IMPACT OF CULTURAL PRACTICES ON THE INDIVIDUAL AND COLLECTIVE ECONOMIC PERFORMANCES IN SHELLFISH FARMING: THE CASE OF OYSTER FARMING IN BAIE DES VEYS

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The access regulation within the shellfish farming sector in France is based on a co-management system relying on both a national legislation, defining the general access conditions to maritime public grounds, and regional regulation systems, called "Regional Structural Schemes". The latter specify the farming rules in cooperation with the administration, scientific and professional representatives. This regulation system, which aims at managing the common primary resources at the scale of a shellfish farming basin, is under review in the *baie des Veys*, on the Normandy coastline. In this context, biological modelling is used to assess the carrying capacity of the bay and to provide tools for modifying the RSS in a more sustainable way. Another objective of the study is to shift to bio-economic modelling, implying for the model to take into account extra technical and economical parameters. A specific survey has therefore been carried out for collecting detailed information on the cultural practices of the oyster farming companies, and for analysing the links with their structural characteristics and performance indicators, in terms of productivity and output. This article reviews the context of oyster farming in the *baie des Veys* from the environmental, socio-economic and institutional point of view. After the presentation of the methodology used for the survey, its results are analysed and a synthesis is made, leading to the identification of the main farming technical profiles. At this stage of the study, only theoretical developments on modelling are considered and outlooks in terms of collective management measures are discussed.

Keywords: aquaculture economics, oyster farming, cultural practices, common resource management

INTRODUCTION

The EAA (ecosystem approach to aquaculture) provides a general frame for addressing the issue of shellfish farming system sustainability and related resource management concerns. The principles of the EAA aim at developing aquaculture by taking into account the full range of the ecosystem functions and services, but should also further integrate the social and economic dimensions of the activities in relation with other economic sectors (Soto et al, 2007). At the local or regional ecosystem scale, this implies confronting management measures based on the best biological/ecological available knowledge to economic and institutional analysis, in particular concerning the issues related to the collective management of coastal waters, which have the characteristics of a classic shared resource (Knowler, 2007).

The sustainability of the bivalve farming sector (as all other activity exploiting renewable natural resources) depends on both its internal dynamics and on its interactions with the ecological and socioeconomic environment. From the technical point of view, the objective of managers should be to adapt the farming potential of companies with the carrying capacity of the ecosystem. This adaptation procedure needs to accurately represent the bio-economical processes which quantify and qualify sustainable exploitation trajectories, and the efficient management measures to achieve them.

In this context, the OGIVE research project is building a multi-step modelling approach with the aim of integrating the ecological, biological and socio-economic dimensions of bivalve farming activities in the

baie des Veys. This modelling approach involves a first stage based on the acquisition of knowledge about the functioning of coastal ecosystems and about the economic sectors exploiting their natural resources. The second stage is dedicated to the exploration of sustainable scenarios for resource exploitation activities, with a view of providing tools for decision-making support.
The modelling approach requires obtaining accurate information about the cultural practices of the companies in order to characterise the main technical itineraries and to specify the parameters of the bio-economic model. A specific survey was therefore carried out for collecting detailed information on the cultural practices, from seeding to harvesting through intermediate operations, and for analysing the links with their structural characteristics and performance indicators, in terms of productivity and output.

This article is based firstly on an overview of the oyster farming sector in the *baie des Veys*. The environmental, economical and institutional context will be described before presenting the modelling developed in the framework of the OGIVE research project. The article will then continue with the presentation of the survey about cultural practices and its main significant results. Finally, the last part will be dedicated to the discussion about the stakes of collective resource management and about which future economic modelling should be developed in order to integrate the economical and social dimension of the shellfish farming activity.

MAIN FEATURES OF OYSTER FARMING IN THE "BAIE DES VEYS"

The *baie des Veys* is located in the Lower-Normandy region (in the Channel coastline) which is one of the main regions for bivalve farming in France, and also the most recent one. The bay is more precisely situated at the East of the Cotentin peninsula and is part of the Calvados County. The significant development of bivalve mollusc farming began in the early 1970s, and then increased thanks to good conditions in growth and of access to farming sites. Today, the Pacific oyster is the main bivalve farming activity in the bay.

The environmental and economic context

The ecosystem of the *baie des Veys* shows high potential for bivalve farming. The extent of the watershed (3,420 km^2) provides the bay with large amounts of freshwater, rich in nutriments, which exceed the outgoing currents from the bay, resulting in a positive sedimentary balance and global enrichment of coastal waters. At the Eastern side of the bay, the surface area dedicated to oyster farming represents around 160 hectares which are broken down into three farming zones: *Grandcamp*, *Géfosse* and a temporary zone, called "*Secteur d'accueil*". Currently, the *baie des Veys* is the third biggest oyster production area of Lower-Normandy, ranging from a 6,000 to 10,000 ton yearly output, which represents 20-30% of the Lower-Normandy production. The oyster farming sector within the bay comprises of about sixty companies and employs 160 full time and 200 part time people (DDAM 2008).
The hydrological characteristics of the bay, determined by The Channels strong currents and low temperatures, are not conducive to oyster spatfall. This makes farmers dependent on external spat supply, either from wild spat collected in other oyster farming basins, mainly from *Arcachon* and *Marennes-Oléron* in the French Atlantic coastline, or from spat produced in hatcheries. Conversely, the high growth potential of the *baie des Veys*, especially in comparison with that observed in the Atlantic production regions, has favoured it as a specialised growing basin for oysters. This is the reason why some outside oyster farming companies, looking for productivity improvements, have relocated part of their rearing cycle there. These production strategies based on the regional diversification of the farming sites generate transfers of oyster livestock between farming regions. As concerns local farming companies, alternative production strategies were also developed, such as the practice of the "short cycle"[1] which consists in focusing the oyster rearing activity on either pre-growing or growing stages. In particular, the strategies of production specialised in growing were relatively widespread twenty years ago. But these practices have tended to become rare due to the lack of half-grown oyster supply and they actually concern only a few companies in the *baie des Veys*.

At the commercialisation level, the companies located in the *baie des Veys* barely benefit from their good production environment. The weakness of the Norman oyster identification on a French market dominated by the refined[2] oysters of *Marennes-Oléron*, reduces the main number of oyster farmers of the bay to the role of simple growers. And despite the fact that well-established local practices of oyster refining exist, and that the majority of the farmers of the *baie des Veys* have obtained their sanitary agreement for selling live bivalves[3], they remain dependent on outside outlets for their final valorisation and sales to consumption markets. About two thirds of marketable size oysters produced in the bay are not actually sold directly on final markets, but to oyster farmer-traders located in other regions, mainly in *Marennes-Oléron*.

Institutional and regulation aspects

The regulation of the oyster farming sector in the *baie des Veys* is obtained by a combination of two main systems: the first one applies at a national level, the second one at a local level.

On one side, the national legislation defines the general access conditions to maritime public grounds and the allocation regime of concessions. The status of bivalve farming concessions remains precarious, insofar as the related authorisation of production is delivered by the administration only for a limited period of time (about 35 years), and could theoretically be suspended at any time. But, in practice, the concessions are renewable, transmissible to family members or tradable in exchange for indemnities, and finally are very similar to individual transferable production rights.

On the other side, regional regulation systems, called Regional Structural Schemes (RSS), specify the farming rules in cooperation with administration, professional and scientific representatives. This regulation system aims at managing the common primary resources at the level of a shellfish farming basin or region. The RSS which applies to the *baie des Veys* is set up for the *Calvados* County only. It delimits the extent of the public maritime domain allocated to mollusc farming and specifies the nature of the concessions according to their use (farming or stocking) as well as the farming conditions according to the species. As concerns the cupped oyster, the RSS determines the main rearing parameters, such as farming technique (cultivation in bags on trestle), farming density (max. 6000 bags per hectare) and fixes the time periods for the operations of concession cleaning.

Moreover, the regional structural scheme defines a set of reference sizes for controlling the total surface of the concessions exploited by a company: the minimum surface at the first installation time, the subsequent minimum reference surface (required for enabling economic viability), and the maximum reference surface (required for limiting the concentration of “production rights”).

The RSS of *Calvados* has already been submitted for modifications since its creation, and is likely to evolve yet again with the current revision of the national legislation. Former modifications aimed at adapting the RSS to the evolution of the farming activities in the bay (notably the decline of mussel farming) and at managing more strictly the exercise of bivalve farming, in order to avoid overloading the farming zones. The trophic carrying capacity of the site was assessed in order to determine the limit beyond which cultivated livestock should not exceed. This management approach, which takes into account the carrying capacity of the bay, is worth mentioning as it represents a first step towards EAA that should be extended with the integration of economical parameters in modelling.

Biological and economic modelling

The problems that had arisen in bivalve farming management present some similarities with those well known in the field of fisheries. The existence of crossed externalities between producers sharing the same collective primary resource implies that when the economic rent is positive, the individual behaviour of each company consists in intensifying their activity beyond the social efficient level (Boncoeur and Troadec 2006). As a result, the well-known “race to fish” of fisheries applied to the shellfish farming sector can lead to productive overcapacities, the intensification of land use and thus to an individual increase of the primary productivity used. This overexploitation process leads in practice to a reduction in the growth function of the cultivated stocks and in long term to the decrease of the biomass produced. The OGIVE project aims at exploring efficient production trajectories of the shellfish farming sector by adapting both production and primary productivity capacities of respectively the companies and their milieu.

The OGIVE project relies on different tools developed according to three complementary steps. The first one consists of a GIS structure, which collects various data on a spatial basis (e.g. shellfish farming cadastre, environmental data, information about shellfish performance). The GIS tool enables the development of spatial indicators in order to answer various questions. The second tool is a biological, non spatial model of the ecosystem, which is used to assess the carrying capacity per area. Finally, the third tool concerns the development of a spatial ecosystem model thanks to the coupling of the former biological model with a spatial hydrodynamic model. This model has the objective to integrate the effects of different management options based on spatial planning optimisation.

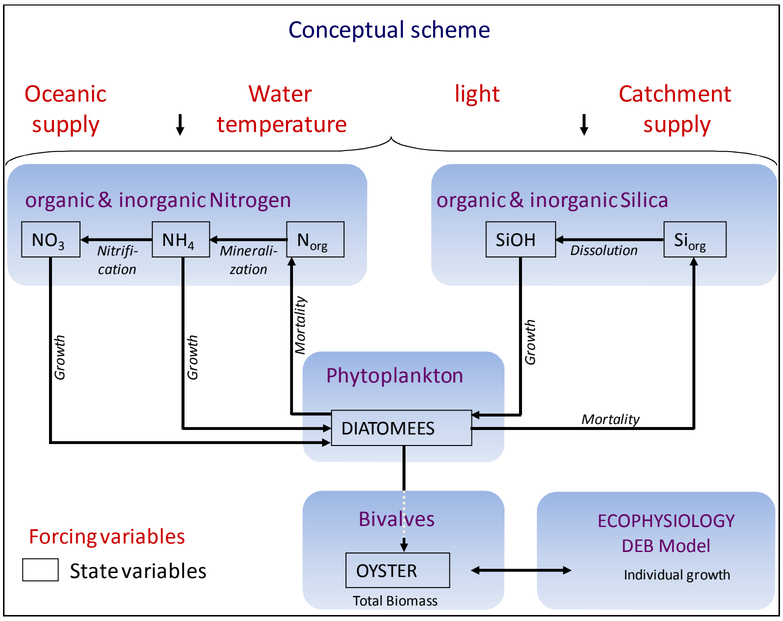


Figure 1. Conceptual scheme of the ecosystem model of the *baie des Veys*.

The conceptual scheme of the biological model is presented in Figure 1. The model reproduces the trophic interactions between the different compartments which sustain the shellfish production. Then, the model simulates the temporal variations of nutrients (nitrogen and silica), primary production (mainly diatoms) and cultivated oysters, which represent the state variables. Phytoplankton growth depends on nutrients and phytoplankton is in turn used for oyster growth. Forcing variables are inputs from the bay and the watershed, and also water temperature and light. Cultivated oysters are represented by a standing stock and their individual growth is simulated by coupling an eco-physiological model to the ecosystem model.

The economic dimension of shellfish farming modelling has been developed in recent research by taking into account the coupling of the ecosystem and economic dimensions (Nobre et al., 2009, Ferreira et al., 2007). The economic structure of these models is based on a neoclassic microeconomic approach which is built around competitive markets, price-taker producers, and profit maximisation of companies. The main objectives of these models are the optimisation of the shellfish farming rent by adapting the global carrying capacity of the ecosystem which basically refers to the capacity of the primary resource to be renewed. Other recent approaches are related to integrative modelling based on forecasting scenarios, in which the shellfish farming (or fishing) factor is considered as a component of a system (Engelen et al., 2003; Engelen, 2004, Pérez Agúndez et al., 2010 a,b). This type of frame enables the analysis of the dynamics of the global model by focusing on the different issues which threaten the global sustainability of the system and of the farming sector: environmental quality, eutrophication, freshwater availability, conflict of uses... The models developed under the OGIVE project clearly focuses on the first type of sector-based approach in which only internal sustainability is analysed. The non-spatial model was developed for the *baie des Veys* and used to assess the trophic carrying capacity (Gangnery, 2008). Results showed that the present oyster biomass in culture has an influence on the ecosystem and led to recommendation not to increase the standing stock. The spatial model is currently under development. It will be used to fine tune the first estimation of the trophic carrying capacity at the level of the bay and also to assess the carrying capacity on a local scale and, in turn, to test feasible scenarios of reorganisation of the shellfish area.

ANALYSIS OF THE OYSTER FARMER STRATEGIES AND CULTURAL PRACTICES

An ad-hoc survey has been carried out for collecting detailed information on the cultural practices of the oyster farming companies of the *baie des Veys*. The objective of the survey was not only to get data for specifying the parameters of the bio-economic model, but also to understand to what extent the strategies and practices of the companies are influenced by their structural characteristics, and in return, could determine their performances.

Presentation of the questionnaire and the survey method

The survey questionnaire was divided into three parts. The first part was dedicated to the collection of general data about the oyster farms, in order to characterise their factors of production, especially labour and “land” (number of concessions, localisation and total farming surfaces); to outline their whole strategy, in terms of farming and commercialisation; and to provide some basic economic results. The second part aimed at detailing the cultural practices of the farmer, through the description of the successive stages of oyster growing, from seeding to the harvest. Main technical data reviewed concern the density of oysters in bags, the number of bags, the frequency of sorting operations and transfers between farming zones, and estimations of oyster weight growth and mortality rates. The final part of the questionnaire was devoted to more qualitative issues, in order to understand the factors influencing the farming strategies of the companies, and to record the opinion of farmers about the collective management measures applied to the bay. It also included a section related to the perception of the farmers towards the future prospects of oyster farming in the *baie des Veys*. This latter was added to take into account the current economic situation of the sector, which has been confronted with high mortalities of young oysters, and to assess the adaptation strategies needed.

The population to be surveyed comprised of 63 companies in 2008. Available data from the DRAM (regional administration entrusted with the management of the maritime sector) provided information about the “land” structure of the companies and their geographical breakdown (in the bay/out of the bay). On average, each farmer has at his disposal 4 hectares of concessions for producing oysters, the majority of which (70% of the surfaces) is located in the *baie des Veys.* Indeed, these average characteristics mask discrepancies in surface allocation, which are mainly related to the geographical specialisation versus diversification of the concessions. The largest number of companies (55%) are specialised in the *baie des Veys* and take up about 3 hectares on average, while other non specialised companies take up 5 hectares, with nearly half of the surface in the bay and half out of the bay (mainly in other Norman oyster basins). These preliminary indicators suggest that growth strategies could partly rely on geographical diversification. Further data available concern the location of the concessions inside the *baie des Veys*. These data show that the zone called “Grandcamp” is the main site of production, as more than 90% of the companies exploit concessions there; on an exclusive basis for one half. The zone called “Géfosse” is also a significant site, but is characterised by high mortality risks, in spite of high productivity, and therefore is rarely exploited exclusively.

Finally, two criteria for sampling the population were selected with regard to the availability and the relevance of the data. Actually, it was deemed that both the size (defined from the surface variable) and the level of geographical specialisation were likely to influence the cultural practices and performances of the oyster farming companies. The concession breakdown inside the bay could have been an extra factor too, but was not precisely known a priori. The population of companies was therefore divided into two categories of size, determined by the median surface of 3 hectares, and split up again according to the level of reliance on the *baie des Veys*. A surface threshold of 25% out of the bay was defined for distinguishing on the one hand, the specialised companies, and on the other hand, the non-specialised or "multi-site" companies. A global sampling rate of about 30% was finally opted for, in order both to comply with statistical requirements and to take into account the given time for the survey.

Main results from survey data processing and analysis

The sample resulting from the initial segmentation and the implementation of the survey was finally made up of 4 groups: 7 small companies specialised "BDV" (versus 22 companies in the whole population), 3 small companies "multi-sites" (versus 10), 4 large companies specialised "BDV" (versus 16) and 6 large companies "multi-sites" (versus 15). Although the proportional allocation of the different groups was nearly achieved, we must bear in mind that the number of companies surveyed per group was relatively small, and therefore we can only highlight the most striking differences between the groups. Along with data processing, a set of indicators was defined for organising and analysing the data of the survey. Moreover, a statistical analysis was carried out for identifying the main farming profiles, as a combination of type of companies and production choices. All these elements are used in the following sections to characterise the structures, strategies and performance of the oyster farming companies, and to describe their cultural practices.

Indicators on the structure and strategies of the companies

The land structure of the surveyed companies is on average close to that of the whole population. These companies exploit a 3.7 hectare average (versus a 4 hectare average for the reference population) and are specialised in the *baie des Veys* up to 70% (idem). As concerns the survey, the surfaces of concession used by multi-site companies are globally higher than those of specialised companies (4.5 versus 3.1 hectares), but this difference is only apparent for the large company groups. Figures on labour, provided by the survey, indicate that the two groups of small companies employ on average 3.3 FTE (full time equivalents) compared to 6.5 FTE for the large companies. The allocation of production factors, measured by the ratio surfaces/labour, reaches an average of 0.76 hectare/FTE for the whole sample. Although this ratio turns out to be the highest for small multi-site companies, this result is not fully representative of the overall tendency, which shows the increase of the ratio with either the size or the multi-localisation of the concessions. In terms of level of production and turnover, the combined effects of the two factors culminate in the group of large multi-site companies which presents the highest output, in volume and value.

In parallel to structural variables, the farming strategies of the companies are described through their productive choices, and especially through alternative versus common choices. For instance, the selected indicators measure the degree of implication of the companies in "short cycle" farming or in the use of hatchery spat. The practice of "short cycle" farming does not finally appear to be very widespread, although half of the surveyed companies have declared to be concerned, but mainly in complement with "long cycle" farming. Neither does the purchase of spat from hatcheries constitute a common practice for the surveyed companies. The resort to hatchery spat enables a more reliable sourcing than wild spat, the supply of which is subject to high temporal variability. In the case of triploids, it is in addition driven by the expectations for enhancing the oyster growth, reducing the mortality rate and selling oysters all year round. However, the positive effect on mortality is contested by some farmers, while the impact on growth performances is considered double-edge, and likely to create sales disturbances on a seasonal market.

Table 1. Main indicators calculated from the survey (average for the whole sample and per group)

		Total	Small BDV	small MS	large BDV	large MS
	sample size	20	7	3	4	6
Production factors and level of production	Labour (FTE)	4 .9	3.8	2.3	6.3	6.7
	Surfaces (hectare)	3.7	2.2	2.2	4.5	5.6
	% surface BDV	70	94	48	91	53
	surfaces/labour (hectare/FTE)	0.76	0.59	0.96	0.73	0.85
	Production (tons)	130	74	65	136	223
	Turnover (1000 euros)	323	166	148	360	570
Strategies of production & commercialisation	% short cycle	16	10	54	15	5
	% hatchery spat supply	21	21	53	4	17
	% seasonality of sales	66	66	73	73	57
	% trade/production (volume)	31	13	0	37	40

On the other hand, the indicator about commercial strategies focuses on the level of involvement in trade. The share of production dedicated to final consumption markets is globally low for the whole sample, and even more for small companies. Conversely, the large companies achieve the valorisation of their production on a more significant basis. The average indicator of around 40% results in fact of the coexistence of companies selling most of their production and others not involved in trade or very little.
At the end of this brief overview, attention must be drawn to the group of small multi-site companies, which turns out to be relatively atypical, as regards their allocation of production factors as well as their implication in specific cultural practices (indicators “short cycle” and “hatchery spat” around 50% versus 20% in the whole sample) .

Identification of the main “farming technical itineraries”

A part of the survey was dedicated to scrutinize the successive operations involved in oyster farming. The production process on Norman sites starts with the spat sowing, at year N, and ends with the harvest of adult oysters at N+2. The period of seeding depends on the type and the size of spat, which is also influenced by the price conditions on the spat market. Wild spats or diploids from hatcheries are always put in bags before the end of the spring growth, while triploid spats are sown later, just before the end of winter, in order to harden the shell and to stimulate the spring growth the following year. At the seeding stage, the density of spat per bag was estimated to reach 2,000 on average (covering a significant variability) for wild spat, and to exceed this amount for hatchery triploids (around 5,000 per bag) as they concern smaller calibres.
Two sorting operations are generally carried out throughout the whole rearing cycle in order to reduce the oyster density in the bags as they grow and to constitute new homogeneous lots. At the end of sorting, both top-sized and bottom-sized oysters are put aside and dispatched to the appropriate concession for either boosting or curbing growth accordingly. The first period of sorting occurs mainly in spring of year N+1, sometimes before, and results in reducing density to around 450 units per bag. The second sorting is generally carried out the following winter, and the oyster lots are divided again to reach a final density of 210 oysters per bag, on average. In addition to the type of spat, the periods of sorting are influenced by the farming sites and growth conditions.
Transfers of cultivated oysters between different farming zones often occur after sorting operations. At the pre-growing stage, transfers concern especially the multi-site companies which relocate their production from the outside to the inside of the bay, to the farming zones of *Grandcamp* or *Géfosse*. On

the other hand, during the growing stage, transfers mostly take place inside the bay, with the *Géfosse* zone as a main destination (nearly half the companies carry out the second part of rearing there).
The period of harvest is also influenced by the choice in terms of seeding. For wild or hatchery diploid spats, the harvest mainly occurs from September to December of the year N+2 while triploid oysters are mainly harvested all summer round, for complying with the demand of sterile oysters[4]. At the end, the length of the whole rearing cycle is globally lower for triploid than for diploids oysters (on average, 23 months versus 30 months according to data survey) because they do not need energy to reproduce, hence saving energy for growth.

Finally, the main farming profiles identified by the statistical analysis resulted in a combination of type of companies (specialised or multi-site) and production choices in terms of type of seeding. The technical itineraries related to these farming profiles are presented in Figure 2. The first itinerary characterises the "traditional" farming activities which are specialised in the bay and based on wild spat seeding, with a variant from top-sized oysters directly cultivated at a lower density after a single sorting and sold nearly one year before the rest of the production. The second itinerary corresponds to multi-site farming which starts outside the bay and is then divided into different variants according to when the production is moved to the *baie des Veys*. The third itinerary is mainly defined by the use of triploid spat and is characterised by the shortening of the whole rearing cycle.

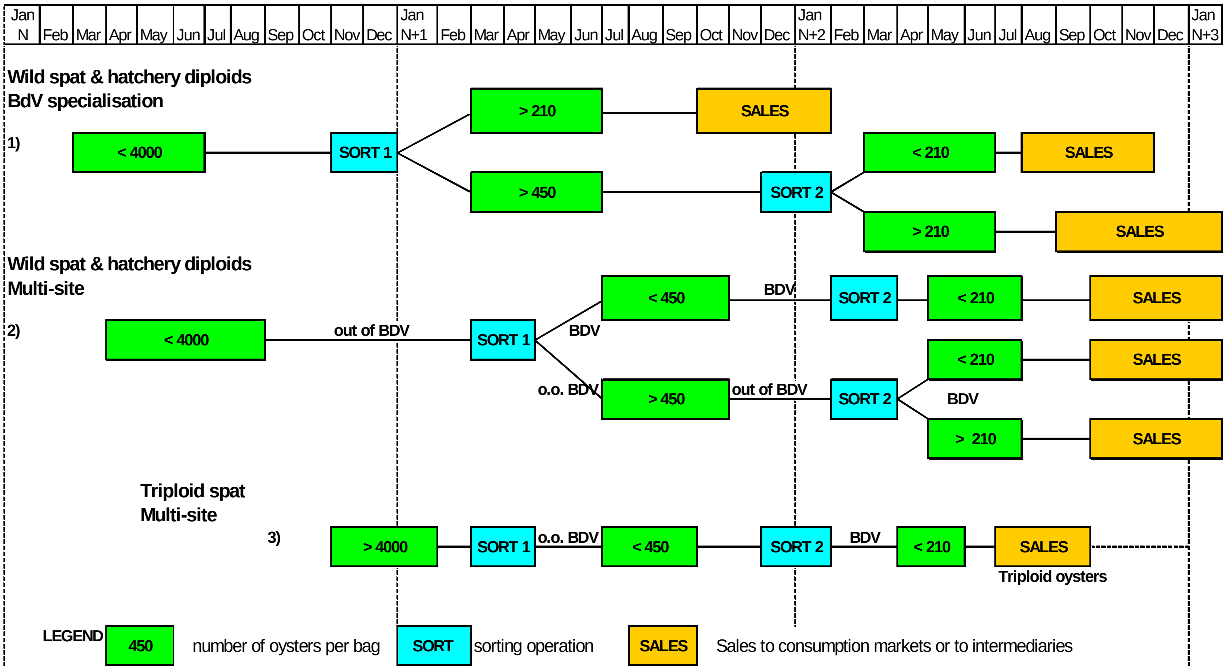
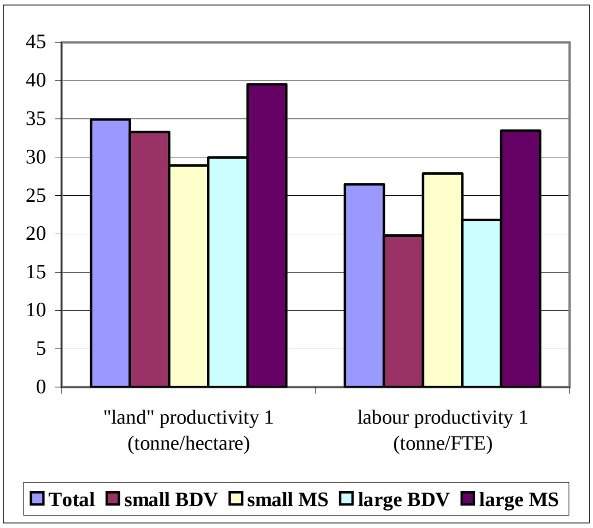


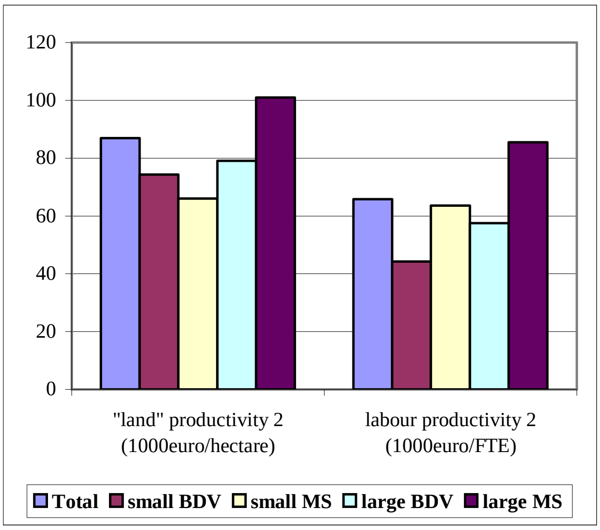
Figure 2: synthesis of the main technical itineraries used in the baie des Veys.

In parallel to the description of farming process, the survey collected data on technical performances. The main indicators reported here are the proportion of bottom-sized oyster estimated after sorting and the mortality rates, which are both likely to affect final output. On average, the rate of bottom-sized oyster was estimated at around 10% for the whole sample while the total rate of mortalities (during pre-growing and growing stages) reached nearly 30%. The comparison between company groups does not show convincing differences in technical performance. Neither the link between these indicators and the type of spat or the farming density can be demonstrated. Actually, it seems that the density of seeding could have a more determining impact on bottom-sized oysters than the farming density. As for the mortality rate, the main determining factor is related to the farming zone, with the *Géfosse* zone clearly emerging as the most affected by mortalities.

Indicators of productivity

The issue of economic profitability is addressed at this preliminary stage thanks to global productivity indicators of land and labour. Physical indicators correspond to the volume of production (expressed in tons) divided by the amount of production factors (respectively expressed in hectares and in FTE). Monetary indicators integrate in addition the average level of valorisation of the production and correspond approximately to the turnover (except resale) per unit of production factor.





Labour productivity 2 = Land productivity 1 x ratio surfaces/FTE x average price

Figure 3. Productivity indicators calculated from the survey (for the whole sample and per group)

The physical land productivity is equal to the yield of the total cultivated surfaces and results on both the intrinsic quality of the concessions and the farming conditions, among which are the cultural practices. This indicator is found to be significantly higher for the group of large MS companies (Figure 3).

The physical labour productivity is derived from the previous indicator, multiplied by the ratio surface/labour. Again the "large MS" group ranks first and is followed by the "small MS" group, for which it is worth emphasizing that weaker land productivity could be balanced out by the farming of more surface area per labour unit. In return, this determined the increased recourse to alternative cultural practice (e.g. hatchery spat and short cycle) in order to face a limiting amount of labour, as confirmed by the farmers themselves. This example illustrates to what extent the allocation of production factor could orientate the choice of cultural practices in view of optimising the quality and structure of land, as well as the amount of labour.

As concerns monetary productivity, the same tendencies among the groups could be observed. The lead of the large MS companies is even more marked, insofar as they do not only combine superior land yield and ratio surface/labour, but also provide a higher valorisation of production resulting from a higher implication in trade. Indeed, the economic efficiency is only approximated by the calculation of global labour productivity, and should be further assessed by taking into account the costs of production and commercialisation.

Notwithstanding, this preliminary approach highlights the links between the allocation of production factors and the economic results, and clearly points out the key role played by the land. Actually, from a quantitative point of view, the two main factors affecting the labour productivity are shown to be the global land productivity (correlation coefficient of 0.65) and the total surfaces exploited (0.62). The first correlation refers to both the quality of land (natural productivity) and the optimisation of concessions by farming strategies, while the second shows that the largest companies could generate economies of scales. Empirical evidence was in addition given by the perception of the interviewed farmers, who ranked first the land structure among the factors determining their economic profitability. Cultural practices (and productive choices) were ranked second, but they were also considered to be largely constrained by the quality of the concessions and the environment, albeit technical skills and years' experience in farming offer some breathing space for productivity enhancement.

The links between the structure, the strategies and the economic performance of the oyster farming companies are outlined in Figure 4. In a dynamic perspective, land strategies of growth or geographical diversification have been set apart from the whole farming company strategy, as they provide a possible way to improve the land structure and hence the economic results of the oyster farming companies. These strategies are indeed dependent on both land and financial availability.

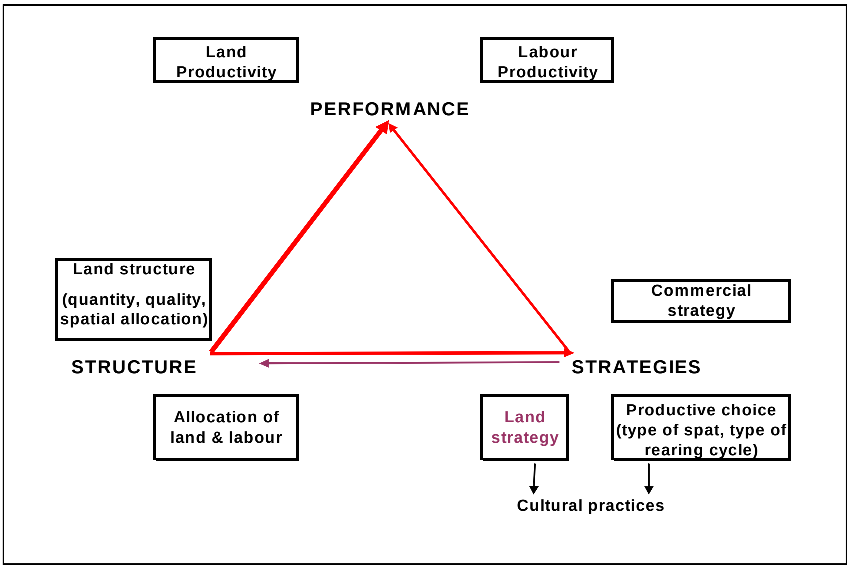


Figure 4. Synthesis of the interactions between structure, strategies and economic performance

DISCUSSION

The role played by land structure in economic profitability has already been emphasized in other oyster farming regions such as the Charente-Maritime (Girard et al, 2009), which are even more heterogeneous than the *Calvados* as regards the allocation of production factors, the quality and specialisation of concessions and the resulting productivity indicators. The strategies implemented by the Norman companies in order to optimise the use of their concessions also highlighted the importance of oyster transfer operations during the complete rearing process. The transfers, between different farming zones or inside the bay, were found to constitute an integral part of cultural and commercial practices, and finally a growth management tool at the company level, but they will have also implications in terms of collective management.

The survey carried out in the framework of the OGIVE project also contributed to the analysis of the farmers' perception towards the efficiency of the technical measures included in the regional structural scheme. In the current context of high mortalities of juveniles, the main measures to be discussed were related to farming densities, and especially the question about whether the regulation should be extended to the control of the oyster density per bag or not. Beyond this measure aiming at strengthening the current management and control of the whole farming biomass, the debate also focused on the issue of transfer regulation. Although opinions were divided on this subject, reflecting opposite interests at stake (economic/commercial/sanitary), the majority of oyster farmers agreed upon the need for restricting at least the transfer of oysters at critical stages (e.g. transfer of spat at certain periods).

Finally, the measures included in the *Calvados* RSS were considered by the local farmers to be rather efficient with respect to the objective of primary resource conservation. This general perception is however modified when broader objectives are taken into account and reservations were expressed concerning some critical issues which are not addressed by the RSS, such as water quality, recurrent oyster mortalities, land access constraints… Another matter of debate concerned the evolution of cultural practices resulting from the rapid development of hatcheries (in particular through the cultivation of triploid oysters) and the imbalance they can create on both oyster production and markets by modifying the growth parameters. This example highlights the need to adapt the regulation system according to evolving practices and to make the RSS even more compatible with principles of precautionary approach and adaptive management.

Through the OGIVE project, different management scenarios will be explored in order to integrate diverse technical itineraries and to assess the impact of changes in management measures. This scenario analysis involves firstly modelling the trophic carrying capacity as accurately as possible and will need thereafter to further integrate the economic and social dimensions. The spatial biological model which is under development is built thanks to a detailed spatial scale in order to reconstitute the shellfish farming cadastre, the biomass of the livestock cultivated and its evolution from the seeding until the harvesting process. In addition, the integration of a socio-economic module should be supported by the characterisation of the companies from a functional assembling of concession. This will enable the structuring of the spatial company's distribution and then the estimation of their capacities of production according mainly to the natural productivity of their concessions. Firstly, the spatial model should be extended to other Norman farming zones in order to achieve the modelling of multi-site companies. Secondly, this spatial analysis could contribute to the assessment of the shellfish farming rent and its distribution by the companies located in the *baie des Veys*.

In further perspectives of modelling development, the integration of oceanic and estuarine forcing variables will enable the integration of interactions between the shellfish farming sector and the external pressures coming from other anthropogenic activities. Negative externalities such as microbiological pollution, eutrophication, competition for freshwater allocation, spatial congestion, etc… represent major global issues which threaten the bivalve farming sector. This type of issue could be analysed under an integrated assessment and managed under an integrated sustainable approach.

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ENDNOTES

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[1] The "short cycles" focus either on the first stage of growing, either called "half-rearing" or pre-growing, or on the second one, called "rearing" or "growing". Conversely, the practice of "long cycle" covers the complete rearing cycle from the spatfall (where it is possible) or the sowing of juveniles to the production of adult, marketable sized oysters.

[2] Refining is a process by which oyster quality and commercial value are improved. Done either in open waters (in beds fully under the influence of the sea), or in claires, with molluscs having reached marketing size or still growing (FAO aquaculture glossary).

[3] According to the European legislation, a "sanitary agreement" is required to be allowed to sell live bivalve molluscs to final consumer. This agreement is delivered to the farming companies equipped with approved on-shore or off-shore installation for the reception, conditioning, washing, cleaning, grading and wrapping of live bivalve molluscs fit for human consumption.

[4] Many consumers do not appreciate eating oysters during the summer, due to the reproductive season, and so prefer triploid oysters, also marketed as "oyster of the four seasons".