A bioenergetics approach to compare anchovy and sardine in the Bay of Biscay, from energy density data to a DEB model

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1. Introduction

Context

• 2 closely related species sharing the same ecosystems

• BUT sometimes contrasted population dynamics or spatial distribution
  → Trophic              Van der Lingen et al. 2006
  → Temperature          Takasuka et al. 2007 & 2008
  → Oxygen               Bertrand et al. 2011
  ...

Simultaneously integrate numerous processes at the individual scale

→ Physiology?

→ ... or a more synthetic approach: «the Bioenergetics»

Jobling (1993)
PhD: Compare biological & life history traits of anchovy and sardine in the Bay of Biscay. A bioenergetics approach

1. Data: Energy Density

2. Whole life cycle model: Dynamic Energy Budget (DEB)
2. Energy density

- Energy density (ED) = \( \frac{\text{Energy}}{\text{Mass}} \) kJ/g

- Sampling in 2014 in the Bay of Biscay at 2 contrasted seasons
  - Spring & autumn ~ min & max

- \(~400\) individual measurements of ED using a bomb calorimeter

- GAM model
  \( ED \sim f(size, season) \)
  \( R^2 = 0.64 \) (Anchovy) 0.71 (Sardine)
2. Energy density

\[ ED = f(\text{species, length, season}) \]

- **Spring:**
  - \(~\text{Same scaling of ED with size}\)
  - \(~\text{Same ED minima in Spring}\)
  - \(\rightarrow\) Energetic exhaustion in winter?
2. Energy density

\[ \text{ED} = f(\text{species, length, season}) \]

- **Spring:**
  - ~ Same scaling of ED with size
  - ~ Same ED minima in Spring
  - \( \Rightarrow \) Energetic exhaustion in winter?

- **Autumn:**
  - ~ Larger ED values for sardine
  - \( \Rightarrow \) Larger storage capacity
  - \( \Rightarrow \) Larger needs? \( \Rightarrow \) Reproduction?
2. Energy density

• ≠ storage capacity

• ≠ energetic needs

• ... in link with specific biological traits (size & spawning)

→ Need for a mechanistic & predictive tool: The DEB
2. Energy density

• ≠ storage capacity

• ≠ energetic needs

• ... in link with specific biological traits (size & spawning)

→ Need for a mechanistic & predictive tool: The DEB

• A calibration for both species in the BoB...

• ... using an approach by scenarios
2 main differences: Size & Spawning

From anchovy to sardine: 2 sets of successive calibration scenarios

1. Size
2 main differences: Size & spawning

From anchovy to sardine: 2 sets of successive calibration scenarios

1. Size

2. Size + Spawning
3. Bioenergetics modelling: DEB

Model fit

Total length (cm)

- Data
- Anchovy model

Wet mass (g)

Egg batches

ED (wet kJ/g)

Month
3. Bioenergetics modelling: DEB

SC1 : Size

- Correct size & weight predictions
- Underestimate ED variability

_Sardine ≠ «big anchovy»_
3. Bioenergetics modelling: DEB

SC1: “Spring anchovy”

SC2: Size & Spawning
SC2.1: Spring
SC2.2: From autumn to spring
SC2.3: Spring & autumn

• Size & weight predictions ≃
• Better ED predictions
3. Bioenergetics modelling: DEB

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Anchovy</th>
<th>Sardine SC2.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K$</td>
<td>0.71</td>
<td>0.58</td>
</tr>
<tr>
<td>$[E_m]$</td>
<td>1815</td>
<td>2346</td>
</tr>
<tr>
<td>$p_{Am}$</td>
<td>884</td>
<td>1060</td>
</tr>
<tr>
<td>$[p_M]$</td>
<td>158</td>
<td>118</td>
</tr>
</tbody>
</table>

- **$K$ (Kappa):** energy allocation between growth & spawning
  - sardine allocate more energy to spawning

- **$[E_m]$:** Maximum storage capacity
  - larger for sardine

- **$p_{Am}$ & $[p_M]$:** assimilation & maintenance rates
  - « waste to hurry » : short life cycle Kooijman 2013
  - more pronounced for anchovy
3. Bioenergetics modelling: DEB

Indeterminate spawning: « Capital » & « Income »

• Anchovy ~ « Income spawner »
  Somarakis et al. 2004
3. Bioenergetics modelling: DEB

Indeterminate spawning: «Capital» & «Income»

• Sardine ~ «Capital spawner»

Ganias et al. 2007
4. General conclusions

- Bioenergetics & Spawning strategies strongly associated

- Operational model
  - To test the sensitivity of both species to environmental conditions
  - To be incorporated in End to End models

For more information
Gatti et al. 2017, Comparing biological traits of anchovy and sardine in the Bay of Biscay: a modelling approach with the Dynamic Energy Budget.