

Bioenergetic modelling of growth, development and reproduction of a small pelagic fish: the Bay of Biscay anchovy.

Understanding the recruitment variability of fish populations is a major challenge in fishery sciences. In the present work, we explore a new approach to study the potential factors that determine this recruitment in the context of biophysical modelling. The adult spawning pattern might influence the survival of the larvae as it determines the environmental conditions they experience during this critical period. We apply our study to the Bay of Biscay anchovy *Engraulis encrasicolus*, which is a multiple-batch spawner.

The objective of the study is to understand the effect of the environmental conditions experienced by an individual *i*) on the energy available for reproduction and *ii*) on the temporal distribution of the spawning events and its consequences on larval growth, development and survival. To study these processes, the Dynamic Energy Budget (DEB) theory is particularly suitable. This theory allows us to identify the common processes and the specificities of each life stage.

First, we actualise the growth curve of Bay of Biscay anchovy. Juvenile growth is reproduced by taking into account they experience in average a higher temperature during this stage than the adults thereafter. Larval growth in fish typically deviates from later juvenile and adult growth. We suggest to consider how food intake depends on body length to explain the observed growth patterns.

Second, the present work allows us to better understand and quantify the effect of environmental conditions experienced by an individual on the length of its spawning season. These conditions determine on one hand the length of the individual and thus its reproduction potential, and on the other hand the amount of energy that it can actually store for reproduction. In limiting conditions, this energy can be mobilised for survival. Hence, the length structure of the population and the limiting conditions encountered by the individuals are determinant factors of the spawning windows.

Third, we are able to identify the food conditions that allow survival until the juvenile stage for larvae issued from different spawning windows. We obtain this result from the selection of environmental scenarios that reproduce the observed age and otolith radius at metamorphosis according to first feeding date. The link between fish metabolism and otolith formation (a complex crystal in the inner ear of the fish) is explicitly modelled. We show the potential of the model to reconstruct individual life history from the observed variations of opacity in the otolith.

The approach we used is a deterministic approach of the link between the environment and the individual, through bioenergetic processes. It allows us to formulate original mechanisms underlying classical observations in fishery sciences. As a better understanding of fish life cycles requires the study of individual behavior and strategies in response to environmental variations, we suggest the present work can be used as a basis for such studies.

Keywords: modelling, bioenergetic, life cycle, *Dynamic Energy Budget* theory, *Engraulis encrasicolus*, spawning windows, larval survival, link fish metabolism - otolith, environmental scenarios, inter-individual variability.