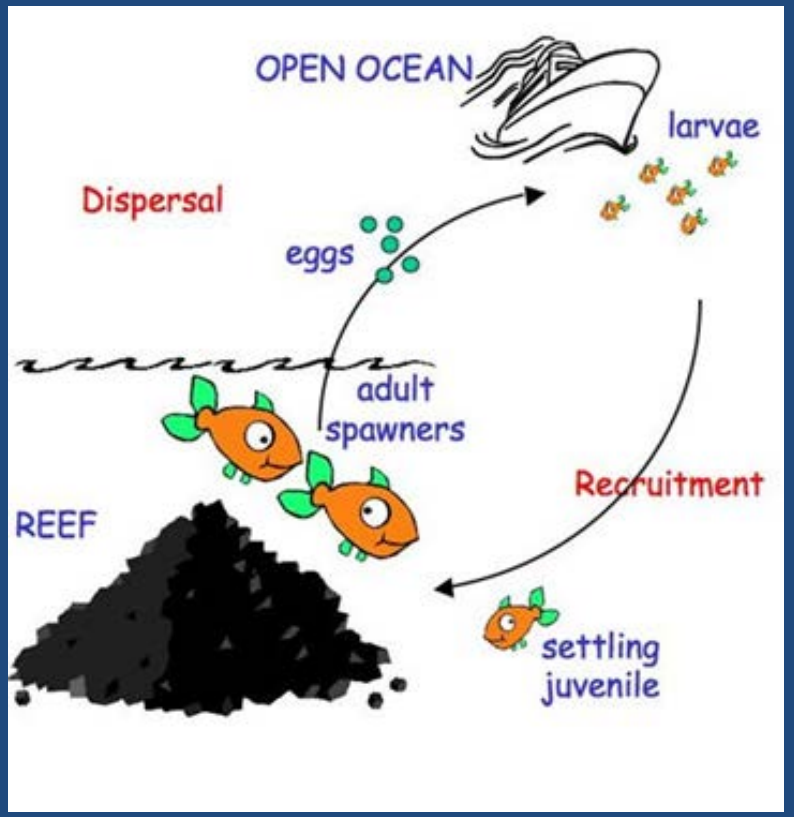
Recruitment

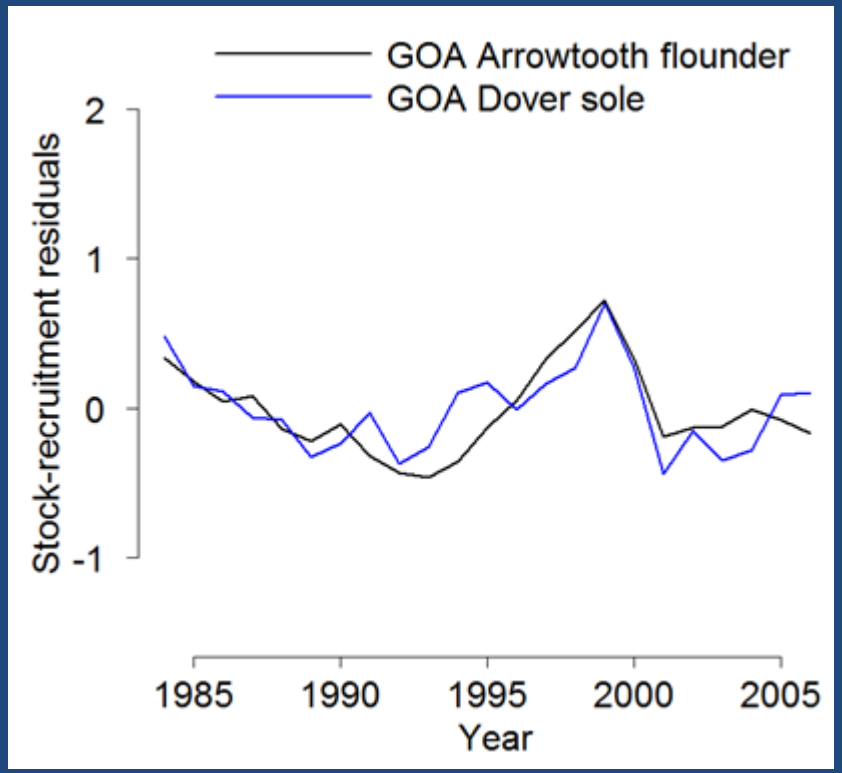
- A yearly estimate of the number of fish in a population that survive to reach the age where they can typically be caught
- For some stocks recruitment is highly variable from year to year
- Impacted by number of spawning fish, egg production, and survival during early life stages
- Few identified environmental drivers are robust over time



http://www.brighthub.com/environment/science-environmental/articles/52572.aspx#imgn_1

Recruitment Synchrony

- Previously identified synchrony in recruitment of Northeast Pacific marine fish
- Ecosystem-wide associations between environmental and biological variability



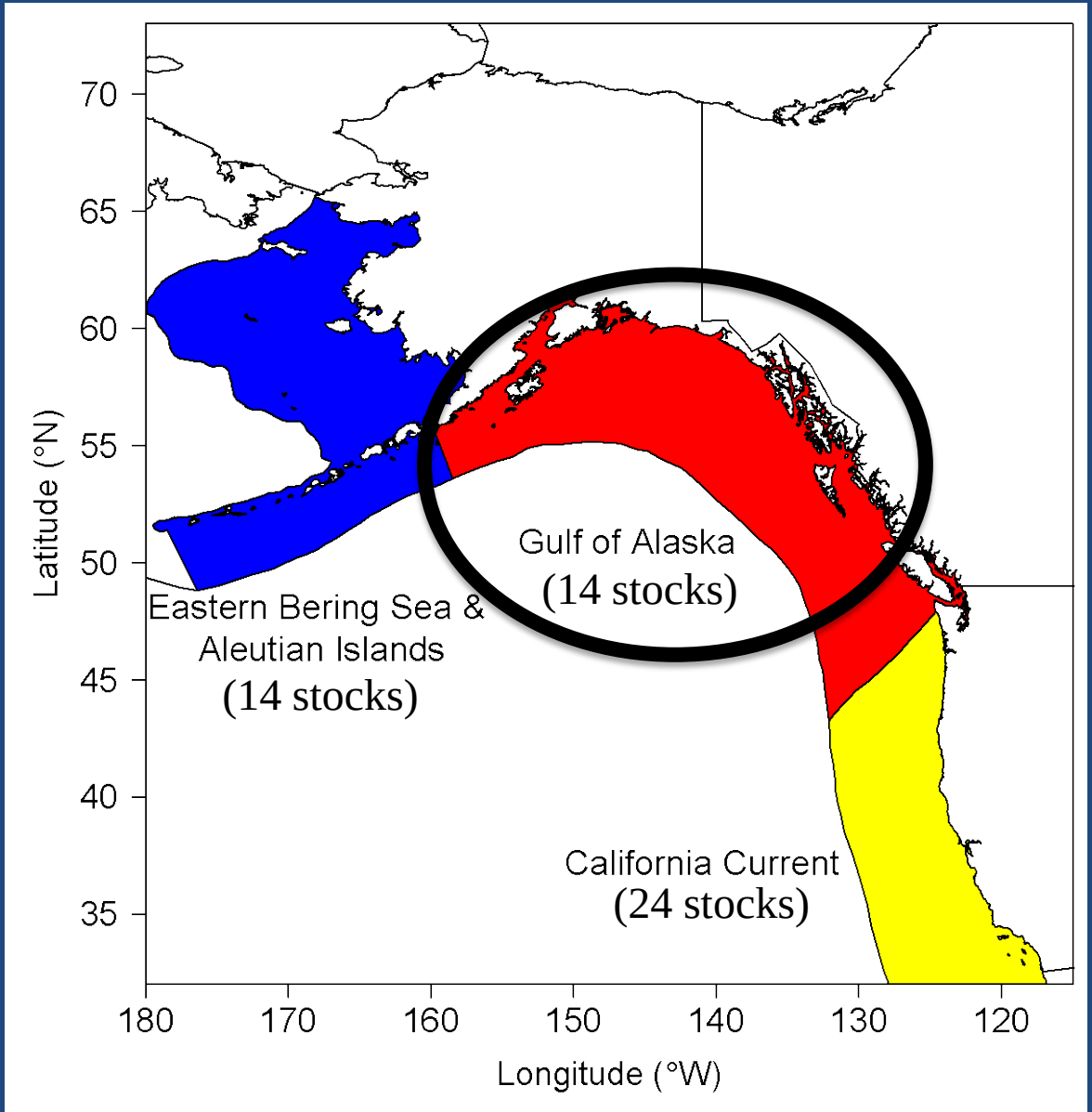
Hypothesis

Synchronous recruitment dynamics of stocks within ecosystems are due to ***shared sensitivity to common environmental drivers***

Approach

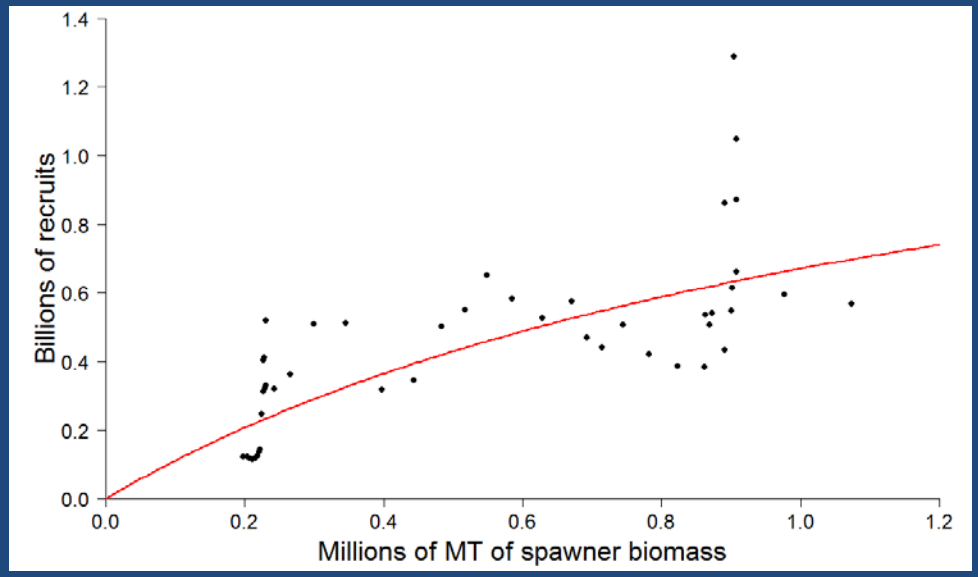
1. Verify recruitment synchrony
2. Identify stocks with similar susceptibility to environmental processes
3. Identify important environmental processes
4. Model environmental influences on recruitment

Recruitment Data



Recruitment Data

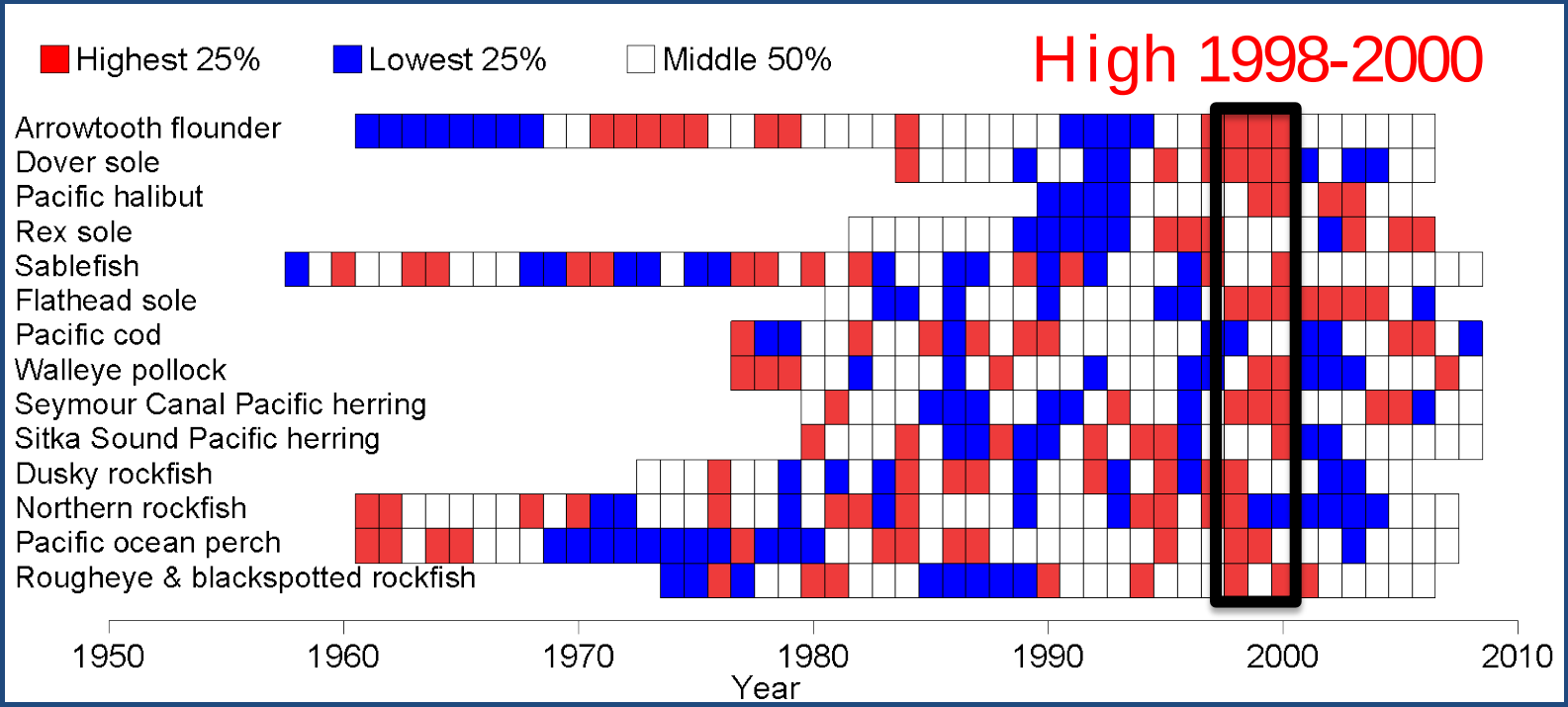
- Removed effects of spawners on recruitment to focus on environmental drivers
- Used residuals from stock-recruitment relationship for analyses



Gulf of Alaska arrowtooth flounder Beverton-Holt spawner-recruitment model fit

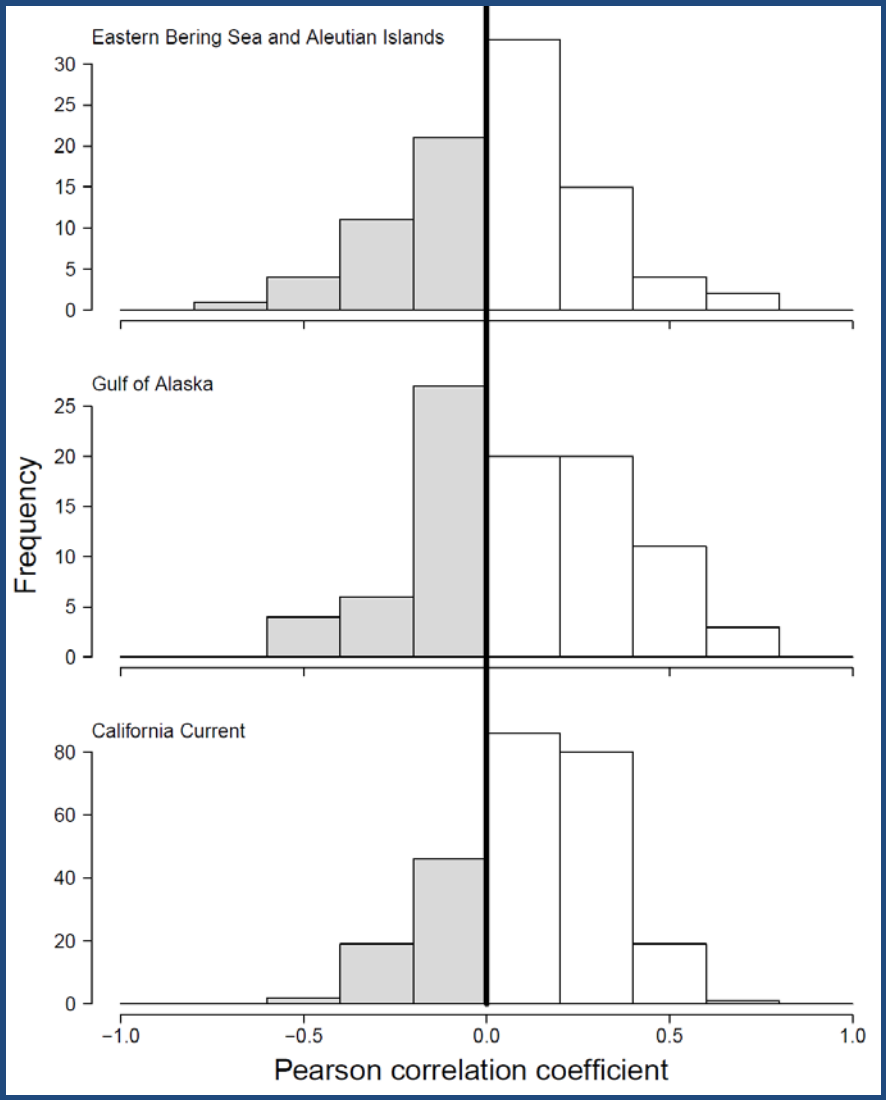
Recruitment Synchrony

- Extreme events
  - Highest and lowest 25% of recruitment events for each stock
  - Chi-square tests to identify synchronous years

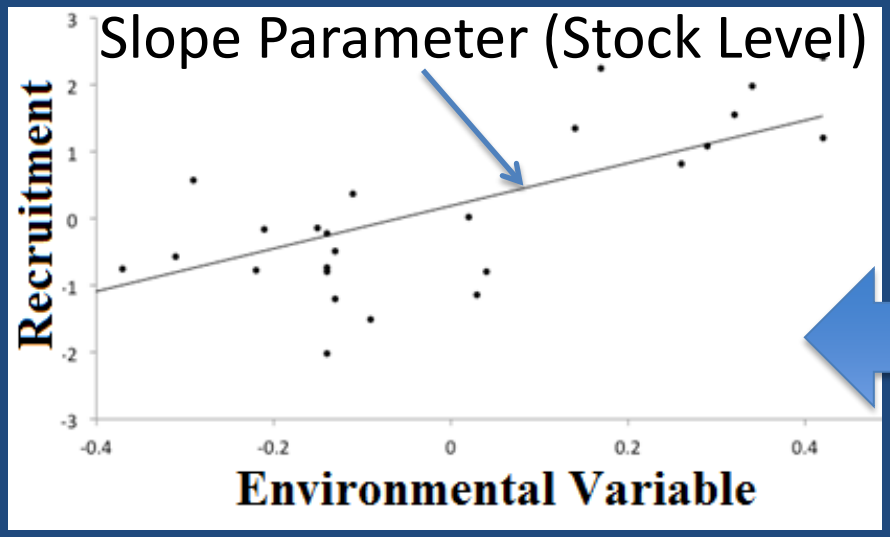


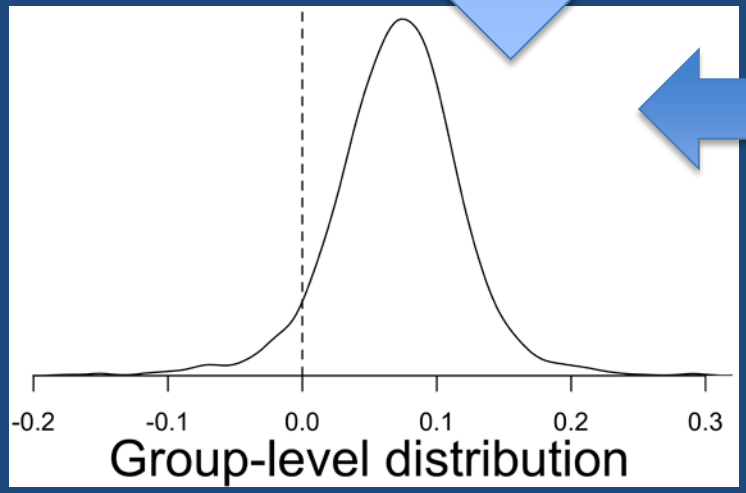
Recruitment Synchrony

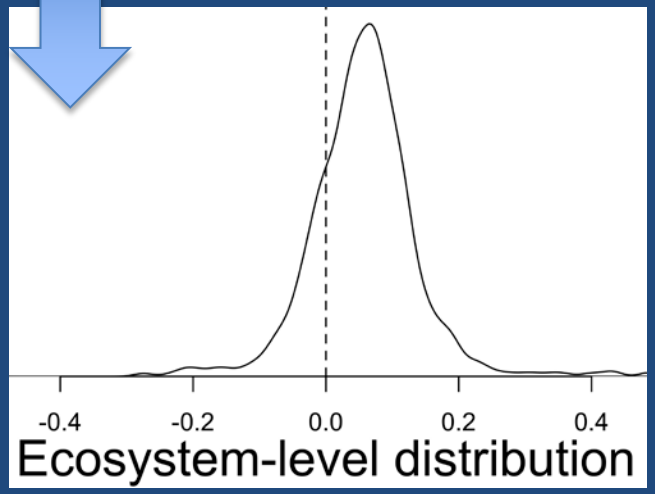
- Correlations between stocks



Bayesian Hierarchical Models





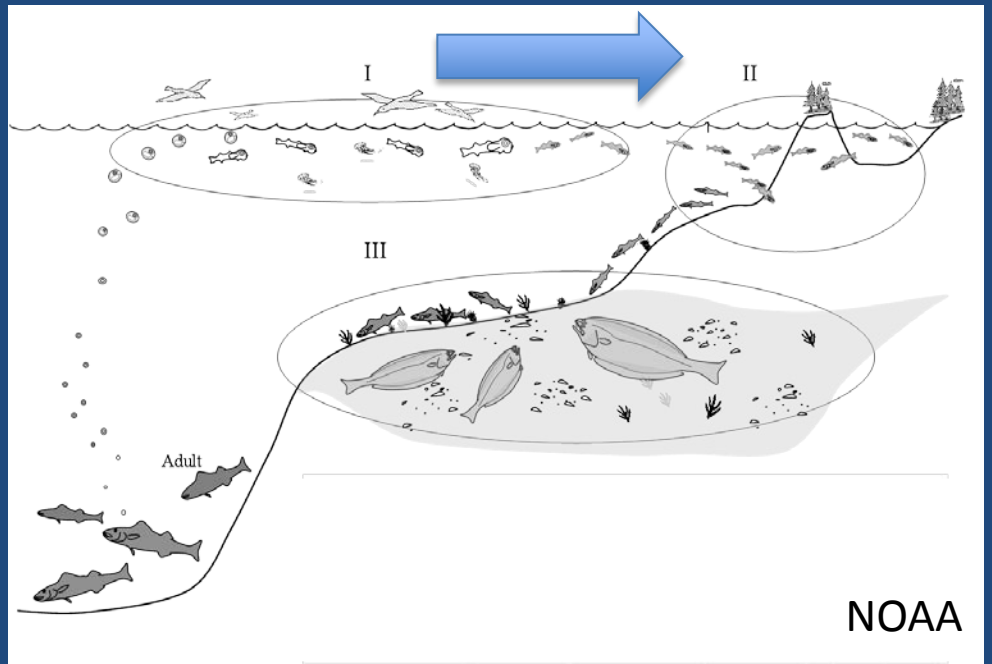


Stock Grouping

- Compiled early life history information
- Workshop of experts
- Considered many different groupings

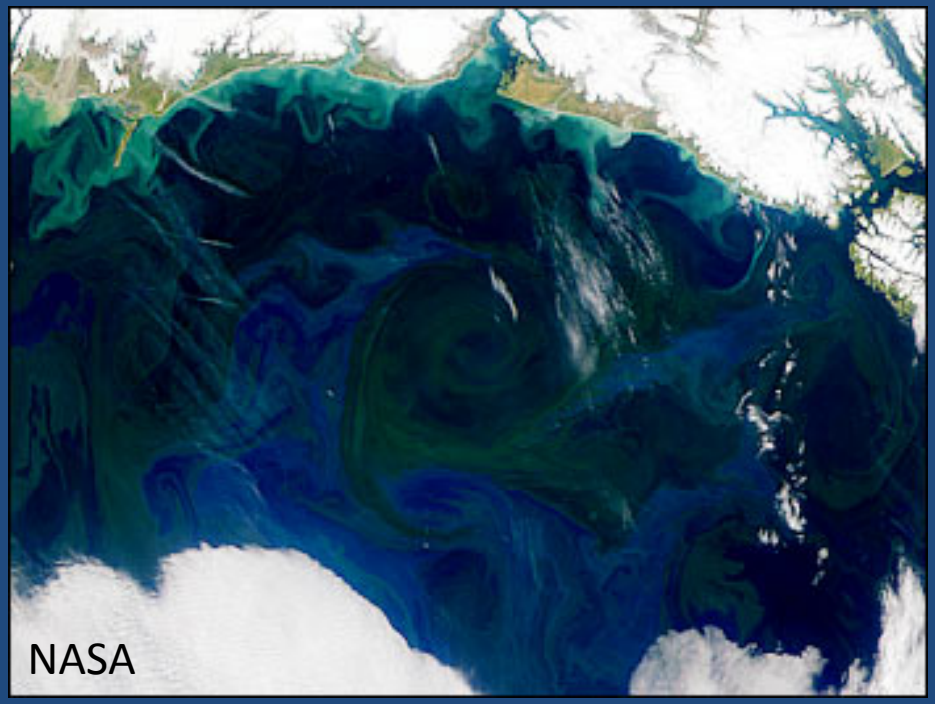
Cross-shelf transport group

- Arrowtooth flounder
- Dover sole
- Pacific halibut
- Rex sole
- Sablefish



Retention group

- Walleye pollock
- Pacific cod
- Flathead sole



Coastal group

- Seymour Canal Pacific herring
- Sitka Sound Pacific herring

Parental investment group

- Dusky rockfish
- Northern rockfish
- Pacific ocean perch
- Rougheye & blackspotted rockfish

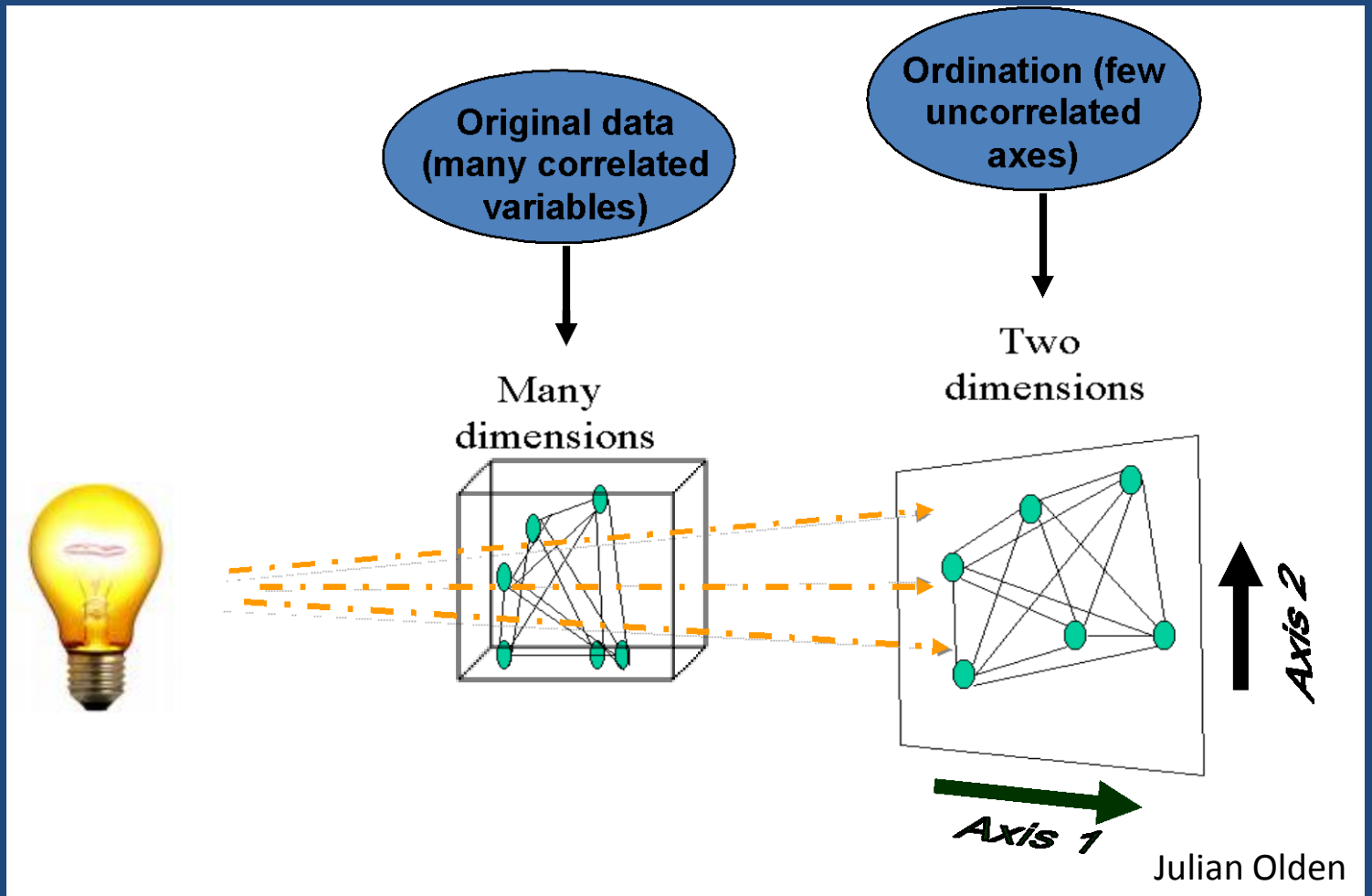
Environmental Variables

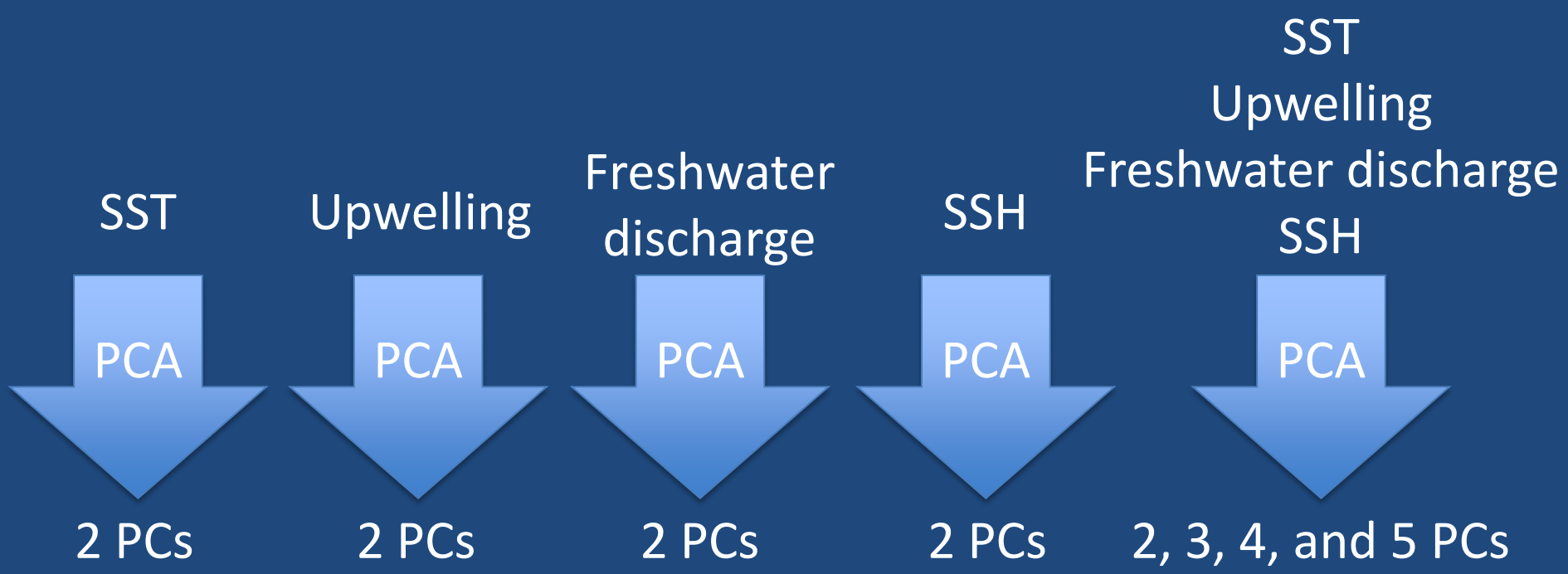
Environmental Variables

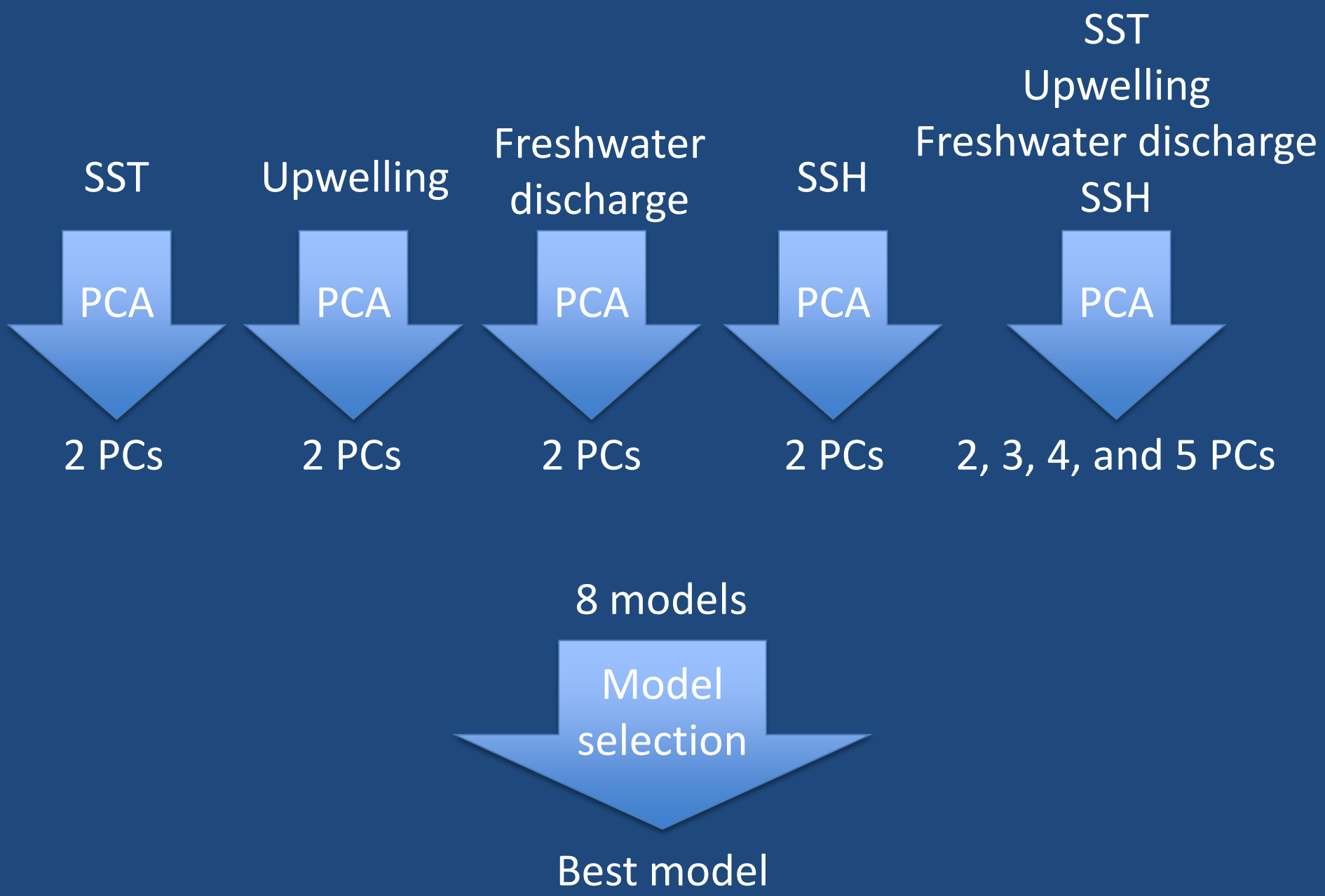
- Sea surface temperature (SST): 16
- Upwelling: 4
- Freshwater discharge: 4
- Sea surface height (SSH): gridded data

Environmental Variables

- Principal component analysis to explain a large portion of the variance as a smaller number of uncorrelated time series




SST
PCA
2 PCs
Upwelling
PCA
2 PCs
Freshwater discharge
PCA
2 PCs
SSH
PCA
2 PCs
SST
Upwelling
Freshwater discharge
SSH
PCA
2, 3, 4, and 5 PCs


SST
Upwelling
Freshwater discharge
SSH
SST
Upwelling
Freshwater discharge
SSH
PCA
PCA
PCA
PCA
PCA
2 PCs
2 PCs
2 PCs
2 PCs
2, 3, 4, and 5 PCs
8 models
Model selection
Best model

GOA Best Model: Sea Surface Height

Gulf of Alaska
- Cross–shelf transport
  - Arrowtooth flounder
  - Dover sole
  - Pacific halibut
  - Rex sole
  - Sablefish
- Retention
  - Flathead sole
  - Pacific cod
  - Walleye pollock
- Coastal
  - Seymour Canal Pacific herring
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- Parental investment
  - Dusky rockfish
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arameter

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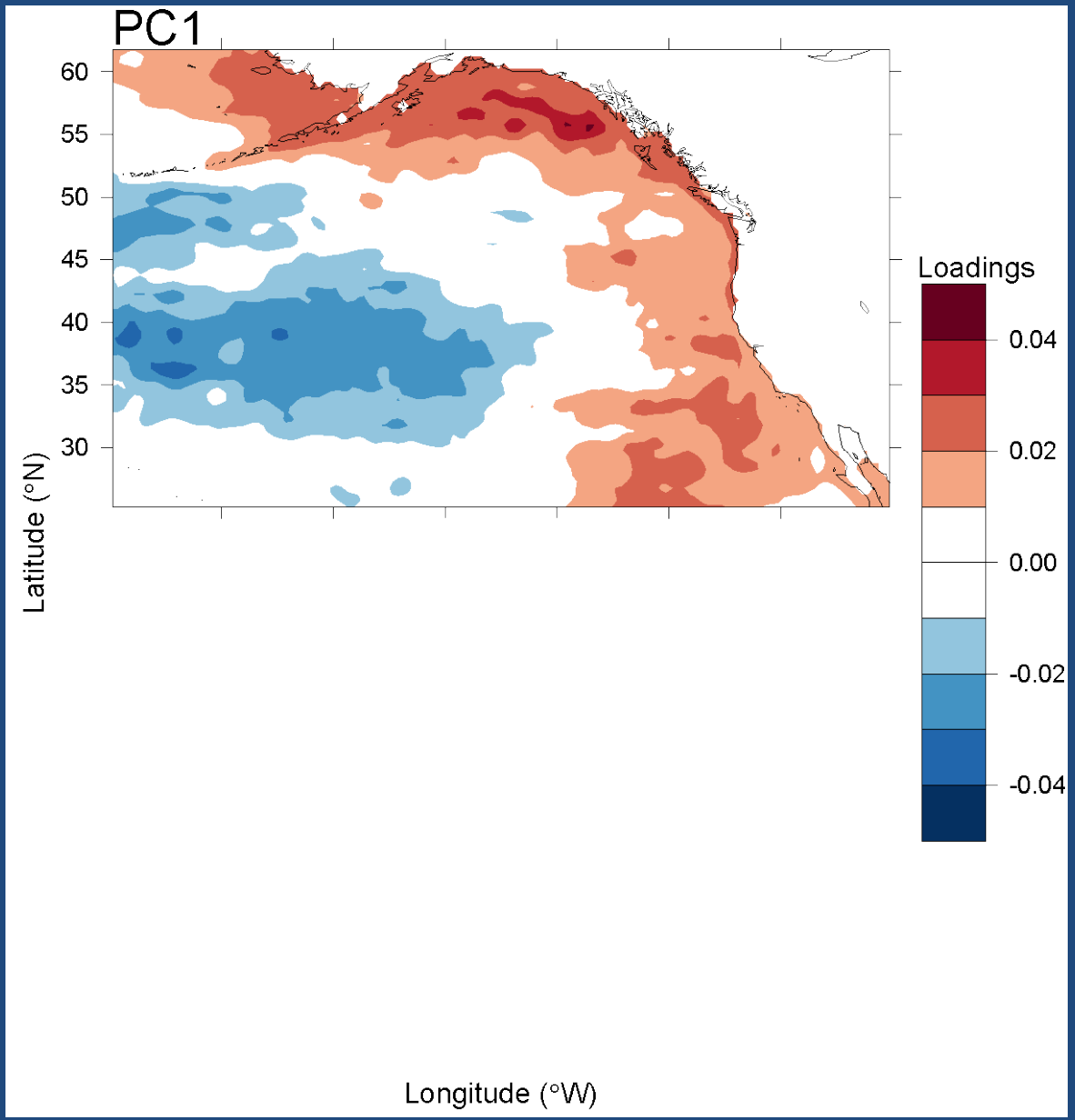
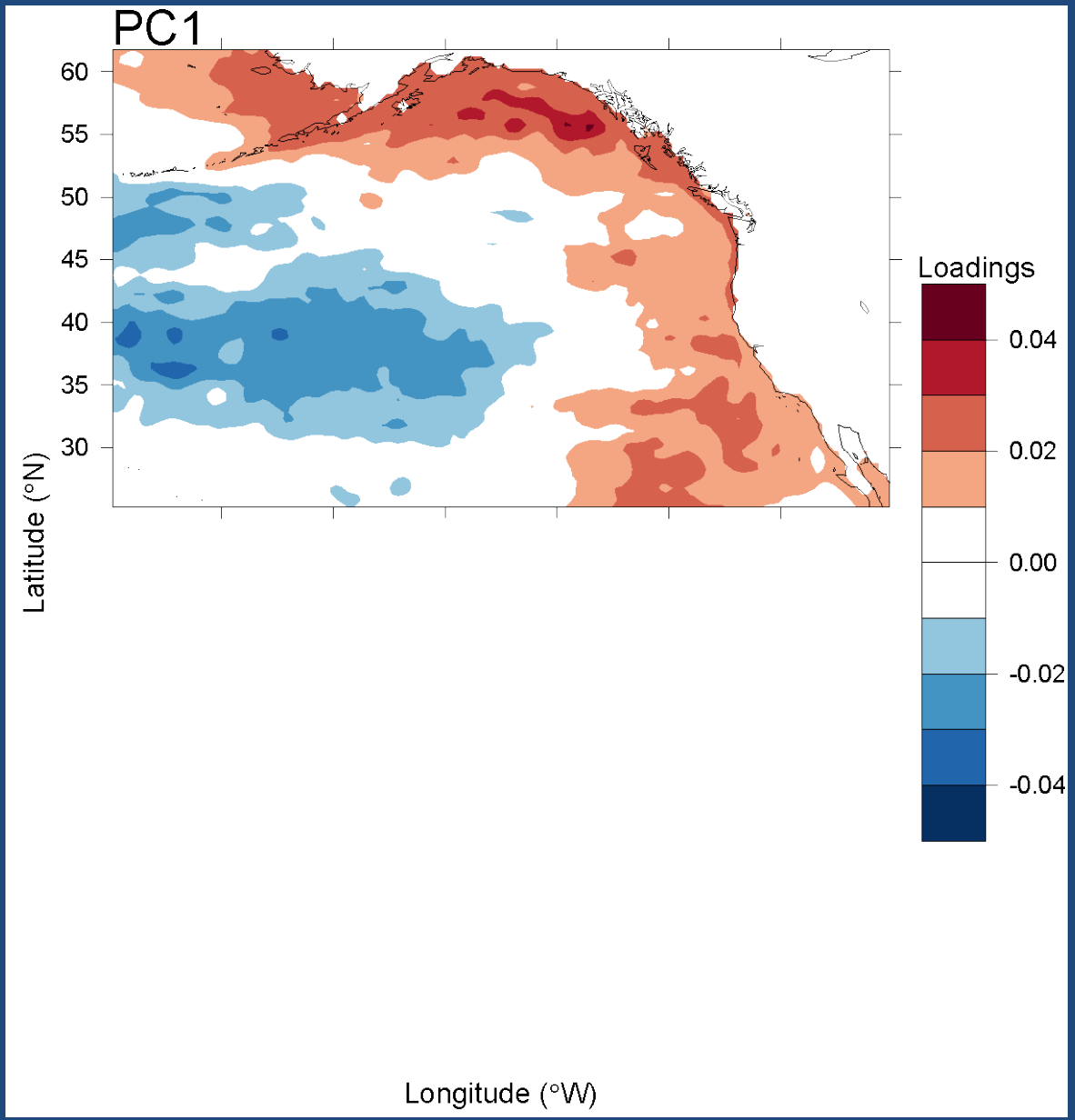
arameter

Sea Surface Height Loadings on PCs



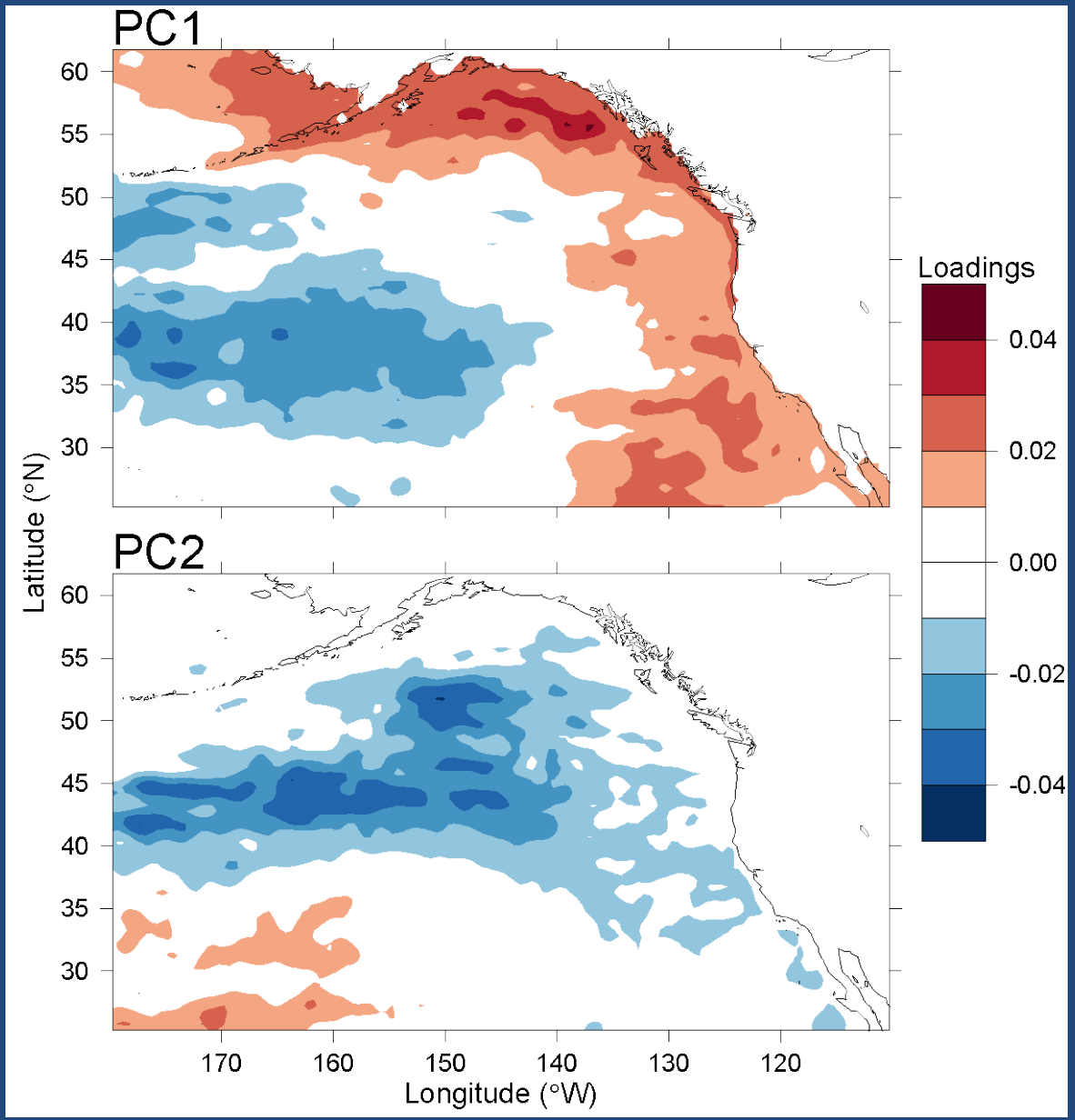
Sea Surface Height Loadings on PCs



PC1

- Onshore transport
- Increased eddy activity

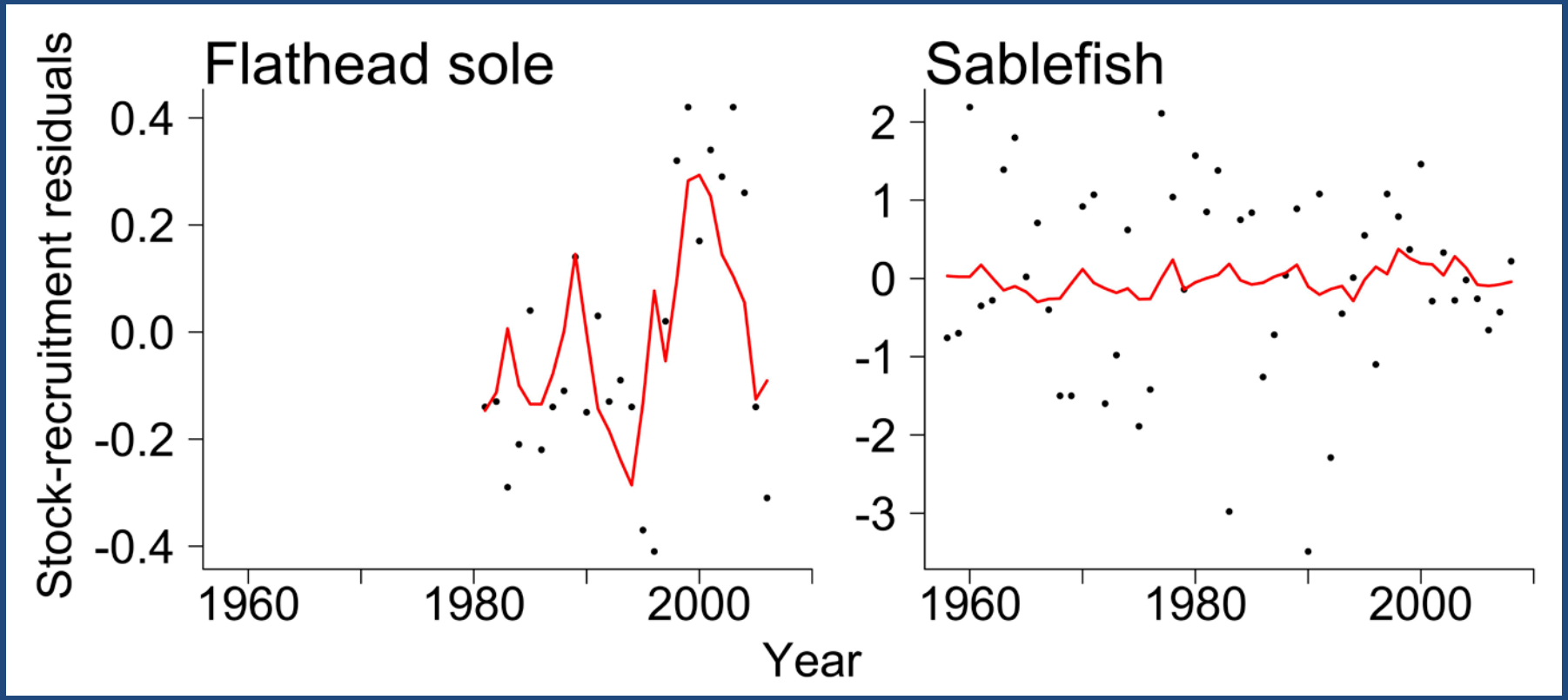
Sea Surface Height Loadings on PCs



PC2

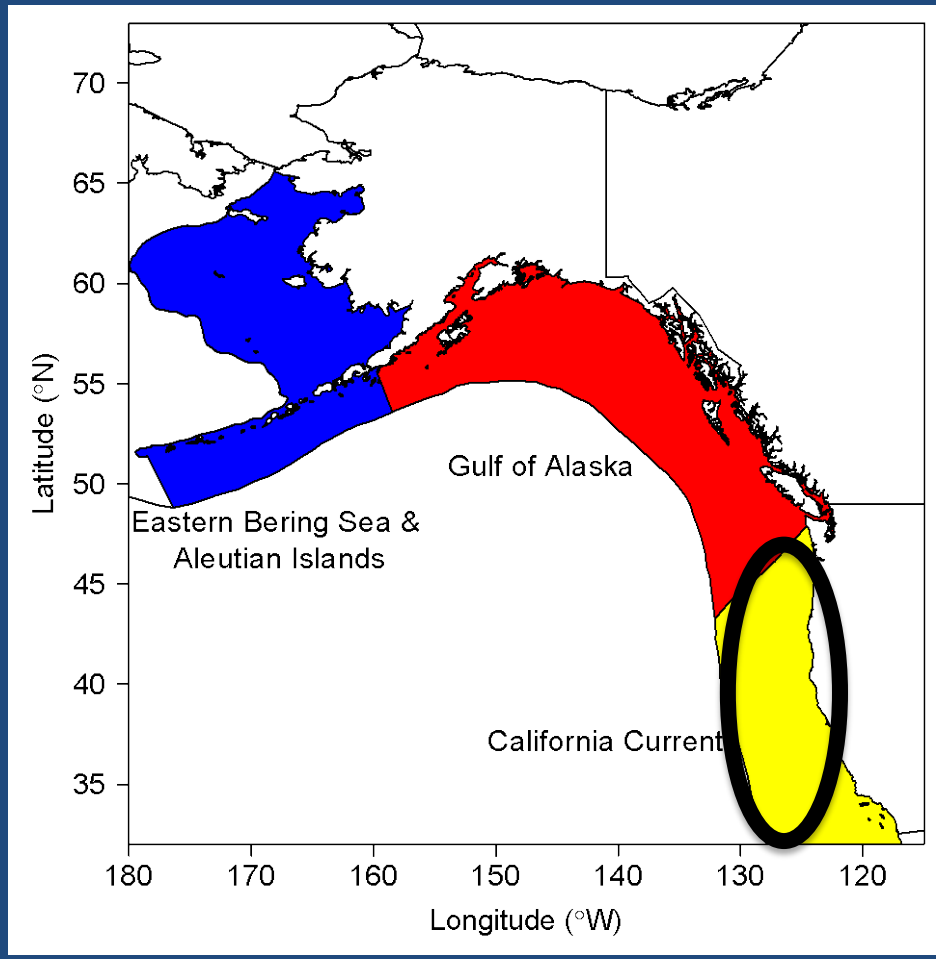
- Increased offshore upwelling

GOA Sea Surface Height Model Fits



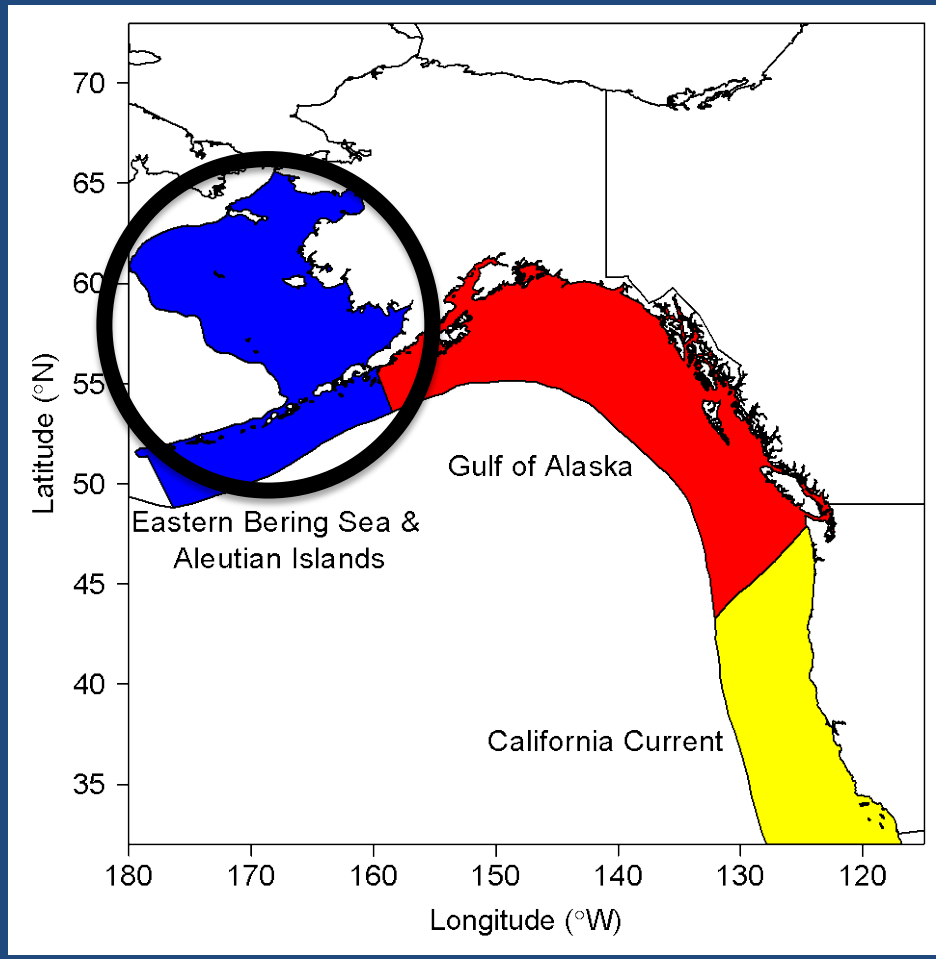
California Current

- Best model: sea level
- High recruitment associated with:
  - High upwelling the year of spawning
  - Low upwelling the year before spawning



Eastern Bering Sea and Aleutian Islands

- Best model: all environmental variables considered
- Not simple to separate out the driving processes



Evaluating Stock Grouping

- Tested best model without separate groups
  - Support for grouped model, especially in the Eastern Bering Sea and Aleutian Islands
- Other grouping structures may improve the fit
  - More early life history information

Conclusions

- Synchrony in Northeast Pacific recruitment
  - Use methods that draw strength from this synchrony
- Some evidence for similar environmental influences within defined groups
- Environmental variables showed common influence on recruitment for several stocks
  - GOA: sea surface height
  - CC: sea level

Thanks!

Fisheries and the Environment (FATE)

Conclusions

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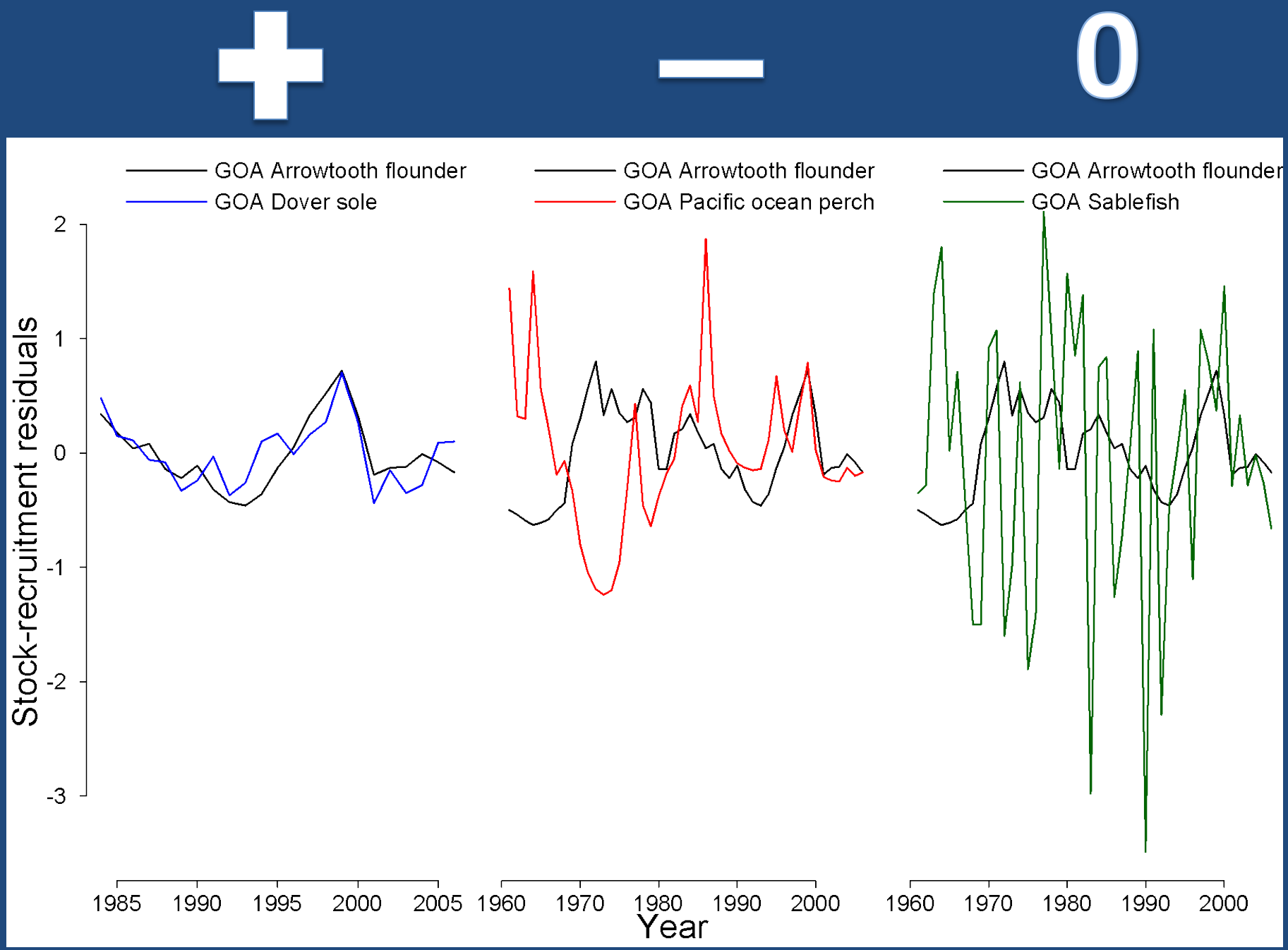
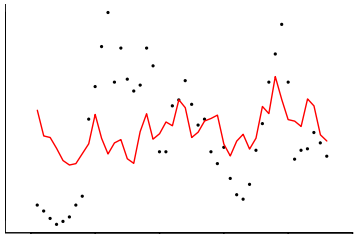
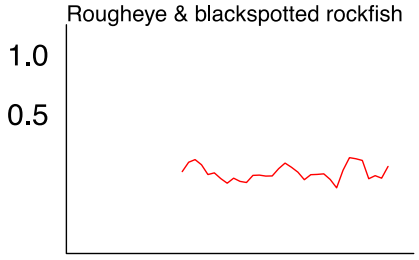
  - GOA: sea surface height
  - CC: sea level

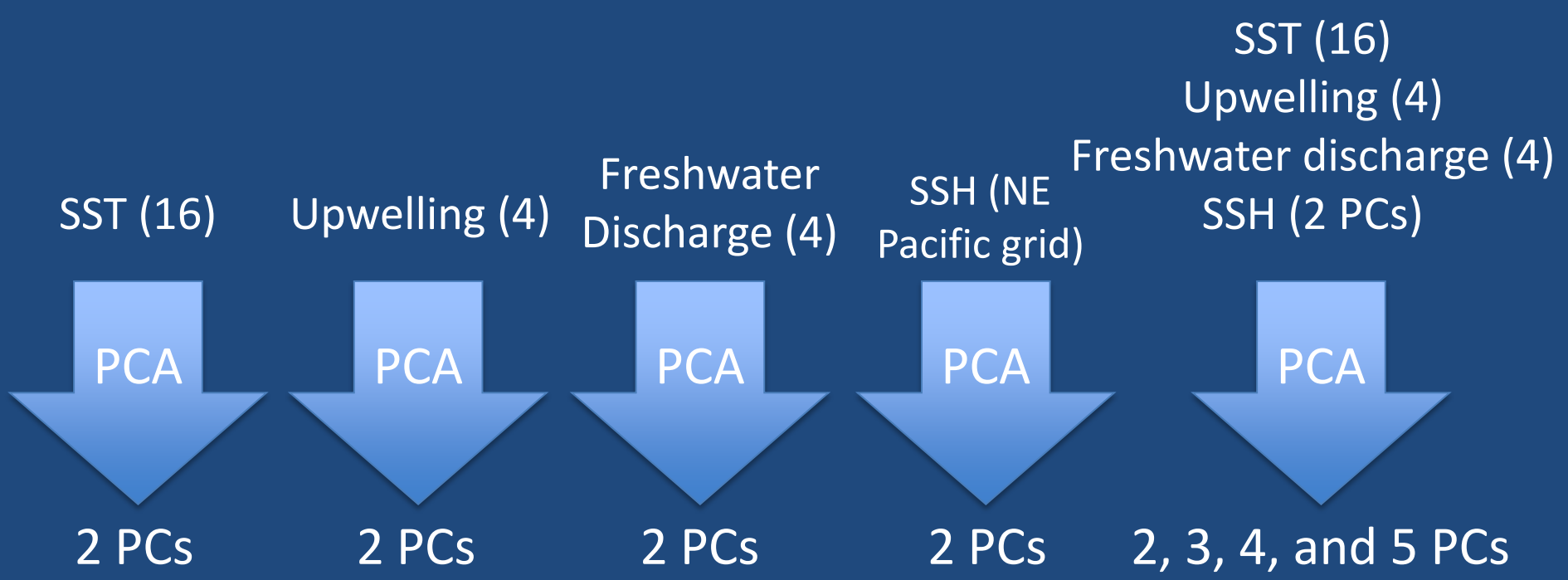
Extra Slides


+
−
0
GOA Arrowtooth flounder
GOA Dover sole
GOA Arrowtooth flounder
GOA Pacific ocean perch
GOA Arrowtooth flounder
GOA Sablefish
Stock-recruitment residuals
2
1
0
-1
-2
-3
1985
1990
1995
2000
2005
1960
1970
1980
1990
2000
1960
1970
1980
1990
2000
Year

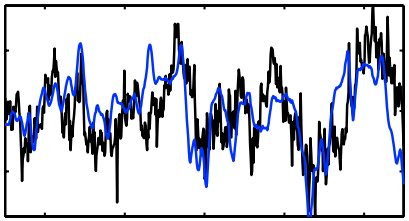
GOA SSH Model Fits

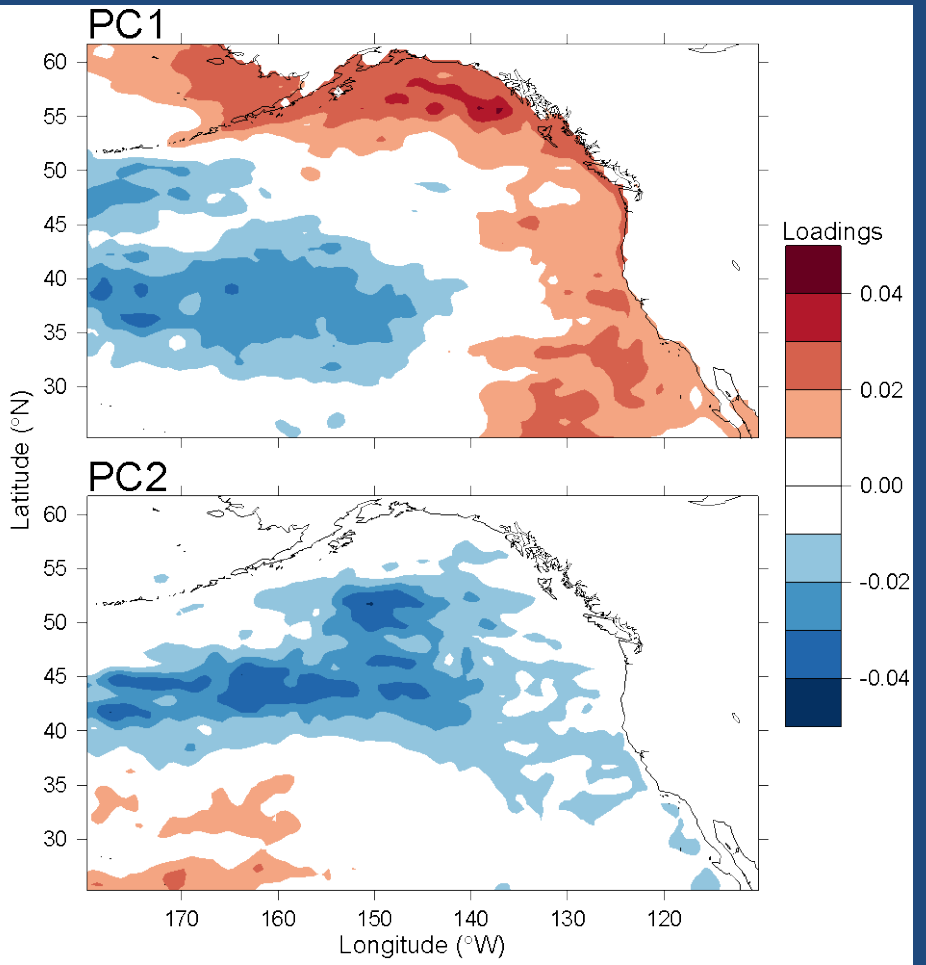





SST (16)
Upwelling (4)
Freshwater Discharge (4)
SSH (NE Pacific grid)
SST (16)
Upwelling (4)
Freshwater discharge (4)
SSH (2 PCs)
PCA
PCA
PCA
PCA
PCA
2 PCs
2 PCs
2 PCs
2 PCs
2, 3, 4, and 5 PCs

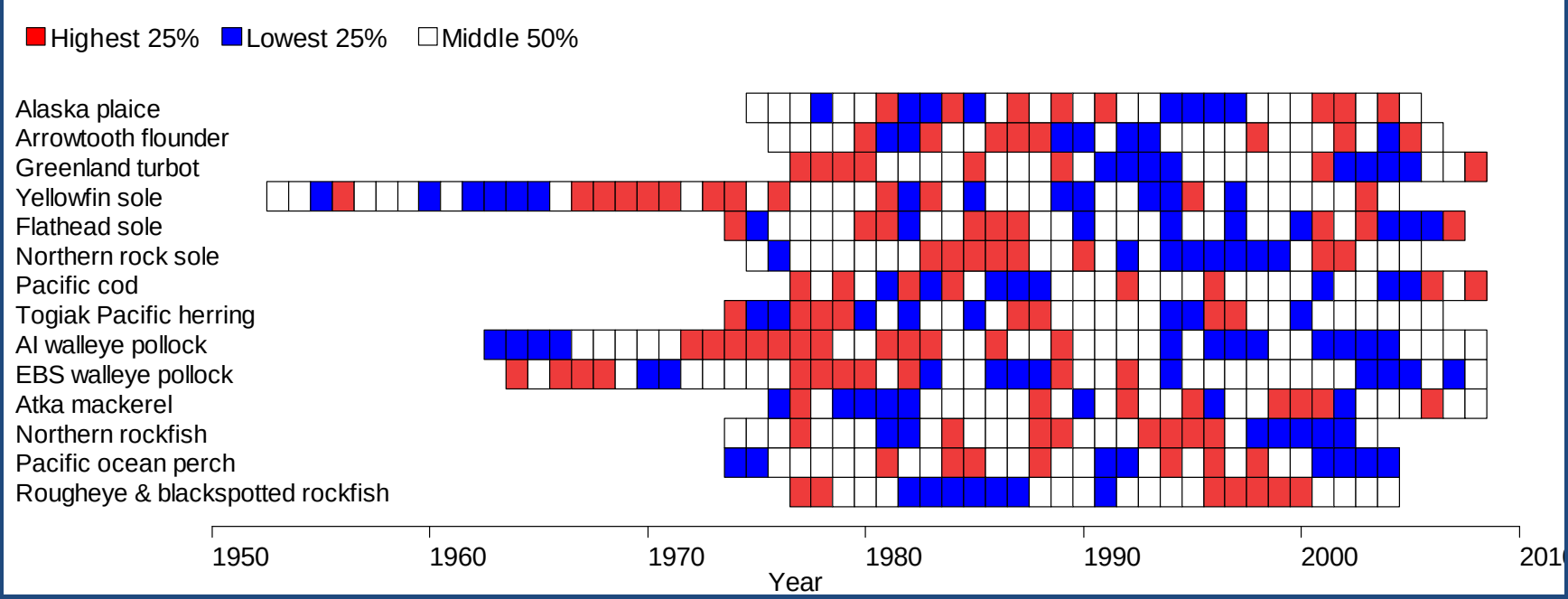
PC1 correlation with the PDO is 0.82
PC2 correlation with the NPGO is 0.72



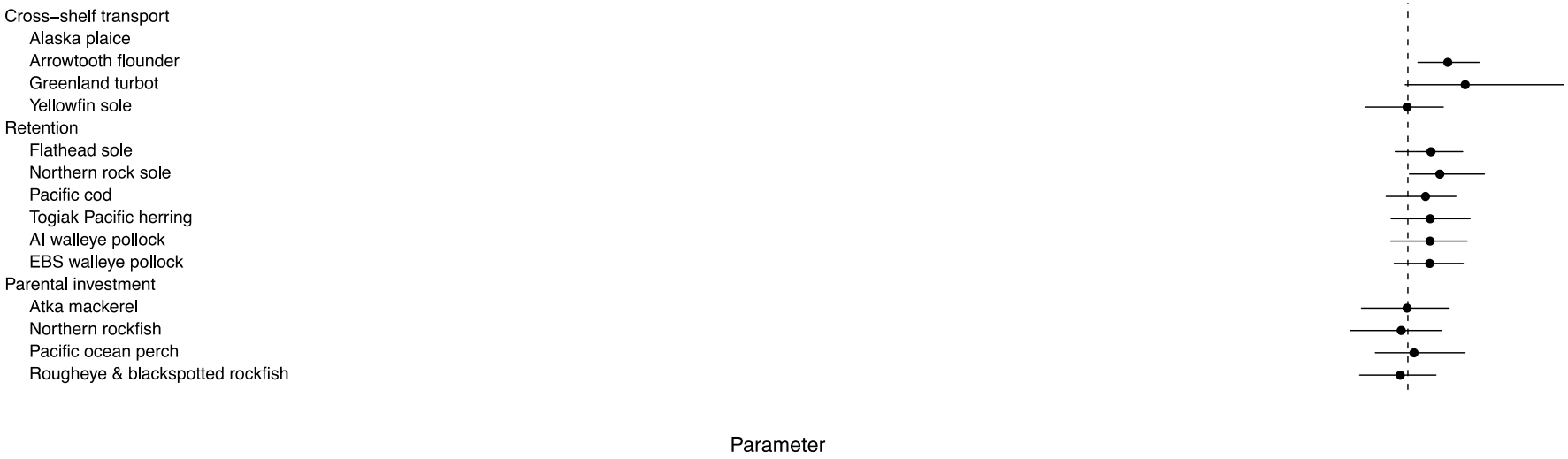


Di Lorenzo et al., 2008

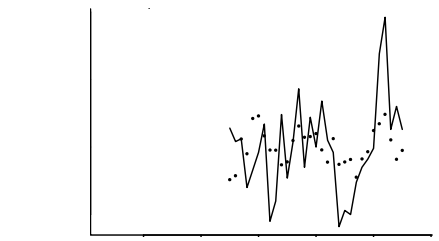
BSAI Extreme Recruitment Events



BSAI All Variables 5 PCs Model



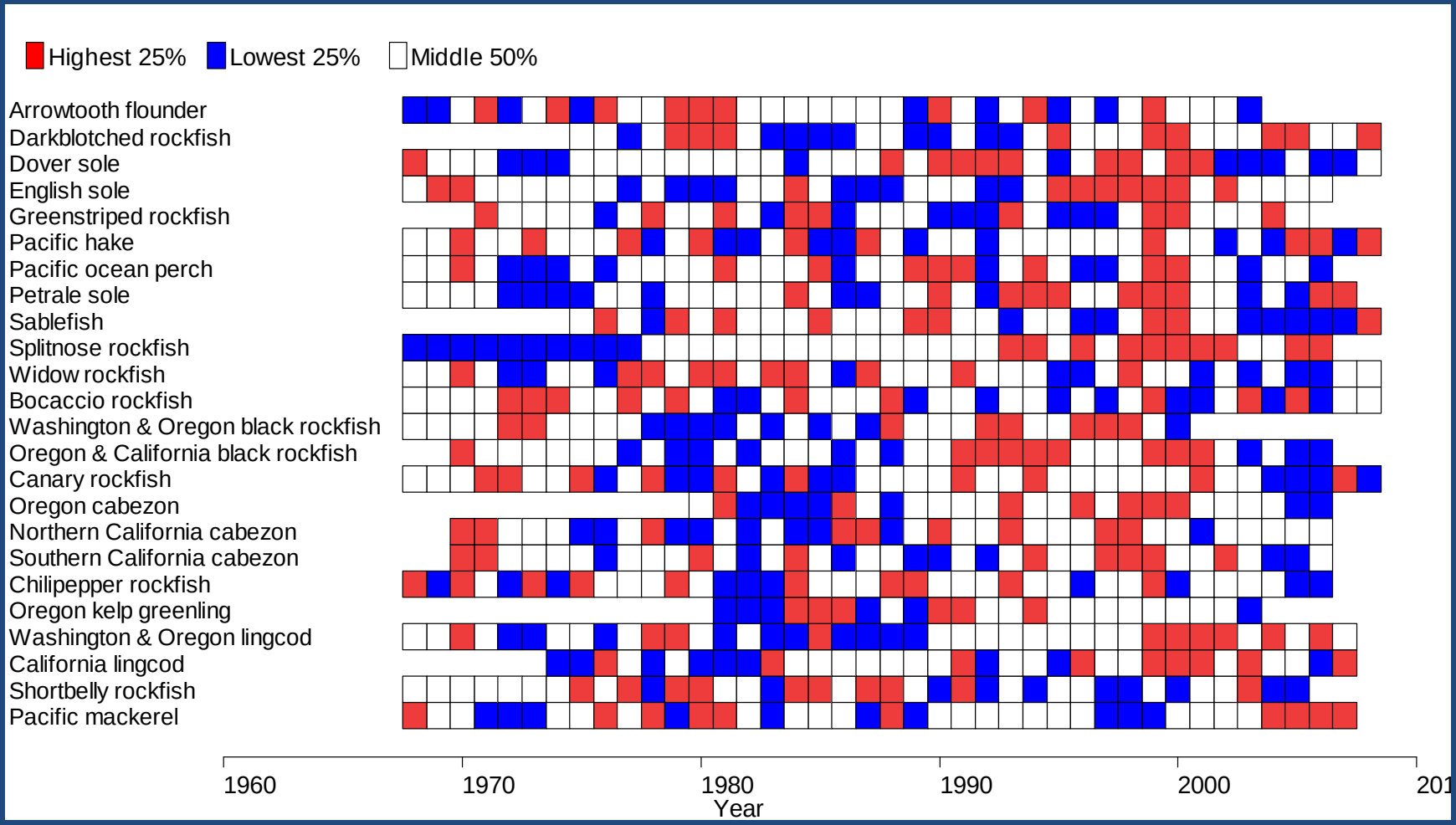
BSAI Model Fits



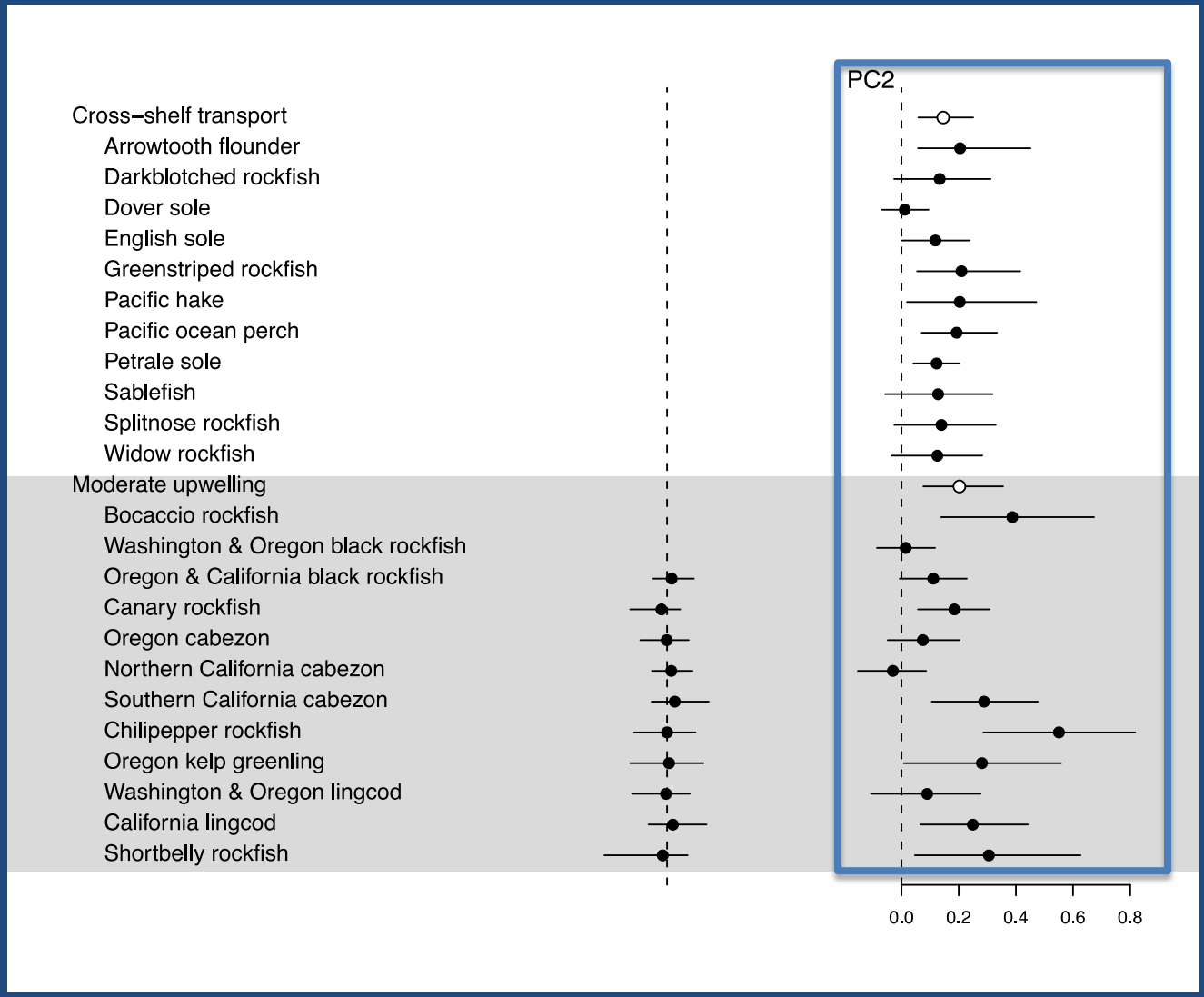
Stock–recruitment residuals

Year

CC Extreme Recruitment Events



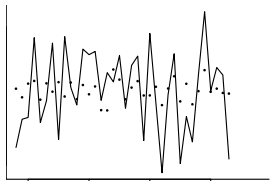
CC Sea Level Pressure Model

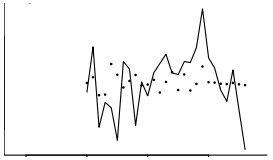


California Current

- Higher recruitment for many stocks was related to low upwelling the year before spawning and high upwelling the year of spawning
  - Higher productivity the year of spawning
  - Reduced competition and cannibalism (e.g. hake)
  - Rockfish may skip spawning during bad years and put more energy into spawning in subsequent years

CC Model Fits





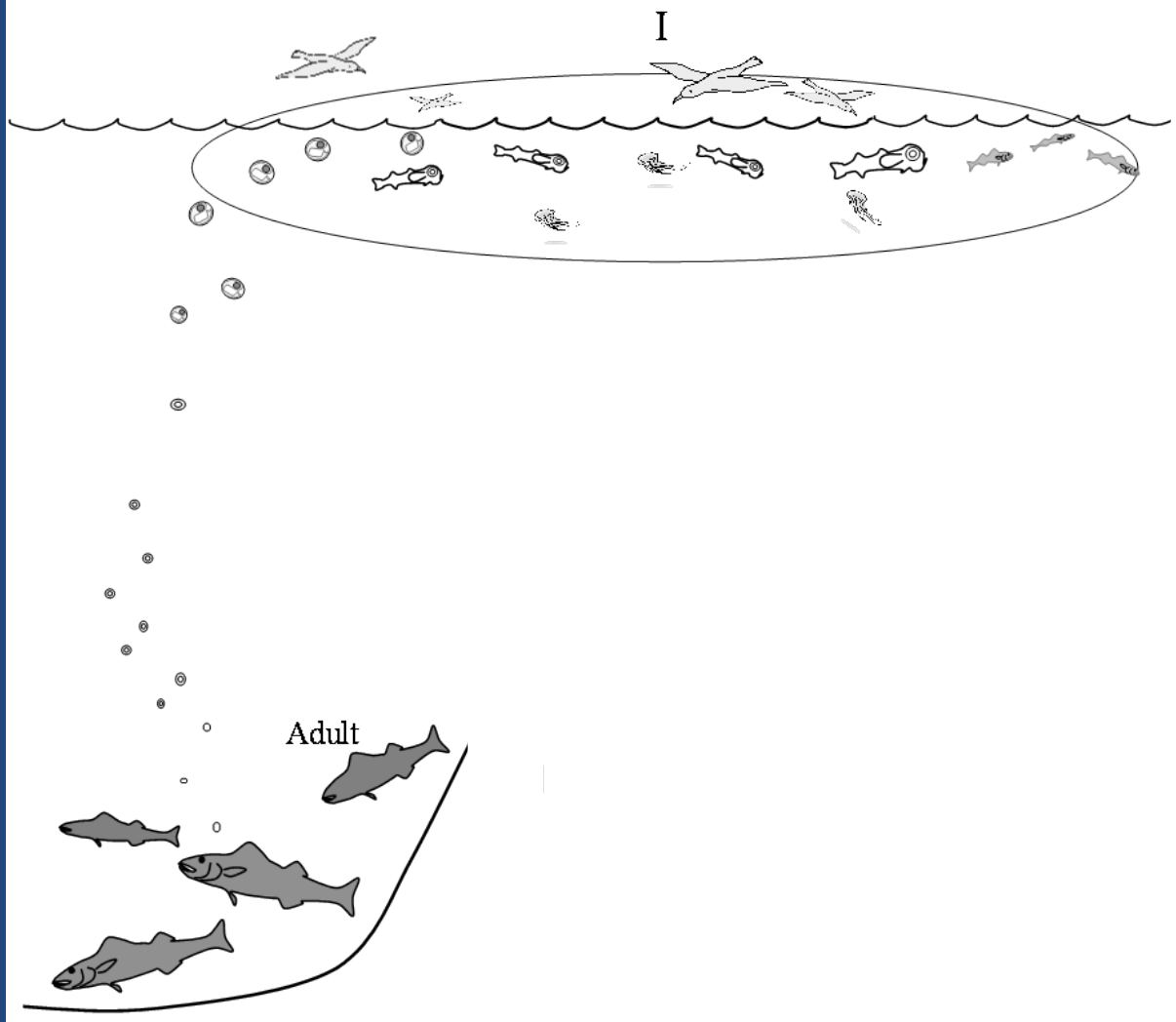
ment residuals

Rockfish Maternal Effects

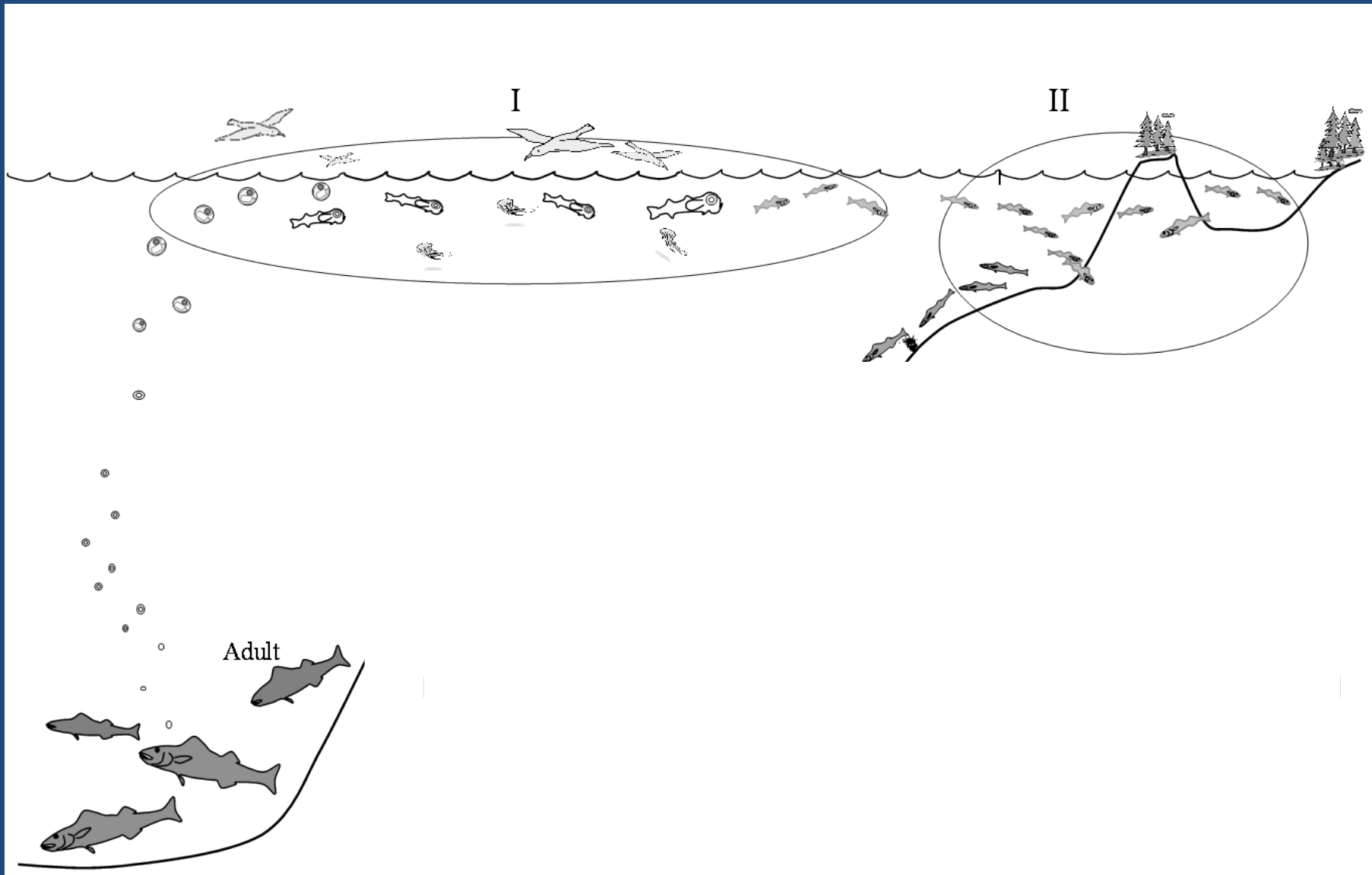
- Accounted for SSB effects, but not other maternal effects
- Maternal age and size important to fecundity, parturition date, oil globule size, growth rate, and starvation resistance for several CC rockfish species
- More important in the CC than GOA and BSAI

Recruitment Data Quality

- Recruitment and spawning stock biomass values estimates from stock assessment models
- Only used estimates from periods for which adequate information was available for recruitment estimation
- Uncertainty in the recruitment and spawning stock biomass estimates not accounted for



Sablefish life history (NOAA, 2010)



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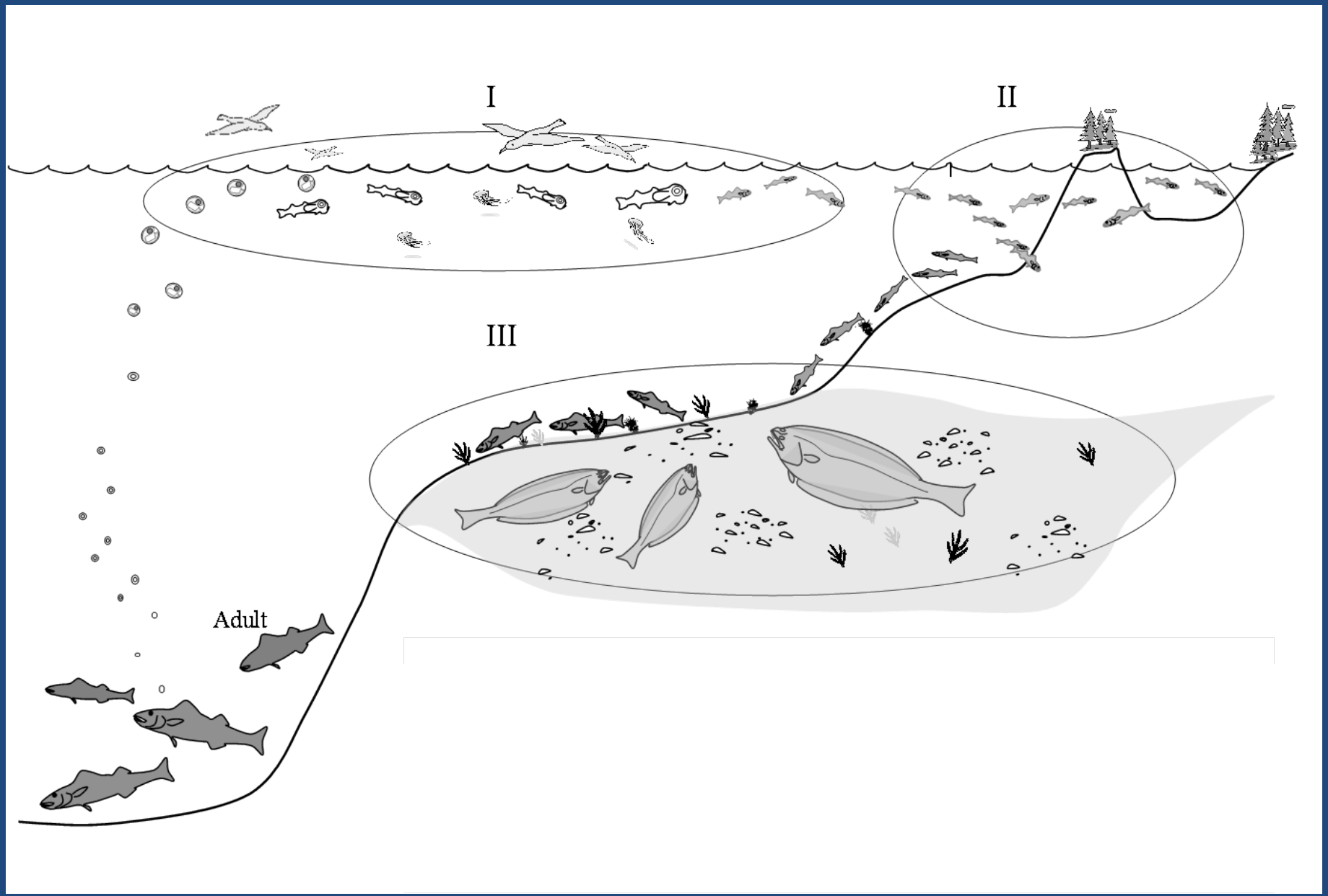

Sablefish life history (NOAA, 2010)

Bayesian Hierarchical Modeling

- Data rich stocks inform data poor stock
- Modeled recruitment as a linear function of environmental variables
- Parameters drawn from a distribution, defined by the group level mean and variance