Calibration of the DEB model for small pelagics.
What data is needed and at which timescale?

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DEB: *Dynamic Energy Budget*

Model energy fluxes
Predict: development / growth / spawning / mortality

- **Ingestion** → **Reserves (E)** → **Maintenance** → **Maturity Reproduction (R)** → **Gametes (G)**

- **K** and **1-K**

- **Food** → **Reserves (E)** → **Faeces**
1. Introduction

Table 3
The completeness of available data can be ranked with marks from low to high at the following levels; each level includes previous levels.

<table>
<thead>
<tr>
<th>Level</th>
<th>Data Description</th>
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<tr>
<td>0</td>
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<td>1</td>
<td>Age, length and weight at birth and puberty for one food level; mean life span (due to ageing)</td>
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<td>4</td>
<td>Growth (curve) at several (&gt;1) food levels; age, length and weight at birth and puberty at several food levels</td>
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<td>6</td>
<td>Respiration as function of length or weight and life span at several (&gt;1) food levels</td>
</tr>
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<td>Elemental composition at one food level, survival due to ageing as function of age</td>
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<td>Energy balance at several body sizes and several food levels (including heat)</td>
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Lika et al. 2011. The “covariation method” for estimating the parameters of the standard Dynamic Energy Budget model I: Philosophy and approach
1. **Introduction**

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1. Length, Weight = \( f(\text{age}) \)
2. Feeding rate = \( f(\text{age}) \)
3. Reproduction = \( f(\text{age}) \)
4. Respiration = \( f(\text{length}) \)
5. Elemental composition
6. Energy balance
1. Introduction

1. Length & weight at age (data)
2. Energy density measurements (data)
1. Length & weight at age (data)
2. Energy density measurements (data)

3. Spawning investment (literature + data)
   1. Spawning window & duration (data + literature)
   2. Spawning frequency (literature)
   3. Relative batch fecundity (literature)
   4. Egg energy content (literature)
1. Length & weight at age (data)
2. Energy density measurements (data)
3. Spawning investment (literature + data)
4. Environmental forcing (model ECO-MARS3D)
1. **Introduction**

- Length & weight at age (data)
- Energy density measurements (data)
- Spawning investment (literature + data)
- Environmental forcing (model ECO-MARS3D)

~ average data completeness
2. Calibration exercise

An approach by scenarios

3 main differences: Size, spawning & feeding

From anchovy to sardine: 3 sets of successive calibration scenarios

1. Size

2. Size + Spawning

3. Size + Spawning + Feeding
2. Calibration exercise

Model fit

SC1: Size

- Correct size & weight predictions
- Underestimate ED variability

Sardine ≠ «big anchovy»
2. Calibration exercise

**SC2 : Size & Spawning**

**SC1 : Spring anchovy**

**SC2.1 : Spring**

**SC2.2 : From autumn to spring**

**SC2.3 : Spring & autumn**

- Size & weight predictions ≃
- Better ED predictions
3. Why is energy data so important?

Energy = V + R + E + G

- Energy
- Structure (V)
- Maintenance
- Maturity Reproduction (R)
- Gametes (G)
- Reserves (E)
3. Why is energy data so important?

Energy = V + E + R + G

Energy

Structure (V)

Reserves (E)

Maintenance

Maturity Reproduction (R)

Gametes (G)
Energy data is so important because it helps us understand the fundamental components of an organism's energy balance. The energy (E) is the sum of structure (V), reserves (E), maintenance (R), and gametes (G).

\[
\text{Energy} = V + E + R + G
\]

Mass is also a critical factor, expressed as:

\[
\text{Mass} = \rho_V V + \rho_E E + \rho_R R + \rho_G G
\]

These components are interconnected through various processes, such as reproduction, maintenance, and gamete production, which are essential for the organism's survival and reproduction.
3. Why is energy data so important?

Energy = V + E + R + G

Mass = \( \rho_V V + \rho_E E + \rho_R R + \rho_G G \)

Length = \( \sqrt[3]{\frac{\rho_V V}{d_V}} / \delta \)
3. Why is energy data so important?

- Energy content data is needed ...
- ...except if you know the chemical composition of the fish

**Chemical (proximal) composition**

Water + Minerals (ash) + Proteins + Lipids ~ 100%

- Water & Minerals → no energy
- ED = weighted mean of lipids and proteins contents
4. Which time scale?

JFF (fish canning manufactory),
St Guénolé
(North of the Bay of Biscay)

Dry mass content ~ ED

Minimum

Maximum

Dry mass content (%) vs Month

20 25 30 35 40

1 2 3 4 5 6 7 8 9 10 11 12
4. Which time scale?
4. Which time scale?
4. Which time scale?
5. Energetic expenses & DEB constraints

Maintenance & Reproduction

➔ largest energetic costs
5. Energetic expenses & DEB constraints

Maintenance & Reproduction

→ Largest energetic costs

→ Largest fluxes to be constrained
How do we measure maintenance? Respirometer? SDA / SMR?
Spawning

→ fecundity, frequency, egg content = f(condition, season, age, length...)

5. Energetic expenses & DEB constraints
6. Energy inputs?

Diagram:
- Food
- Reserves (E)
  - Structure (V)
  - Maintenance
  - Maturity Reproduction (R)
    - Gametes (G)
6. Energy inputs?

SC3: Size, Spawning & Feeding

SC2.1: anchovy (large preys)
SC3.1: sardine (small preys)
SC3.2: hybrid (small & large)

Daily consumption rate ~1-4%

Energy content of the food is needed
7. General conclusions

What data do we need?

Hartman and Brandt 1995, *Estimating Energy Density of Fish*

“Despite the widespread use of bioenergetics models in fisheries, information on one key input variable, energy density (J/g) of predators and prey, has been limited.”

“If results obtained from the use of bioenergetics models are to be accurate, estimates of energy density of predators and prey are required for specific seasons, fish ages, and ecosystems.”
To properly calibrate a DEB model

1. Length & weight data (are not enough)
2. Energy content / proximate composition
3. Energetic cost of spawning
4. Energetic cost of maintenance
5. Energetic input from the food

... following the appropriate schedule of each variable...

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.
To properly calibrate a DEB model

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... following the appropriate schedule of each variable...

We probably need all these data for all bioenergetics models (not only for the DEB...)

7. General conclusions
Thank you!
2. Introduction

**DEB: Dynamic Energy Budget**
Model energy fluxes
Predict: development / growth / spawning / mortality

- Ingestion
- Reserves (E)
- Faeces
- Maintenance
- Maturity Reproduction (R)
- Gametes

Food

Kinetics & Temperature

Overheads
4. Which time scale?

Indeterminate spawning: «Capital» & «Income»

- Anchovy ~ «Income spawner»
  Somarakis et al. 2004
4. Which time scale?

Indeterminate spawning: «Capital» & «Income»

- **Sardine ~ «Capital spawner»**
  
  Ganias et al. 2007
4. Which time scale?

Indeterminate spawning: «Capital» & «Income»

- «Income/Capital» : «match/mismatch»

Reproduction / bloom zooplankton

Somarakis et al. 2004, Ganias et al. 2007 & McBrides et al. 2015