

'GENERIC':
Conception and application of a generic model of growth, reproduction and survival in the Pacific oyster

Crassostrea gigas



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Study context

Shellfisheries play a **major economic role** in French aquacultural production. In 2004, 191800 tonnes of shellfish were produced nationally, worth an estimated 380 million euros (2nd highest production value in Europe), of which 115250 tonnes were oysters (largest production in Europe) and 75549 tonnes were mussels (2nd largest in Europe) [1]. In 2002, the French Shellfish industry depended on 3719 businesses which generated employment equivalent to 10524 full time jobs (compared with 10810 in fishing). There are presently 52600 concessions on public maritime land along the coast, growing bivalve shellfish on an area of 20000 hectares, of which 59% is devoted to oysters [2]. The **Pacific oyster *Crassostrea gigas*** is grown along all three French coasts: the English Channel (e.g. 27000 tonnes/year from Normandy), Atlantic (21500 and 22000 tonnes from North and South Brittany respectively; 27500 and 13000 tonnes, from Marennes-Oléron and Arcachon respectively) and Mediterranean (8500 tonnes from the bassin de Thau) [3]. In the **Poitou-Charentes region** notably, shellfisheries generate 3500 UTA (Unité Travail Année: number of full-time years worked), involving 8000 people [4]. In 2001, 44% of Pacific oysters consumed in France came from the industry in Poitou-Charentes [3]. The Charentais production basins are the most important in France, as much for the supply of spat to other zones as for local production and finishing stages in the oyster ponds of the coastal marshes.



The Pacific oyster *C. gigas* is widely distributed around the world (New Zealand, Australia, United States, Japan *etc.*). Within Europe the species is found from the Norwegian Sea to the coasts of Morocco. Its wide distribution is accompanied by **high spatial and temporal variability in growth performance**. Ecophysiological models of Pacific oysters, based on energy balances (e.g. [5], [6], [7], [8]), are the tools favoured for monitoring and predicting the growth of *C. gigas* in relation to the environment. They may be used alone or in combination with models of overall population dynamics (e.g. Bacher & Gangnery, in press), ecosystems or even evolution.

These models however are based on the concept of 'scope for growth' (*i.e.* growth potential of an individual) and therefore do not include details of energy partitioning within the organism. They also have two major recurrent limitations which the work of my PhD aims to address. Firstly, these models have only been validated for part of the year, usually the somatic growth phase from the end of winter until the beginning of summer, and very few of the models have been validated over more than one year. Secondly, these models have proved highly sensitive and their predictions are generally specific to the study sites for which they were developed. The large number of parameters in these models can limit their use for new environments, making it difficult to compare the ecophysiology of the Pacific oyster between its different production areas using a single tool.

A **generic energy partitioning model** of the animal is needed to understand and quantify the relationships between environmental conditions, growth performances, gametogenesis and

survival of the Pacific oyster *C. gigas*. It would allow growth simulation of *C. gigas* over several years and in different growing areas. It would also form a valuable tool for attempting to answer outstanding questions about energy deficits and weakening of oysters in the summer on French coasts, variability in growth and reproductive performance (collection of wild spat), optimisation of genitor conditioning techniques in hatcheries and would also help us to foresee changes in performance linked to potential environmental changes.

Objectives of the project

The objective of my doctoral work is to construct a bioenergetic model of the Pacific oyster based on the principle of dynamic energy budgets, and to validate its generic character for different living environments of this species. The model will allow us to explain physiological differences (growth, reproduction and energy status of the oyster) which depend on the environmental conditions of the different production sites.

Our model is based on the **DEB theory** (Dynamic Energy Budget) developed by Kooijman [9]. As in all bio-energetic models, energy acquisition by the animal is made via **food ingestion**. Parameters of the model linked to food ingestion must therefore be estimated precisely in order to describe the subsequent fluxes of energy to the different tissues of the organism. Study of oyster ingestion parameters will also give a picture of how nutritional behaviour differs according to the environment.

As the characteristics of Pacific oyster nutrition are becoming better understood, the **generic** quality of the model under construction is being validated step by step starting on 'simple' environments (*i.e.* clear seawater, known food, a single total induced spawning, *etc.*) and progressing to the detail of oyster feeding behaviour in more **complex environments** (turbid seawater, strong tidal influence, complex food sources, temperatures which induce partial spawnings, *etc.*). This validation work is done by comparing simulations of the model with growth observations in an existing dataset, made throughout the year.

Methods

1. Study of nutrition in the Pacific oyster

This study is based on experiments made at the population level and on individuals. The population level study is being made under controlled conditions (Ifremer, Argenton <http://www.ifremer.fr/argenton/>), on several batches of oysters from the same population fed with different types of micro-algae at different food densities.

At the level of the individual, oyster nutrition is being studied with a through-flow ecophysiology measurement system (Fig. 1) which measures the hydrobiological parameters of sea water circulating in control chambers and compares them with results from chambers containing oysters.

Figure 1. Through-flow ecophysiology measurement system.

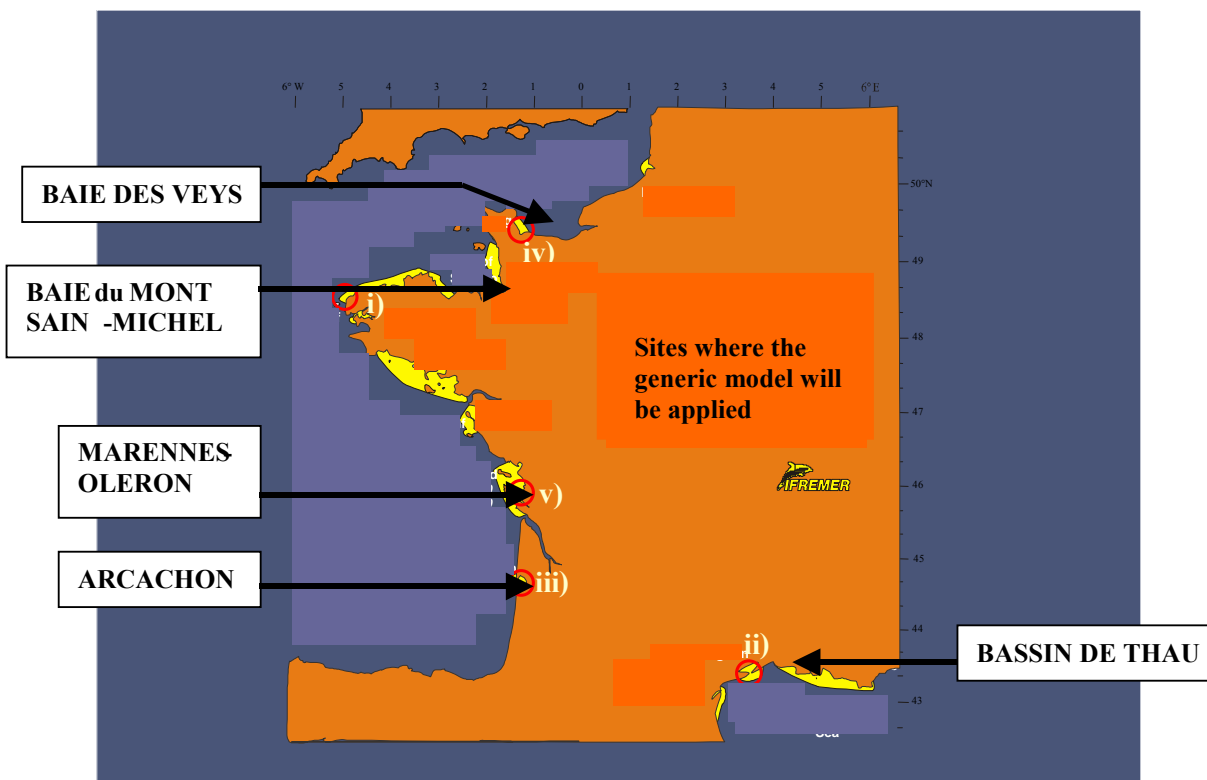


2. Validation of the generic character of the model

Numerous growth studies in the last two decades, have been coupled with fine scale environmental monitoring (temperature and indicators of food availability for oysters), both by permanent IFREMER networks (REPHY, REMORA) and as specific isolated studies. The objective has been to identify the environmental variables that best explain oyster growth. Over the course of the present study on growth and reproduction of the Pacific oyster in the different production areas, the model is likely to develop to take into account the most important environmental variables (e.g. chlorophyll a concentrations, number of phytoplankton, density of suspended matter).

3. Study areas where the generic character of the model have to be validated

The following map shows the French sites where the **generic character** of the model is **being validated**.



Preliminary results on the validation of the oyster-DEB model

The initial development of the **generic** model is already the subject of a scientific publication (Pouveau *et al.*, 2006 [10]). Since this first step, validation of the model has been pursued at numerous oyster growing sites, particularly in the Arcachon and Marennes-Oléron basins (Figs 2 & 3).

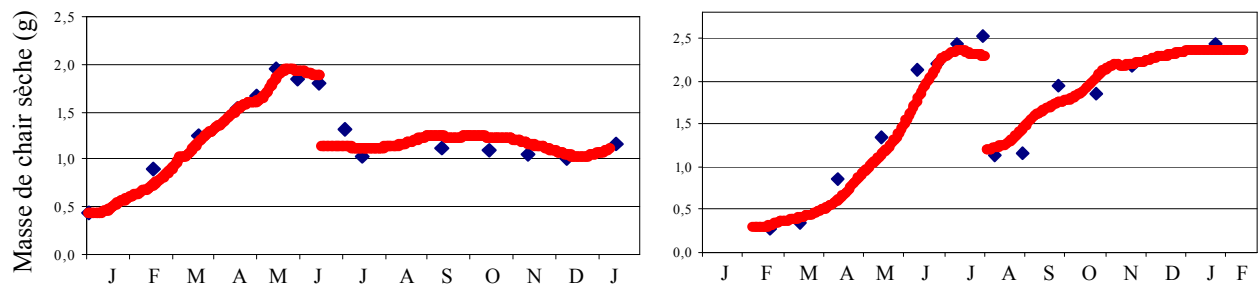


Figure 2. Comparisons between observed (dots) and simulated (red lines) dry flesh mass of oysters in Arcachon in 1993 (left) and 1995 (right).

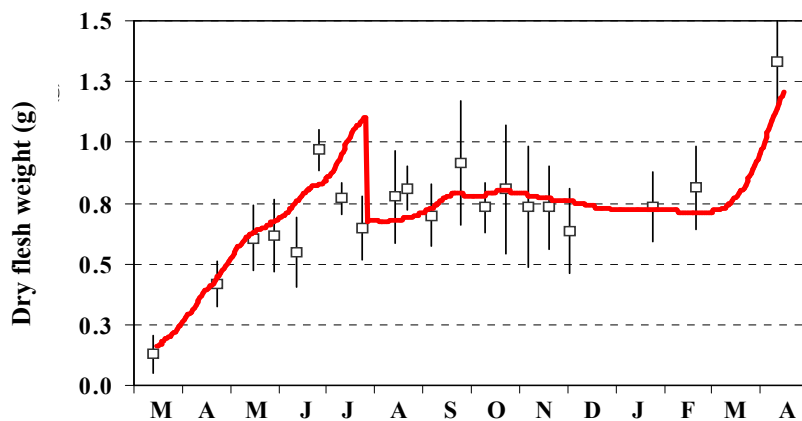


Figure 3. Comparison between observed dry flesh mass (dots) and simulated dry flesh mass (red line) of oysters reared in Marennes-Oléron in 2002-2003.

Publications & communications

- **Bourles, Y.**, Alunno-Bruscia, M., Pouvreau, S., et al. Bioenergetics of the Pacific oyster *Crassostrea gigas* reared in an Atlantic coastal pond: application of a DEB model. *In prep.*
- Pouvreau, S., **Bourles, Y.**, Lefebvre, S., Gangnery, A., Alunno-Bruscia, M., 2006. Application of a dynamic energy budget model to the Pacific oyster *Crassostrea gigas*, reared under various environmental conditions. *Journal of Sea Research* 56, 156-167.
- **Bourles, Y.**, Pouvreau, S., Maurer, D., Gangnery, A., Lefebvre, S., Alunno-Bruscia, M., 2005. A Dynamic Energy Budget model to simulate the growth and reproduction of the Pacific oyster *Crassostrea gigas* reared under various environments: First results. Présentation orale à la 8^{ième} conférence ICSR, Brest, France, 5-8 octobre 2005.
- **Bourles, Y.**, Pouvreau, S., Maurer, D., Gangnery, A., Alunno-Bruscia, M., 2006. A Dynamic Energy Budget model to simulate the growth and reproduction of the Pacific oyster *Crassostrea gigas* reared under various environments: New results. Poster présenté à la conférence AQUA 2006 de la World Aquaculture Society, à Florence, Italie, 9-13 mai 2006.
- **Bourles, Y.**, 2006. Conception et mise en application d'un modèle générique de croissance et de reproduction de l'huître creuse *Crassostrea gigas*. Présentation orale et poster présentés au colloque de doctorants de l'Université de La Rochelle, France, 11-12 mai 2006.

References

- [1] OFIMER. Les chiffres clés de la filière pêche et aquaculture en France, Edition 2006. http://www.ofimer.fr/99_up99load/2_actudoc/971d1_01.pdf
- [2] Ministère français de l'Agriculture. L'aquaculture en France. http://www.agriculture.gouv.fr/spip/ressources.themes.pecheaquaculture.aquaculture_r61.html
- [3] Comité Nationale de la Conchyliculture (C.N.C.): La Production française. <http://www.cnc-france.com/index.php?rub=2&page=11&type=theme&id=22>
- [4] Anonyme, 2003. L'huître : perle de l'élevage conchylicole. Premier recensement de la conchyliculture. AGRESTE Primeur, N°126.
- [5] Barillé, L., Bougrier, S., Geairon, S., Robert, J.M. 1997. Ecophysiological deterministic model for *Crassostrea gigas* in an estuarine environment. *Aquat. Living Resour.*, **10** : 31-48.
- [6] Gangnery, A., Chabirand, J.M., Lagarde, F., Le Gall, P., Oheix, J., Bacher, C., Buestel, D. 2003. Growth model of the Pacific oyster, *Crassostrea gigas*, cultured in Thau Lagoon (Méditerranée, France). *Aquaculture*, **215** : 267-290.
- [7] Grant J., Bacher C. 1998. Comparative models of mussel bioenergetics and their variation at field culture sites. *J. Exp. Mar. Biol. Ecol.* **219** : 21-44.
- [8] Ren, J.S., Ross, A.H. 2001. A dynamic energy budget model of the Pacific oyster *Crassostrea gigas*. *Ecol. Model.*, **142** : 105-120.
- [9] Kooijman, S.A.L.M. 2000. Dynamic Energy and Mass Budgets in Biological Systems. Cambridge University Press, 2nd edition.
- [10] Pouvreau, S., Bourles, Y., Lefebvre, S., Gangnery, A., Alunno-Bruscia, M., 2006. Application of a dynamic energy budget model to the Pacific oyster *Crassostrea gigas*, reared under various environmental conditions. *J. Sea Res.* **56**, 156-167.