Resolving environmental effect on stage transitions in anchovy early life history using Dynamic Energy Budget (DEB) theory

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Metamorphosis = end of a critical period

Larval stage
• After metamorphosis, recruitment can be predicted.

• Fish species spawn over extended periods of time.

• Seasonal variability of environmental conditions.

We often do not know which environmental conditions allowed survival to the juvenile stage in natural environments but need for predictions purposes.

We might know how individual traits at metamorphosis (age, length) vary during the season.
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→ We might know how individual traits at metamorphosis (age, length) vary during the season
Individual traits at metamorphosis vary with the season as read in otoliths of anchovy juveniles.

Age and otolith radius at metamorphosis decrease according to date at first feeding.
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Research question

Can we reconstruct the environmental conditions that allowed survival of individuals in natural conditions if we know the distribution of their traits at metamorphosis?

Age and otolith radius at metamorphosis decrease according to date at first feeding
Outline

1. How did we obtain the traits at metamorphosis for the Bay of Biscay anchovy?

2. Development of a bioenergetic model for larval growth and survival

3. Environmental scenarios that reproduce observed age at metamorphosis

4. Interpretation of the otolith radius at metamorphosis?
Age and otolith radius at metamorphosis can be obtained from the pattern of otolith growth rate.

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- Juvenile surveys, Otolith growth rate: 125 individuals in 1999; 68 in 2003
Model for larval growth and survival

- Based on Dynamic Energy Budget (DEB) Theory (Kooijman 2000)
- Extension of a DEB model for anchovy growth and reproduction; juvenile and adult stage (Pecquerie et al. 2009)
- Specific assumption for larvae to reproduce a Gompertz growth type: change in shape during growth
- Mortality due to starvation
Larval growth

- Gompertz equation = empirical model
- Anchovy DEB model = process-based model
- Continuity with a von Bertalanffy growth type for juvenile and adult stage
Larval survival to starvation conditions

At mouth opening, egg initial reserves allow longer survival under starvation.

Maintenance cost depends on T: higher mortality at high T.

Lasker et al. (1970)
Larval survival to starvation conditions

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Lasker et al. (1970)
Scenarios analysis

Simulations
Average food conditions

Age at metamorphosis (d)

Time (julian days)

Temperature (°C)

Time (julian days)

Scaled functional response (-)

Time (julian days)

Average food conditions
Scenarios analysis: stochastic environment

Hatching dates of individuals that survived

- 1999
- 2003
Challenge: extracting more information from otolith patterns

- In a DEB context, we can extract more information if we know how length at metamorphosis varies with food conditions.

- We have information on otolith radius at metamorphosis from the data.

- Otolith model coupled with the bioenergetic model for juvenile and adult anchovy (cf R. Fablet talk on Monday)

Which assumptions to explain the observed pattern?
Conclusions

- Observed age at metamorphosis as read in juvenile otoliths for anchovy can reveal food conditions experienced by juveniles that survived the larval period.

- For the Bay of Biscay anchovy, we suggest environmental conditions were more suitable for larval survival in 1999 compared to 2003 → in agreement with higher recruitment levels in 1999.

- Our modeling framework has the potential to extract more information on food conditions from otolith patterns → But we need a better understanding of otolith growth during the larval stage and the metamorphosis period.
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