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Oyster farming value chains in light of sanitary hazards: the case of oyster farmers

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2018/04

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Oyster farming value chains in light of sanitary hazards: the case of oyster farmers

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Abstract

Since the mid-2000s, the French oyster industry has faced hazards of various origins. The results of a field survey conducted under the “GIGASSAT”¹ ANR Agrobiosphere programme have highlighted productive changes in the oyster farming industry in the Bay of Bourgneuf and the Mor Braz area (Southern Brittany). Beyond this observation, one may wonder to what extent technological and biotechnological developments as well as environmental risks participate in the reorganization of production. In order to study this dynamics, we have relied on the theoretical concept of Porter’s value chain (1986) in the context of a value chain analysis.

The survey covered different topics such as the perception of oyster mortality causes, adaptation strategies in terms of supply, abandonment of offshore farming areas in favour of foreshore areas and economic performance in oyster farming. The analysis of oyster farmers’ operational activities raises questions about the existence of various types of value chains at the beginning of the period of study, which should be seen in the context of technological innovation, natural advantages and interactions with other actors. The survey also shows that in a sanitary crisis context, some oyster farmers question the configuration of their value chain from a survival perspective, whereas others maintain it. This work contributes to the identification and characterization of the various trajectories adopted by farms within the same sector in the face of environmental changes.

1. Introduction

Since the 1970s, epidemics, mass mortalities, harmful algal blooms and other population explosions have been occurring in marine environments at a historically unprecedented rate due to climate change. Several species of invertebrates of economic and ecological significance have been affected by mass mortality events [1][2][3]. Shellfish aquaculture

¹ <http://www.agence-nationale-recherche.fr/?Projet=ANR-12-AGRO-0001>.

is vulnerable to global warming because it increases the incidence of disease. In France, oyster farming is the most important aquaculture industry. However, this industry, which is based on the exploitation of the Pacific oyster *Crassostrea gigas*, is currently undergoing the most serious crisis since the introduction of the species in the 1970s. Severe mass mortalities of one year-old *C. gigas* have been occurring all along the French coast since 2008 and are thought to be associated in particular with a particular genotype of the Ostreid herpesvirus [4][5]. These mortalities have caused considerable concern among growers, associations and public authorities about the future of the French oyster production. In response to this problem, an integrated and participative research program with and on the oyster-farming industry was developed as part of the GIGASSAT programme, focusing on both environmental and socio-economic dimensions of the impact of climate change. The GIGASSAT project proposed to observe, analyse and help manage the effect of global change on oyster-farming ecosystems as regards animal health and physiology, the environment and economics.

This paper focuses on economic outcomes. The aim is to analyse the adaptation of shellfish farmers in relation with mass mortality events. The work was conducted in two geographical areas: the Mor Braz area (southern Brittany) and the Bay of Bourgneuf (in the Pays de la Loire region). The findings, based on accounting records and interviews, highlights performance-related productive changes among certain farms. Rearrangements of productive activities were put into perspective using Mickaël Porter's value chains [6].

2. Material and characteristics of the data

The GIGASSAT project was carried out in three French departments: Morbihan, Loire-Atlantique and Vendée (figure 1). These departments represent 11,257 tons of trade-size oysters and 51.4 million euros, accounting respectively for 15% and 13% of the national oyster trade. Within these departments, two areas were selected because of the concentration of oyster farms: the Mor Braz and the Bay of Bourgneuf.

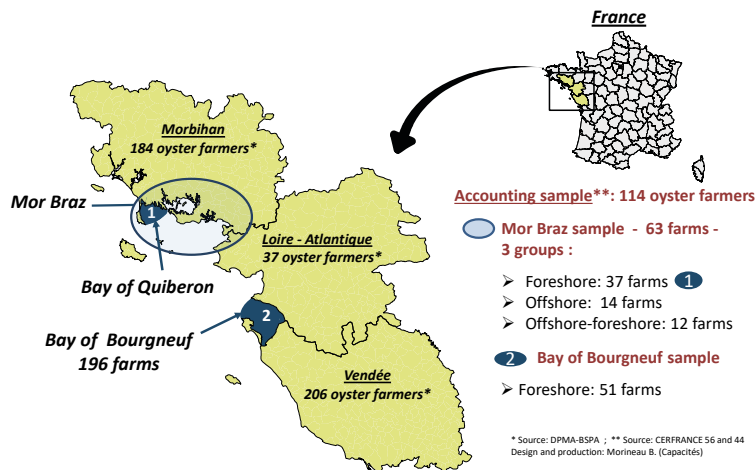


Fig. 1. Geographic study area

Adaptation strategies devised to cope with high oyster mortality outbreaks were analyzed using two statistical sources: accounting data and a survey. From a list provided by the regional oyster farming councils (CRC Bretagne Sud and CRC Pays de la Loire), 93 face-to-face surveys of oyster farmers were carried out in 2014, 44 in Morbihan and 49 in the Bay of Bourgneuf (Table 1). Two certified public accountants specialized in aquaculture (CERFRANCE 56 and 44) provided accounting and extra-accounting data on the 2006-2013 period. The sample is not constant and varies between 113 (in 2006) and 126 (in 2013) over the years. At the beginning of the period, the number of firms is lower because of unavailable data (no computerized data). The average sample includes 117 oyster farms (65 in Morbihan and 52 in Pays de la Loire).

Table 1

Survey and accounting data samples

	Morbihan	Pays de la Loire	Total
Number of oyster farms *	184	243	427
Survey sample	44	49	93
Sample / population (%)	24%	20%	22%
Oyster farm sample of accounting data	65	52	117
Oyster farm sample of accounting data / population (%)	35%	21%	27%
Oyster farms present in the two samples	44	42	86
Oyster farms present in the two samples	24%	17%	20%

* Source: Aquaculture survey 2011 - DPMA / BSPA and CERFRANCE

Regardless of the sources, the selection of the farms in the sample was built using selection criteria designed to obtain representative samples of the two areas. These criteria were developed during exchanges with the CRC and CERFRANCE 56 and 44. One of the most important criteria is the method of production resulting from natural conditions. In particular, the oyster farms are distinguished according to whether they carry out offshore or foreshore activities. The production tools, the know-how, the levels of investment or employment differ widely from one activity to the other [7]. The differences are fundamental, with a mechanized system on the one hand (offshore cultivation) and a more craftsman-like system on the other (foreshore cultivation). Other variables were selected so as to characterize the farms: smaller and bigger farms (in terms of oyster tonnage), single or multiple locations of leaseholds, farms which only rear oysters born in a natural environment, farms which only produce hatchery-bred triploids or diploids or oysters from mixed origins and ploidy oysters, younger and older farmers.

Using the accounting data, four clusters were built. Three groups are located in Morbihan: the first group is made up of 14 oyster farms which retained significant offshore activity during the 2006-2013 period; the second group includes 12 farms which retained a small offshore activity and developed a greater activity on the foreshore at the end of the period; the third group contains 36 farms cultivating oysters on the foreshore only. The fourth group is located in the Bay of Bourgneuf and counts 52 farms which cultivate oysters on the foreshore.

In this paper, we shall only focus on two groups, i.e those in which the variation of profitability due to environmental hazards is the most sensitive: the first group includes offshore oyster farms in the Bay of Quiberon (hereafter referred to as “OFBQ”) while the second group comprises those farming on the foreshore of the Bay of Bourgneuf (hereafter referred to as “FFBB”). Quantitative and qualitative data collected for 2006 (before environmental hazards took place) are displayed in Table 2.

Table 2

Statistics of selected variables (2006)

	Bay of Quiberon (OFBQ)				Bay of Bourgneuf (FFBB)			
	Mean	S.D	Min	Max	Mean	S.D	Min	Max
FTE (number)	4.81	2.02	2.00	8.32	2.09	0.92	1.00	5.11
Market size sales (tons)	187	122	56	421	32	19	4	112
Depreciation of capital (€)	46,205	26,879	21,024	96,854	15,060	10,605	1,851	51,491
Financial costs (€)	62,990	49,257	11,237	187,612	45,041	38,177	6,662	144,829
Value of shellfish stocks (€)	217,401	110,083	50,235	358,380	70,208	29,776	23,580	163,314
Debt ratio (%)	0.44	0.14	0.18	0.60	0.46	0.27	0.09	1.28

FTE: Full-Time Equivalent

S.D.: standard deviation; Min: minimum; Max: maximum

Source: calculated with CERFRANCE 56 and 85 data

For small-size farms, the average Full-Time-Equivalent employment in OFBQ is more than twice as high as in FFBB. The average market size sales reach 187 tons for the OFBQ sample, 32 tons for FFBB. In financial terms, the depreciation of capital and the financial costs are 1.39 and 3 times more important for OFBQ than for FFBB. 90% of FFBB is performed by family businesses compared with 17% for OFBQ. These different characteristics are related to activities.

3. Theory and application to oyster farmers

The research in this paper builds on research by Michael Porter. His work is well-known in the field of management. His research focuses on strategic policies adopted by organizations, mostly according to the idea of a value chain. This value chain was considered relevant in the study of oyster farms activities.

3.1. Michael Porter’s value chain

The performance of a farm is the result of two factors: the average profitability in that economic field, as well as its position in relation to the competition. This competitive

edge is the result of the core activities of the business and of the way these are handled. The generic value chain concept is displayed below (figure 2).

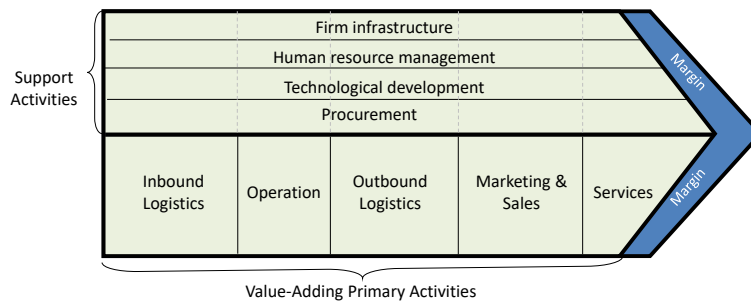


Fig. 2. Porter's value chain [6]

Primary (or core) activities relate directly to the physical creation, sale, maintenance and support of a product or service. They consist in inbound logistics, operations, outbound logistics, marketing and sales as well as services. These primary activities are a key factor in creating value. Support activities strengthen the primary functions above. Each support, or secondary activity, can play a role in each primary activity. The value created by a company is the profit margin which can be defined by the difference between the value created and the cost of creating that value. Michael Porter considers there are two different available groups of generic strategies. The first one is the cost leadership strategy: products are similar to those proposed by competitors but are on offer at lower prices. The competitive edge is due to the economies of scale resulting from mass production. The second one is the differentiation strategy: products are perceived as different and better than those proposed by competitors. This difference justifies the higher price of the products. Michael Porter considers that businesses have an interest in choosing either one or the other. The application of the value chain theory to the oyster industry makes it possible to highlight the different strategies implemented to cope with natural hazards.

In France, oyster farming requires leaseholds from the State and the payment of fees for the right to use parts of the maritime domain. The oyster farming industry produces live oysters of market grade for the final consumer. Different periods in the natural diploid oyster's life cycle can be highlighted (table 3). Once oyster larvae have attached to hard surfaces (collectors placed by oyster farmers), they are known as spat. When they have reached an adequate size, the young oysters are separated to be raised (on-growing). Usually, the oyster life cycle lasts about 3 years.

Table 3

Main periods in the life cycle of the natural diploid *Crassostrea gigas*

From birth until the market	Period
Collection of oyster larvae in the natural environment	July to September
Spat	1 year
On-growing	2 years
Marketable oysters	3 years

The whole of the generic operational activities in the industry are set out in figure 3. The oyster farming industry is meant to supply live oysters of a certain grade (market oysters) to the final consumer. The supply of oysters of non-market grade and the rearing of oysters to a marketable grade are always part of the chain of value. These activities can be defined as core activities. Maturing, which ensures flavour and fullness, and transporting between various production sites may not always appear in the value chain.

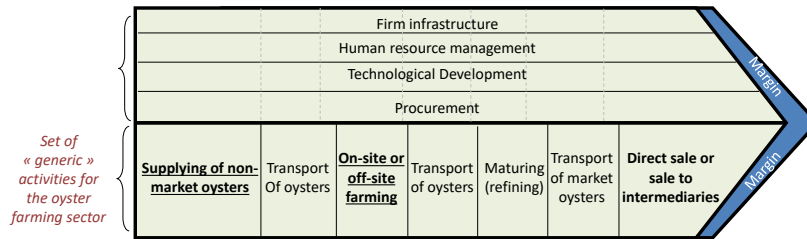


Fig. 3. Porter's value chain as applied to oyster farms

Regarding the sample, two different types of approaches appear to correspond to Porter's generic strategy: a cost leadership strategy on the one hand which can be distinguished from a differentiation strategy on the other hand. In light of their respective implementation of core activities, we find differences in the presence or absence of optional activities.

3.2. Application of the concept of value chain to the sample oysters farms

3.2.1. Value chain of off-shore oysters farms in the Bay of Quiberon in 2006

The value chain of offshore oyster farms in the Bay of Quiberon reflects past events. Formerly intended for fishermen, the Bay of Quiberon was, at the end of the Second World War, a new territory waiting for local shellfish farmers to raise flat oysters (*Ostrea Edulis*). In 1948, Marcel Thiéblemont-Colson, an oyster farmer in Carnac, explained why professionals became interested in the Bay of Quiberon: high producer prices and an overabundance of spat resulted in a shortage of land for raising and growing oysters on the foreshore [8]. However, the culture of *Crassostrea gigas* and the development of new techniques did not become a reality before the 1980s. Oyster farmers had to invest heavily in mechanization in order to facilitate their work in the Bay. For example, they experimented with shovels and water cannons to scatter small oysters in the leaseholds. These concessions were cleaned up with harrows and dredgers, ships were equipped with computers, in particular for bathymetric surveys, lifting and handling tools as well as storage containers were used, dredgers were purchased to lift crops on-board ships [9][7].

In the Bay of Quiberon, oysters are spread on the ocean floor and left there to grow. Although the method does not allow farmers to check on their development with each tide, it provides for faster growth. The characterization of the value chain (figure 4)

reflects an economic (highlighted in blue in figure 4) and technical consistency in relation with the natural environment (highlighted in red).

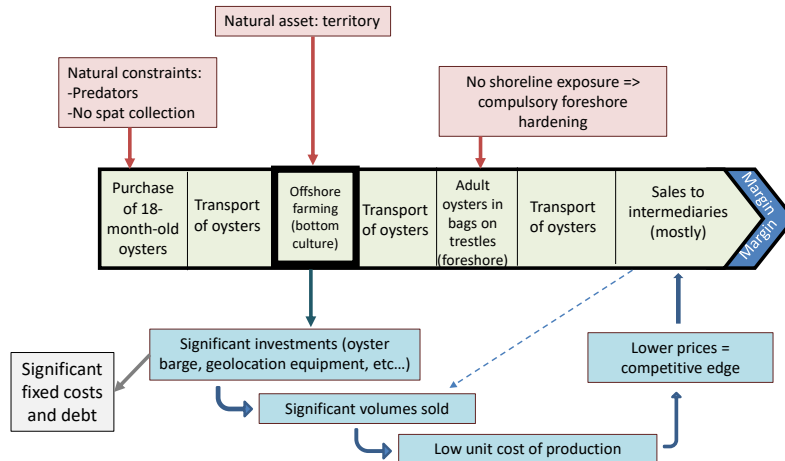


Fig. 4. Classic value chain of an off-shore oyster farm in the Bay of Quiberon (in 2006)

Offshore farming entails high-volume production. In order to derive maximum profit, farmers will structure not only the sales activity for strategic positioning purposes in a cost leadership strategy but also the other production activities in order to limit losses. The location of the leaseholds makes it necessary to spread oysters that are at least 18-months old in order to limit the losses due to predators such as spat-eating sea breams and starfish. The absence of natural collection due to water temperature means that farmers have to get supplies from other oyster farmers on other sites such as Marennes-Oleron or Arcachon (along the French southern seashore). Another constraint lies in the fact that oysters grown on the ocean bottom do not have muscles that are strong enough to withstand transport and dry storage before consumption. Hardening on the foreshore is therefore necessary.

Farmers not only need an oyster barge to farm offshore but also geolocation and diving equipment to be able to check on the growth of oysters. They also require dragging equipment for spat collection. Such investments and their funding will generate significant fixed costs (see table 2 for depreciation of capital and financial cost items). The unit cost of production will go down with the increase in volumes sold, which will allow farmers to determine a lower cost that will provide them with a competitive edge. To guarantee significant sales volumes, one must therefore favour sales to wholesalers and central purchasing organisations.

3.2.2. Current value chain of a foreshore oyster farm in the Bay of Bourgneuf

As regards oyster farms in the Bay of Quiberon, the activities were the result of natural environment and history (highlighted in red) and these resulted in a strategic choice that differed from the approach which the farms in the Bay of Quiberon opted for (figure 5).

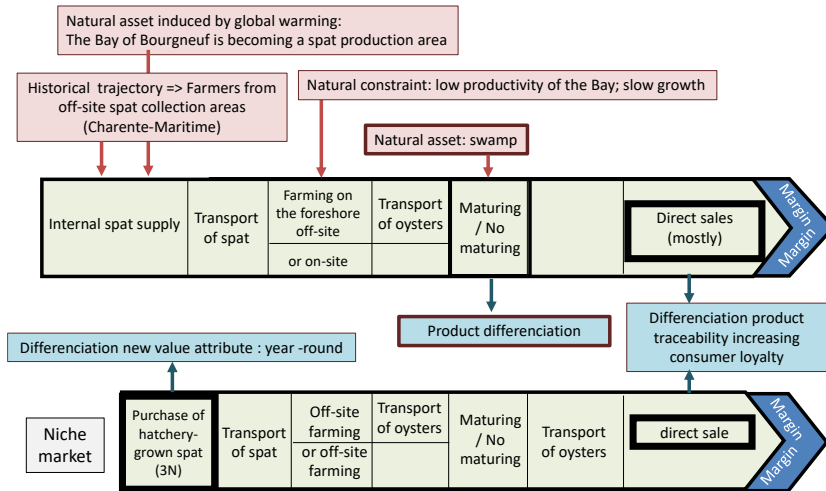


Fig. 5. Classic value chain of a foreshore oyster farm in the Bay of Bourgneuf

At the beginning of the 20th century, as in all places on the French coast, oyster farming was very intensive and soon, natural resources became exhausted. After World War II, because of lack of space, spat surpluses and insufficient growth, oyster farmers from Charente-Maritime settled in the Bay of Bourgneuf ([9][10][11]). Initially, oysters were sowed on the ground and then raised on tables. During the 70's, Portuguese oysters were decimated by a haemocyte infection virus and were replaced by *Crassostrea gigas* oysters. New problems appeared due to overloading, competitors and predators. An action plan to restore the Bay was implemented in 2003: cleaning up, restructuring of the areas of animal husbandry, predator removal.

Farmers in the Bay of Bourgneuf have kept their concessions in Charente-Maritime and supply their production sites in the Bay of Bourgneuf. These farms are thus autonomous in terms of spat supply. It is important to underline that global warming has made spat collection in the Bay of Bourgneuf possible. As the Bay of Bourgneuf has a lower productivity rate than other areas such as northern Brittany or Normandy, some farmers prefer to relocate their activity: most oysters are thus sent to these areas for faster growth and only come back to Bourgneuf for the last stage of farming. As a result, transport is a significant activity in this value chain as it covers several sites. It is also important to note that everything on these small-size foreshore farms is done by hand. Farmers make small equipment investments, have lower fixed costs, fewer debts and access to cheaper spat supplies than Quiberon farmers (table 2). It is an economic advantage that allows these farms to make a profit with less volume than the farms in the Bay of Quiberon.

The oyster farmers in Bourgneuf enjoy two competitive advantages:

- The first one is a tradition of direct sales. Direct sales to final consumers create a personal relationship based on trust. This is conducive to customer loyalty. Customers value direct contact with oyster farmers.
- The second one is the existence of a last phase of oyster production: the refining ("*affinage*") of oysters. This additional process, which consists in ending the rearing of oysters by a temporary immersion in marshland ponds ("*claires*"), provides a significant added value to the final product in terms of taste.

This activity generates product differentiation which allows producers to set a higher price. However, unlike other regions, the adoption of a brand or origin label such as a “protected geographical indication (PGI)” (for example: “Huîtres Marennes-Oléron”) does not reinforce this differentiation strategy.

Differentiation is also possible through the purchase of triploid spat from hatcheries. Triploid oysters grow faster than diploid oysters because of sterility. They are born in hatcheries throughout the year whereas natural collection is only possible in spring. These oysters can be sold all year round. This is a value attribute for some consumers. This value chain was a niche strategy in 2006. This gave oyster farmers a certain amount of leeway but on the downside, supply of triploid seeds is more expensive.

Explaining the two value chains of the sample farms reveals the impact of environmental hazards on these chains, especially as regards the outcome of environmental constraints. Dealing with environmental issues results in either more or less profitability. The sign of the success of a value chain is its capacity to generate profits. The accounting data analysis is relevant in showing lower or higher profits.

4. Results and discussion

4.1. Environmental hazards and financial results of 2 groups of oyster farms

Economic consequences vary with the type of environmental hazard affecting farmers. Table 4 summarizes the environmental risks that affected the sites monitored by the GIGASSAT multidisciplinary research program:

Table 4

Environmental hazards since the 2000's

Event	Bourgneuf (foreshore)	Quiberon (offshore)
Hypoxia: lack of oxygen in the environment		2006 and 2010: marketable oyster mortality
Vibrio bacterium		2006: adult oyster mortality
Predators: starfish, sea bream		Existed before 2006, but heavier impact owing to hypoxia and Vibrio bacterium which reduced the quantity of prey Impact: fewer marketable oysters
Ostreid herpesvirus	Since 2008-2014: spat mortality	2008-2014 : spat mortality

Over the reference period (2006-2013), offshore farms in the Bay of Quiberon were affected by more environmental hazards than those in the Bay of Bourgneuf. Hypoxia of

the environment, the *Vibrio* bacterium and predation reduced the quantity of marketable adult oysters. From 2008, comparatively high spat death rates resulting from oyster herpes affected both basins. The timing of these hazards affected offshore (OFBQ) and foreshore (FFBB) oyster farmers in different ways.

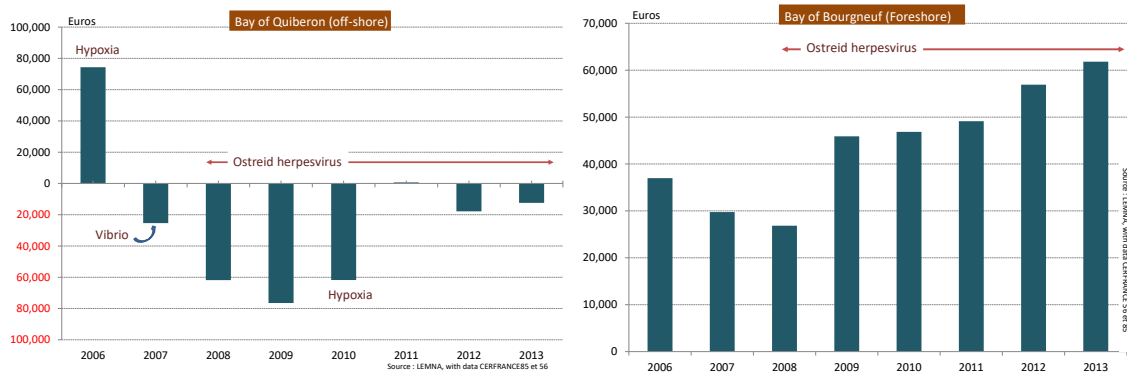


Fig. 6. Environmental hazards and consequences on operating results before State aids for the farms in the Bay of Quiberon (OFBQ) and the Bay of Bourgneuf (FFBB) (2006-2013)

The impact of *Ostreid herpesvirus* on the volumes sold was felt with a two-year offset corresponding to the duration of farming. On the other hand, the 2006 *Vibrio* bacteria outbreak had an impact on the 2007 results. In both cases, a first period of decline was followed by a period of recovery starting in 2010. But, as showed on figure 6, the financial results of the two groups contrast with each other. Offshore farms in the Bay of Quiberon (OFBQ) suffered losses over almost all the reference period. In the Bourgneuf area, foreshore farms (FFBB) were making profits which increased during the same period. Although these results may seem paradoxical, they express differences in terms of sensitivity to environmental hazards.

4.2. Transformation of the value chain as a prerequisite for the survival of offshore farms in the Bay of Quiberon

Between 2006 and 2013, two periods can be distinguished as regards the evolution of the main economic indicators.

4.2.1. 2006-2009: first impact

The combined action of predators, hypoxia and the *Vibrio* bacterium roughly caused a 40% drop in the volume of marketable oysters (figure 6). Sales decreased significantly in the wholesale market (170 tons in 2006 to 92 tons in 2009) due to the oyster shortage but also because of lower selling prices (1.53€/kg in 2009). The dependence on the wholesale

market remained but the percentage of sales in this main distribution network decreased from 83% to 75% of all oyster sales.

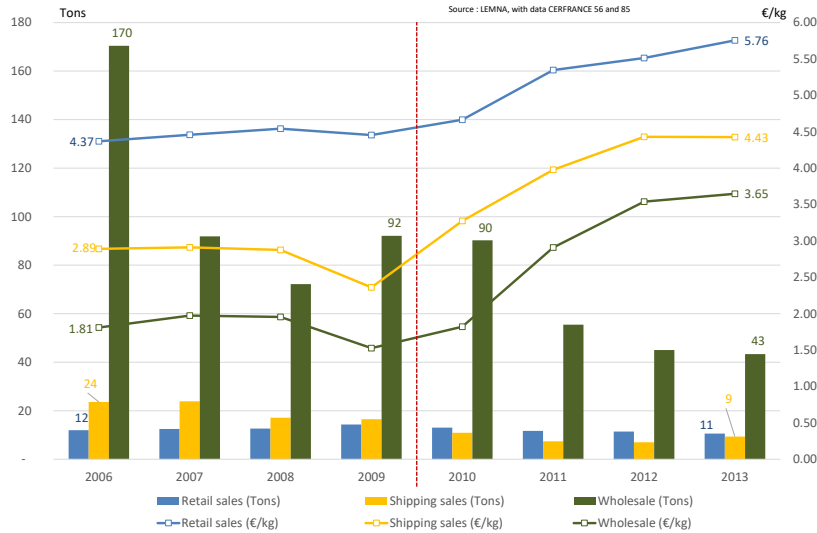


Fig. 7. Evolution of quantities and prices on retail sales, shipping sales and wholesale (2006-2013) for the offshore farms in the Bay of Quiberon

Given the stagnating prices during the 2006-2009 period, the turnover experienced a 50% collapse (figure 8), which resulted in losses.

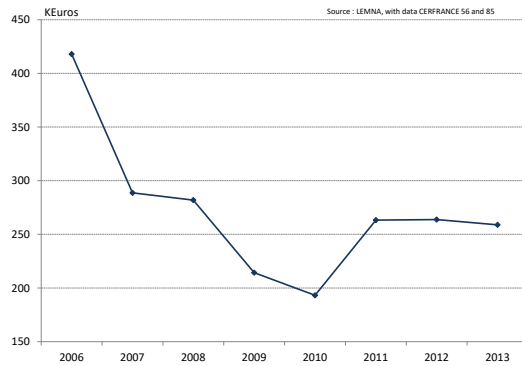


Fig. 8. Evolution of turnover (2006-2013) for the offshore farms in the Bay of Quiberon

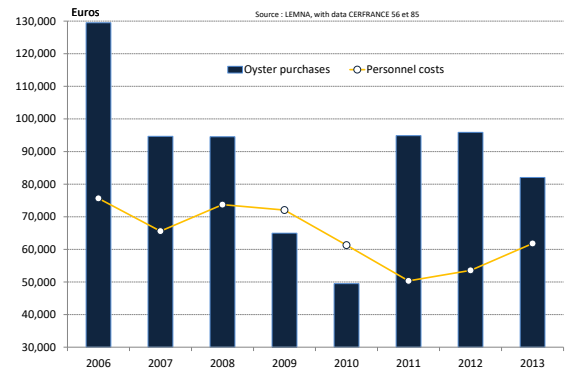


Fig. 9. Evolution of oyster purchase and personnel costs (2006-2013) for the offshore farms in the Bay of Quiberon

The cost leadership strategy can be profitable only if fixed costs are covered by sufficient volumes. Below a certain threshold, fixed costs become a liability that causes a very sharp drop in financial results. Due to the drop in profitability, farms withdrew from offshore activities, except those which had invested in cages so as to prevent predation. Farms began to transfer a part of their offshore activities to the foreshore as a means to avoid the effects of hypoxia and predation. With a limited supply of land, spat oyster purchases and the workforce had to be cut (figure 9). Losses reached their peak in 2009. State aids (figure 10) fulfilled a double objective: preventing the closing of businesses

and supporting risk mitigation measures (for example, redeployment of offshore activities, investments in cages).

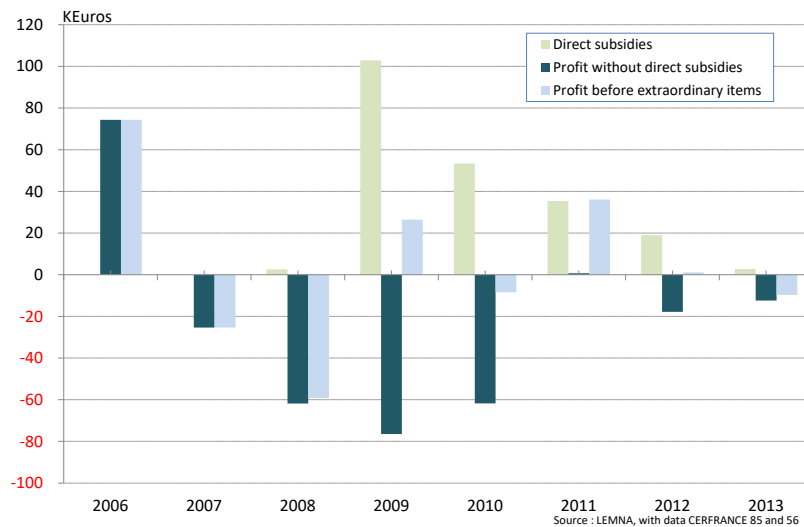


Fig. 10. Evolution of direct subsidies, profit without direct subsidies and profit before extraordinary items (2006-2013) for the offshore farms in the Bay of Quiberon

4.2.2. Second impact 2010-2013: Oyster herpes

Spat death rates in 2008 impacted sales in 2010 and the following years. The environmental hazard left no French production area untouched, which resulted in a supply shortage and a rise in prices. The reversal of prices, properly speaking, took place between 2009 and 2010 and translated into a price increase ranging from 29% (on retail sales) to 139% (on wholesale) over the 2009-2013 period (figure 7). However, the offshore farms in the Bay of Quiberon could only offer limited supplies because of the restricted foreshore areas where they relocated their activities. Another reason for this limited supply was the spat purchases that took place in the two previous years. Indeed, the smallest sales (2010-2012) correspond to the smallest purchases (2009 and 2010 - figure 9) made over the period with a two-year offset. Revenue did increase as a result, but that was insufficient (figure 8) to cover farming costs. To anticipate and make up for losses at the spat stage, natural or hatchery-grown spats purchases rose from 2011. This strategy was supported by State aids but farms had difficulties in maintaining a profit (figure 10).

In terms of financial structure, the farms still had to deal with the payment of interests linked to the financing of investments in offshore activities (table 5). The debt ratio increased by 7 points between 2006 and 2013 and reached 51% in 2013. Offshore activities generate important fixed costs which may in turn give rise to serious constraints from the moment the production level is reduced significantly. Some of these costs are unrecoverable, such as those related to oyster barges or the lifting cranes which are adapted for offshore activity only. Reducing company costs cannot be achieved by the sale of such equipment as it is required for production.

Table 5

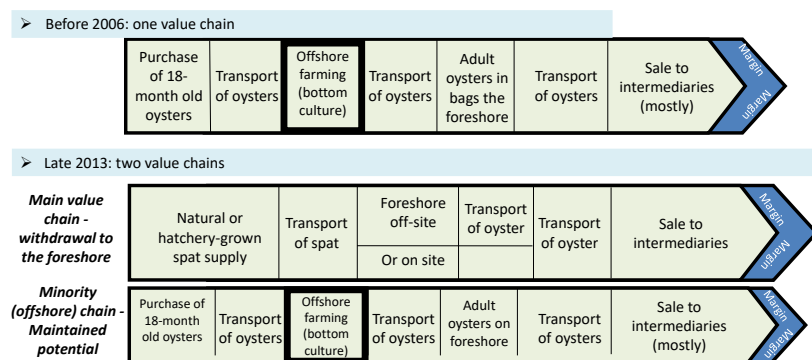
Statistics of selected variables (2013)

	Bay of Quiberon (OFBQ)				Bay of Bourgneuf (FFBB)			
	Mean	S.D	Min	Max	Mean	S.D	Min	Max
Full-Time Equivalent (FTE - nb)	3.33	2.22	1.00	8.00	2.34	1.22	1.00	6.77
Market size sales (tons)	60	46	7	42	38	34	0.21	183
Depreciation of capital (€)	41,758	33,766	6,784	123,890	22,656	21,752	0	98,593
Financial costs (€)	2,447	1,893	182	9,253	2,845	4,309	0	23,265
Value of shellfish stocks (€)	139,012	111,095	26,758	393,346	83,295	55,850	18,706	333,226
Debt ratio (%)	0.51	0.32	0.11	1.16	0.36	0.26	0.04	1.57

S.D.: standard deviation; Min: minimum; Max: maximum

Source: calculated with CERFRANCE 56 and 85 data

Regarding the activities in the value chain, the transfer of activity to the foreshore continued. Some farms internalised the supply of spat either by purchasing a concession in a collection area or starting a hatching activity (figure 11).

**Fig. 11.** Modification of the value chain of a foreshore oyster farm in the Bay of Quiberon before and after 2006

4.3. Maintaining the value chains of oyster farms on the foreshore of the Bay of Bourgneuf

4.3.1. First impact (2006-2008): no hazards

As regards the farms on the foreshore of the Bay of Bourgneuf, the first phase was characterized by an absence of environmental hazards.

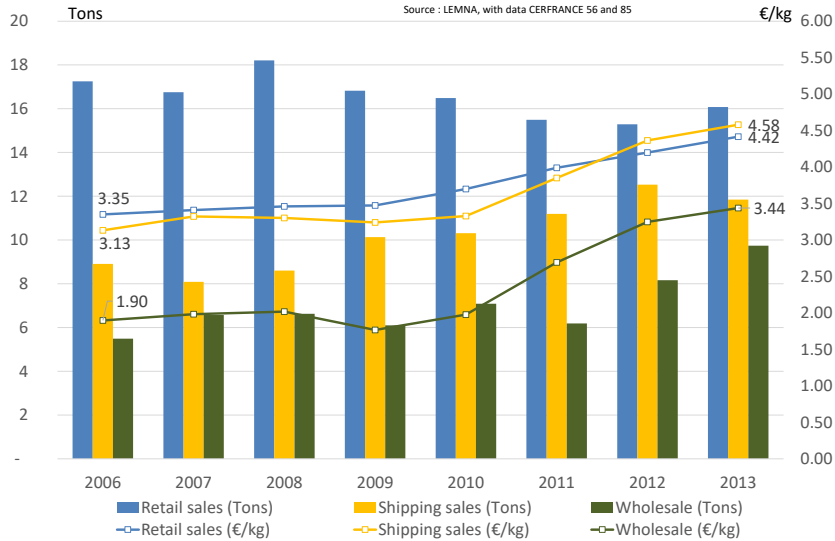


Fig. 12. Evolution of quantities and prices on retail sales, shipping sales and wholesale (2006-2013) for the foreshore farms in the Bay of Bourgneuf

The volumes sold remained stable and prices stagnated while changes in the distribution of sales per circuit caused a slight drop in turnovers (figure 12 and figure 13).

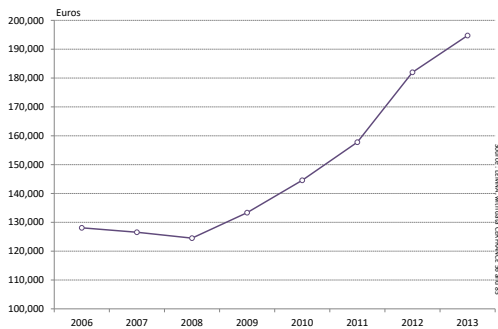


Fig. 13. Evolution of turnover (2006-2013) for the foreshore farms in the Bay of Bourgneuf

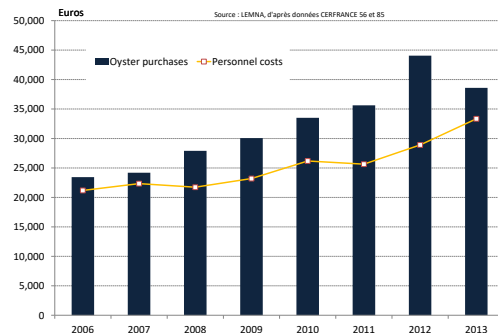


Fig. 14. Evolution of oyster purchase and personnel costs (2006-2013) for the offshore farms in the Bay of Quiberon

The Bay of Bourgneuf suffers from low natural productivity, which results in longer rearing periods. The ratio between the Bay of Bourgneuf and the most productive basin (northern Brittany) is around 1 to 1.4 ([12] and [13]). As a result, farms have been buying oysters in hatcheries to raise fast-growing triploids. Others have relocated their farming activities (northern Brittany), which requires truckload transport and therefore generates fuel expenses and investment. Overall, high diesel oil prices and low growth in the Bay combined with a slight drop in turnovers, which caused a drop in profits (figure 15).

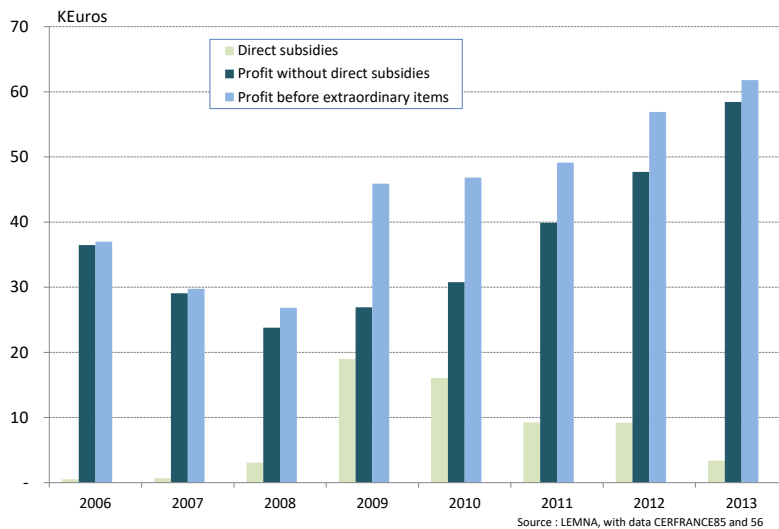


Fig. 15. Evolution of direct subsidies, profit without direct subsidies and profit before extraordinary items (2006-2013) for the foreshore farms in the Bay of Bourgneuf

The impact of oyster herpes revitalized the economic activity and generated profits.

4.3.2. Second impact (2009-2013): differed impact of spat mortality on adult oysters

The spat in the Bay of Bourgneuf were as affected by the herpes virus as the other areas in France. In order to deal with spat mortality, oyster farmers collected more spat even if this activity increased working time (figure 13). This was completed by increased purchases of hatchery spat to make up for the shortage outside natural spat collection periods. As the 2006-2009 period had been rather slow, oyster farmers had not used all the available production area. Now with a shortage of marketable oysters, the increased quantities (+19%) associated with high prices generated a 50% increase in turnover. Despite the supplementary costs of spat procurement, the aim of which was to secure an additional volume of marketable oysters that proved very lucrative in this context of shortage, profits before aids were multiplied by two over the period. As State aids are granted on the basis of spat purchase invoices, oyster farms also benefited from subsidies (Figure 15). The value chain of these farms was not altered but reinforced because it turned out to be profitable.

5. Conclusions and future research directions

The analysis of the financial results of two groups, one specialized in offshore production, the other specialized in foreshore production, shows that the impact of environmental hazards is not always synonymous with financial difficulties. In some cases, some oyster farms can benefit from opportunities. When the impact of the hazard is local and does not affect the national market, only the oyster farms in the affected area

experience financial difficulties. When the impact of the hazard is national and results in shortages and high prices, oyster farms which have the possibility to maintain or offer additional (even though modest) volumes clearly win out. For these two groups, environmental hazards were either an opportunity to make profits or a threat to their activity.

Within the value chain, the impact of environmental hazards is reflected in support activities (farm infrastructure, human resource management, etc.) and modifies the added value of primary activities. In the Bay of Bourgneuf, high spat death rates led farmers to strengthen their value chains. They control spat collection, which becomes a strategic activity in this case. This made it possible for them to maintain the volumes sold on a very lucrative market.

The Quiberon offshore value chain was more sensitive to the various hazards that affected the area between 2006 and 2013. The characteristics that made the success of the offshore value chain (location, production methods) require high volumes to be fully profitable. The decrease in merchandisable volume has jeopardised the viability of these farms, which have had to adapt their value chains.

This survival strategy was possible only because the farms already had leaseholds on the foreshore where they could carry out the hardening of oysters and because the farmers had the necessary know-how. Preserving a specific offshore value chain allows farmers to maintain their capacity to offer high volumes for sale when market and environmental conditions change.

In 2013 and 2014, spat death rates were less significant but oyster farms maintained their production volumes to make up for anticipated deaths of adult oysters. Where no deaths occur, the merchandisable volumes are likely to increase, which may result in lower prices and a decrease in profitability. A change in environmental conditions and their economic impact will most certainly redistribute the value chains in the oyster farming industry.

Such findings point out to further research directions which would, among others, take into account the modification of value chains (activities or the handling of activities) after 2013, whether it be for the two sample groups or for all oyster farms in France (for example, creation of a label, geographical identification of species, etc).

This research only takes into account the trajectories of two of the four clusters built with the accounting data. Further work should help better characterize the farms that remained offshore and those that redeployed on the foreshore. For example, do similar environmental crises account for the decision to cease or maintain offshore farming activities? It will be interesting to carry out a longitudinal study so as to show the link between environmental hazards and innovation in terms of technique, localization and changing shellfish species.

The chosen methodology is based on groups and average data. Furthermore, only one kind of actors (oyster farms) has been studied. The next research will be based on an analysis of the accounting data of each farm in the GIGASSAT sample with the productivity surplus method [14]. This approach will allow us to highlight the winners and losers among all the actors (hatcheries, customers, the State, etc).

In terms of support policy to the shellfish sector, different dimensions should be taken into account. The economic consequences of sanitary hazards are different according to territorial scale (local, national). The production methods, the duration of the production cycle, the cost structures of farms and the actors' behavioural latency constitute essential elements for efficient environmental risk mitigation.

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