Environmental variability and energetic adaptability of the great scallop, Pecten maximus, facing climate change ATT. dubbelpromotie

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Summary

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The relationship between environmental conditions and life history has intrigued biologists for centuries. This thesis aims to better understand the variability of life history traits of the great scallop, *Pecten maximus*, facing environmental variability. This economically important species for French, English and Norwegian fisheries has a wide distribution range (from the Azores to Lofoten Islands). Growth and reproduction patterns are very variable within this area, potentially due to the environmental variability. Great scallops living at the head of Norway's fjords are the biggest but grow slowly whereas individuals from lower latitudes have faster growth rates and reach a smaller ultimate size and those from the continental shelf display both low growth rates and a reduced size. The variability in biological traits might be attributed to a plasticity or genetic adaptation of the physiological response of individuals to the environment, to mechanistic causes related to energy fluxes that fuel the metabolism again with regard to environmental forcings or to a combination of these two mechanisms.

The approach considered here to study the causes of this variability focuses on the dynamics of energy fluxes which allow us to deal with all the metabolic functions of the individual. The Dynamic Energy Budget (DEB) theory provides a mechanistic framework that allows a quantitative description of feeding, assimilation, growth, reproduction, maturation and maintenance over the full life cycle, in relation to thermal and trophic conditions. The first part of this thesis is dedicated to the development of a DEB model for *P. maximus*, with an emphasis on feeding implementation. The model makes use of the Synthesizing Units to provide the system with two substrates which quantifies food selection by the animal. We tested the model on the great scallop population from the Bay of Brest (France), with two proxies of trophic resource: phytoplankton cell counts and suspended organic particles.

The second chapter expands on the integration of this individual bioenergetic model to a 3D biogeochemical model in the English Channel. This modeling system allows the mapping of growth and reproduction capacities

according to environmental conditions. The individual model simulations enabled us to improve a spatialized model of population dynamics divided in age-classes and including the planktonic larval stage. We carried out predictions over a period of 30 years, thus providing a potential tool for exploited stock forecasting in the English Channel.

In the third part of this thesis, we investigated the seasonality and diversity of the diet of this suspension-feeding bivalve in a coastal environment, with the aim to improve our knowledge on the seasonal dynamics of feeding in this species and better understand how we feed the bioenergetic model. We used the combination of three trophic markers (pigments, fatty acids and sterols), measured in the seawater and in two parts of the digestive tract. This study revealed five important pieces of information: (i) the unexpected importance of dinoflagellates in the diet of *P. maximus*; (ii) the recurrent switch between ingestion of diatoms and dinoflagellates along with the succession of algae blooms; (iii) the probable ingestion and assimilation of cyanobacteria and other bacteria, in particular during low microalgae densities; (iv) the selection capacity of the great scallop, which can preferentially select some algae classes and neglect some others; (v) trophic inputs from the water column proved to be more important than from the benthos except in early spring.

In the two last chapters, we developed and applied a modeling approach consisting of the inversion of the DEB model in order to reconstruct the functional response of food assimilation from growth data (obtained from the sclerochronological study of the shell) and temperature. Indeed, it is generally difficult to simply link the dynamics of trophic availability with the dynamics of assimilation and the method proposed here overcomes this issue. The process relies on a simplified equation of growth as described in DEB theory. This, therefore, facilitates the inversion of the model while also allowing the reconstruction of state variables and some energy fluxes (reserve dynamics, maintenance costs). As for many organisms producing a carbonated skeleton, *P. maximus*' shell grows by sequential increments. The analysis of the striae allows an accurate measurement of daily growth dynamics. We exploited these high frequency data in order to reconstruct the history of functional response along the growth trajectory. This method was applied in a study of the variability of growth patterns along latitudinal and bathymetric gradients. The highly fluctuating pattern of food availability seems to be a key factor in understanding the energy fluxes dynamics in northern and deep-sea populations. The combination of mild temperatures and low and varying food conditions on the continental shelf might lead to a local selection of smaller individuals which require limited maintenance costs. Moreover, this approach allowed us to explore the relationship between the functional response and various markers of trophic availability. It showed that chlorophyll-a measurements in the water column did well and truly explain the major part of the variability of assimilation, at least when phytoplanktonic production in the water column is important.

This work shows that the modeling of energy fluxes provides a tool that helps understanding the origin and fate of various energy sources as well as the distribution patterns of individuals. This tool also provides a mechanistic explanation to intra-specific variability patterns. Nevertheless, some physiological traits such as the filtration rate are very likely to show some plasticity. Indeed, the simulation carried out in northern and deep-water populations using the parameter set that was estimated in the Bay of Brest provided less relevant results. Further investigations should be conducted on data from early stages and in contrasting environments, in order to better integrate the variability within this species, which would help refine the DEB parameter set. The study of *P. maximus* physiological capacities, carried out on a spatial scale in this thesis, and the stepping to the population level could be useful tools for a better assessment and management of scallop fisheries (which fluctuating recruitment is still poorly understood). Finally, while the effects of global change are being investigated, the use of DEB theory in this work could provide a powerful framework to evaluate the impact of changing environments on the energetics of the great scallop.