Changement de régime ou événements exceptionnels ? L'exemple anchois-sardine

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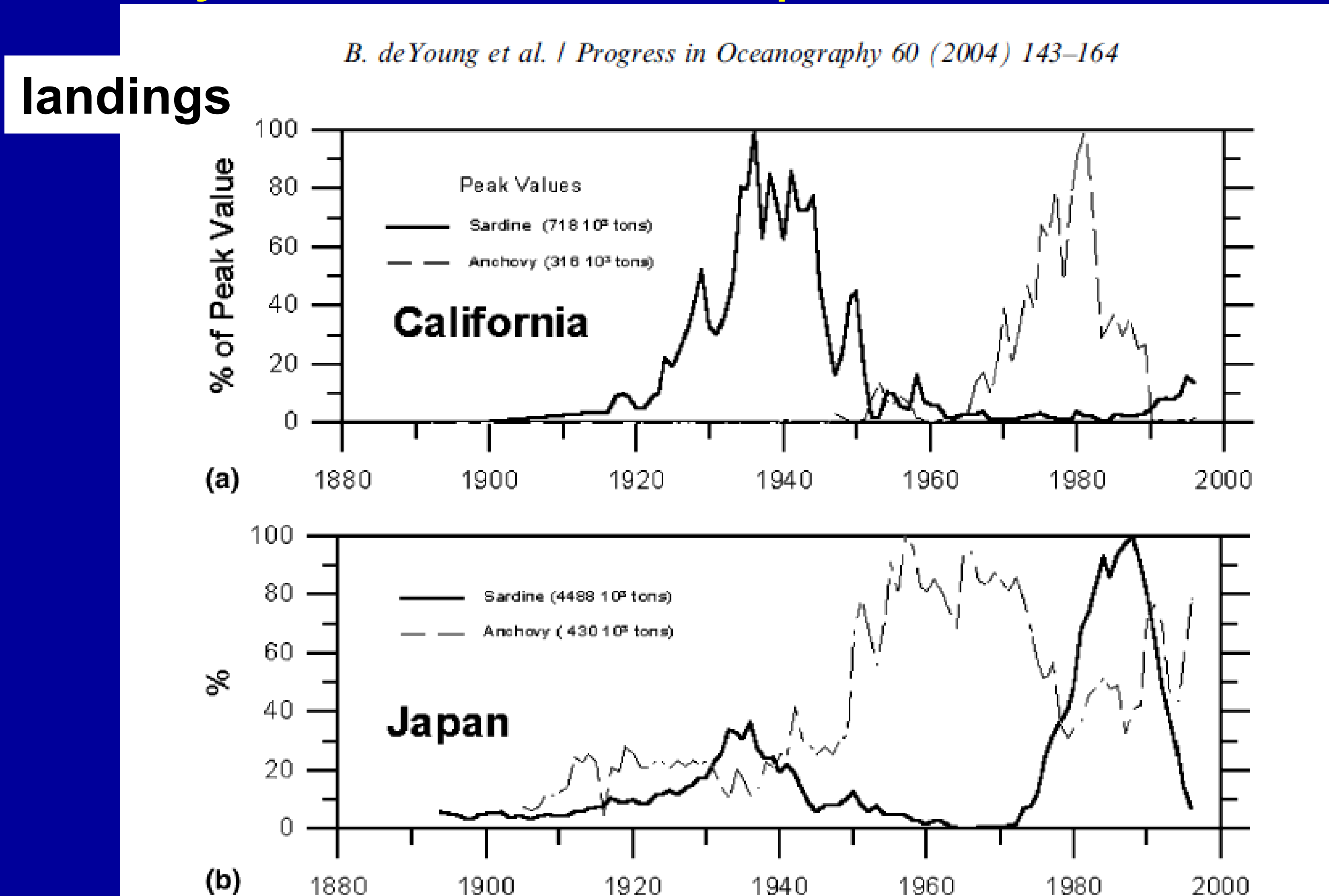
AFH 2011, Boulogne-sur-Mer

The <u>F</u>orage Fish Inter<u>act</u>ion<u>s</u> project

- 2010-12
- 15 partners
- Objectives
  - Quantify trophic interactions between forage fish (FF) and their prey and predators, establish levels of competition between FF, and assess the impact of climate change on FF.
  - Quantify ecosystem responses to FF fisheries and environmental change.
  - Provide cost-benefit analyses of fishing and predation (birds & mammals) on FF.
  - Develop case study specific and generic advice for ecosystem-based fisheries management of FF.

Does competition explain anchovy-sardine cycles? If not which processes do?



Process hypotheses

1. Environmental dependence

Sardine and anchovy have different requirements for recruitment, spawning habitat, …

Regime shifts created by environmental forcing

2. Interspecific competition

Sardine and anchovy impact each other negatively through egg predation, schooling behaviour, …

Interspecific feedbacks following exceptional events create impression of regime shifts

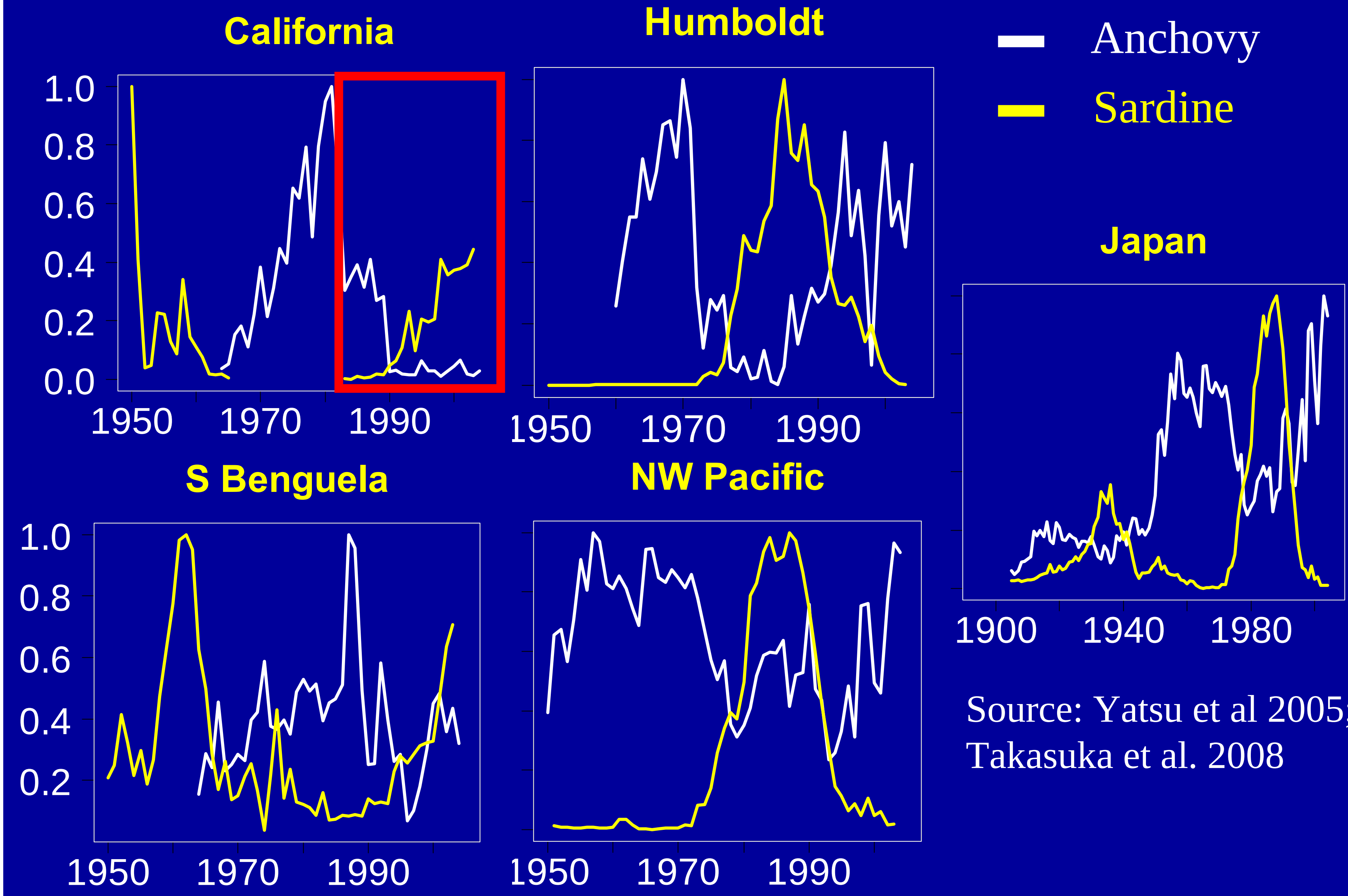
3. Observation error

Negative correlation of landings due to spatial distribution shifts, management,…

4. Independence

Sardine and anchovy dynamics are independent but short time series suggest dependence by chance

Landings data



Source: Yatsu et al 2005;
Takasuka et al. 2008

Source: Barange et al 2009

State-space modelling

Gompertz process model $\log(\mathbf{x}_t) = \mathbf{A}\log(\mathbf{x}_{t-1}) + \mathbf{b} + \boldsymbol{\varepsilon}_{t-1}$ $\boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}_\varepsilon)$

Observation model $\log(\mathbf{y}_t) = \log(\mathbf{x}_t) + \boldsymbol{\omega}_t$ $\boldsymbol{\omega}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}_\omega)$

$\mathbf{x}_\mathbf{t} = (x_\mathbf{t}^{\text{anchovy}}, x_\mathbf{t}^{\text{sardine}})$ latent state vector

$\mathbf{A}$ = density dependent growth

$\mathbf{b}$ = density independent growth

$\boldsymbol{\varepsilon}$ = process error

$\mathbf{y}_\mathrm{t}$ = observations

$\boldsymbol{\omega}$ = observation error

State-space modelling

Gompertz process model $\log(\mathbf{x}_t) = \mathbf{A}\log(\mathbf{x}_{t-1}) + \mathbf{b} + \boldsymbol{\varepsilon}_{t-1}$ $\boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}_\varepsilon)$

Observation model $\log(\mathbf{y}_t) = \log(\mathbf{x}_t) + \boldsymbol{\omega}_t$ $\boldsymbol{\omega}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}_\omega)$

<u>Model variants for testing hypotheses</u>

1. Environmental dependence

   Correlated process error

   $$\boldsymbol{\Sigma}_\varepsilon = \begin{bmatrix} \sigma_\varepsilon^A & \rho\sigma_\varepsilon^A\sigma_\varepsilon^S \\ \rho\sigma_\varepsilon^A\sigma_\varepsilon^S & \sigma_\varepsilon^S \end{bmatrix}$$

2. Interspecific competition

   Correlated density dependence

   $$\mathbf{A} = \begin{bmatrix} a^A & a^{AS} \\ a^{SA} & a^S \end{bmatrix}$$

3. Observation error

   Correlated observation error

   $$\boldsymbol{\Sigma}_\omega = \begin{bmatrix} \sigma_\omega^A & \rho\sigma_\omega^A\sigma_\omega^S \\ \rho\sigma_\omega^A\sigma_\omega^S & \sigma_\omega^S \end{bmatrix}$$

4. Independence

$$\mathbf{A} = \begin{bmatrix} a^A & 0 \\ 0 & a^S \end{bmatrix} \quad \boldsymbol{\Sigma}_\varepsilon = \begin{bmatrix} \sigma_\varepsilon^A & 0 \\ 0 & \sigma_\varepsilon^S \end{bmatrix} \quad \boldsymbol{\Sigma}_\omega = \begin{bmatrix} \sigma_\omega^A & 0 \\ 0 & \sigma_\omega^S \end{bmatrix}$$

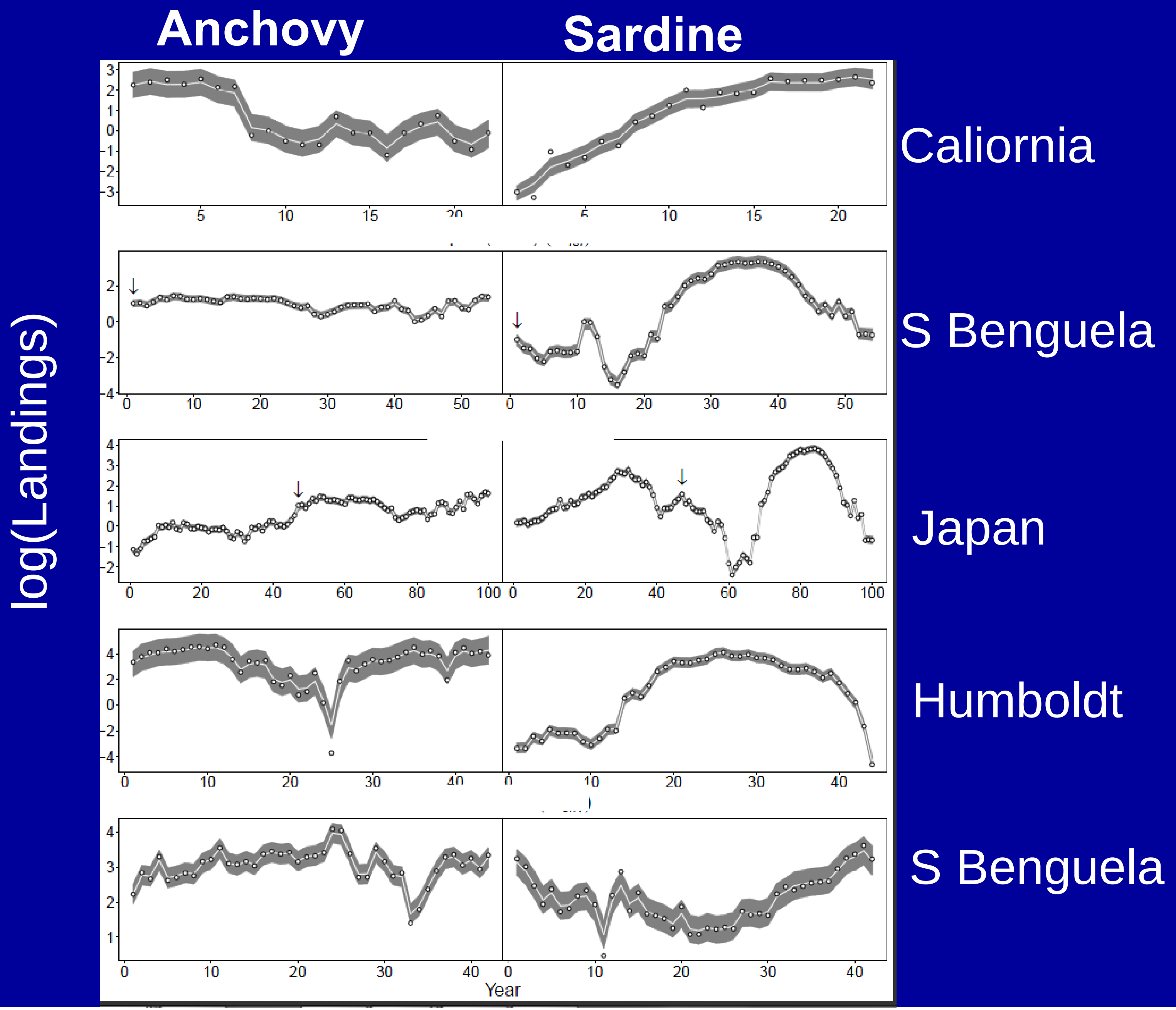
Bayesian model fitting

- Kalman filter for state vector (linear model, Gaussian noise)
- Adaptive MCMC for parameters
- Reasonable priors
- Hypothesis testing by model comparison
  - Bayes factor
  - DIC

Results: Best models

Ecosystem	Environment	Competition	Obs. error	Independent
California	*			*
Humboldt	*	*	*	*
S Benguela	*			
NW Pacific		*		
Japan	*			

Results: Best model fits

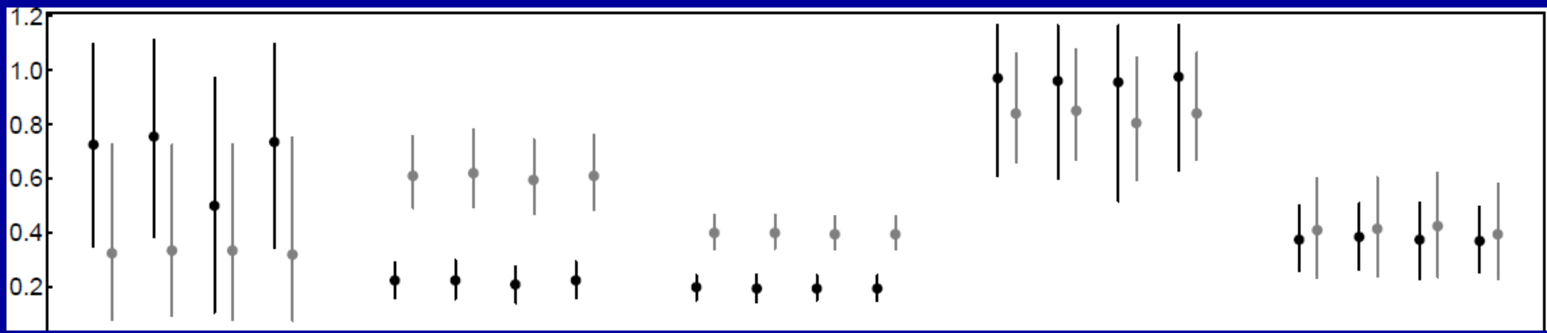


Results: Process errors

$$\log(x_t) = \mathbf{A}\log(x_{t-1}) + \mathbf{b} + \varepsilon_{t-1}$$

$$\Sigma_\varepsilon = \begin{bmatrix} \sigma_\varepsilon^A & 0 \\ 0 & \sigma_\varepsilon^S \end{bmatrix}$$

California NW Pacific Japan Humboldt S Benguela



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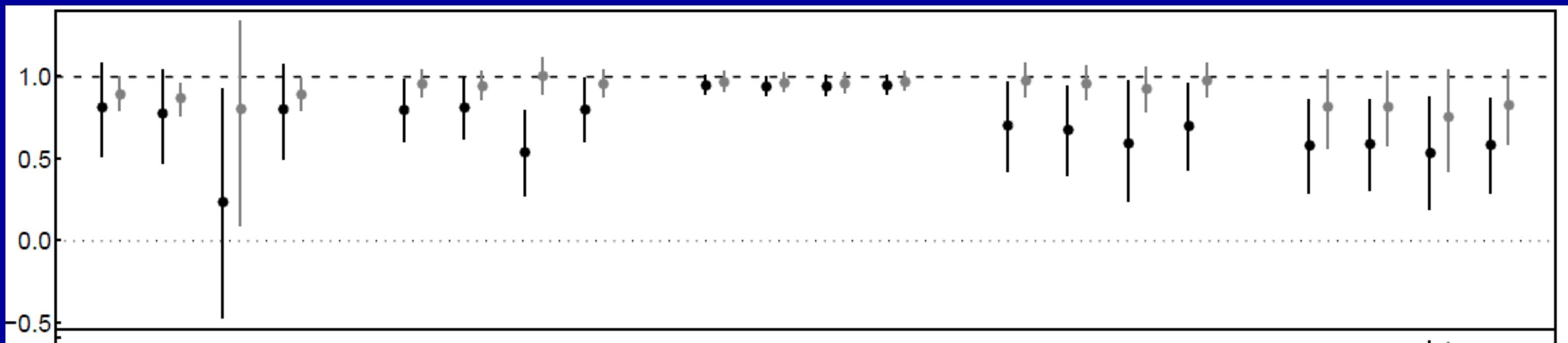
Process errors vary between regions for both Sardine and Anchovy but are stable across models

Results: Intra-specific density dependence

$$\log(x_t) = \mathbf{A}\log(x_{t-1}) + \mathbf{b} + \varepsilon_{t-1}$$

$$\mathbf{A} = \begin{bmatrix} a^A & a^{AS} \\ a^{SA} & a^S \end{bmatrix}$$

California NW Pacific Japan Humboldt S Benguela



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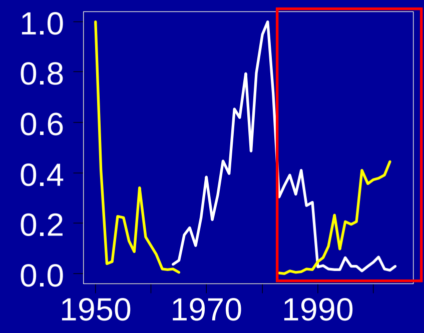
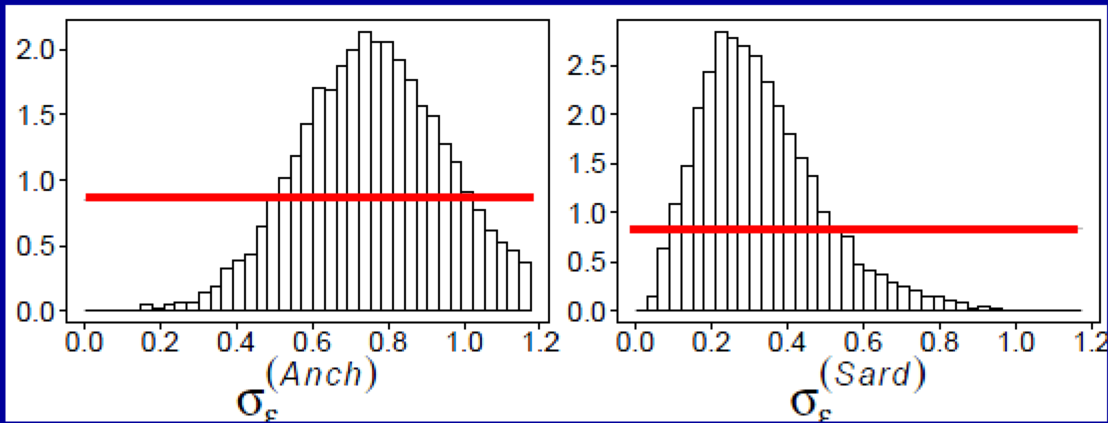
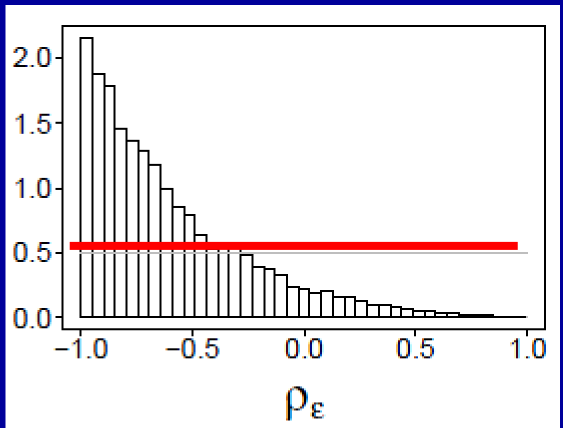
Sardine has larger density dependence than Anchovy in most areas independent of the model

California: Environmental dependence hypothesis supported





Process error: A > S



Strongly negatively correlated process errors

—— priors

Discussion

Which processes could explain anchovy-sardine cycles?

- Environmental dependence model was among best fitting models for four out of five areas
- Competition was best model for NW Pacific only
- Independence or environmental dependence had similar fit for California: short time series
- No best model for Humboldt stocks: stocks only partially spatially overlapping

Conclusions

Regime shifts or exceptional events?

- Environmental dependence (negatively correlated process errors) most common best model which is in agreement with regime shifts created by environmental forcing but not necessarily

- Evidence only in NW Pacific for competition creating feedbacks between anchovy and sardine so exceptional events leading to apparent regime shifts have no general support in the data

Implications for modelling

Environmental factors more important than competition