SHELLFISH CULTURE IN FRANCE: PRESENT STATUS AND NEW APPROACHES TO OPTIMISE PRODUCTION

Dr Philippe Goulletquer

IFREMER, Shellfish Aquaculture Laboratory
La Tremblade, France

Abstract

France is presently one of the leading countries in Europe for shellfish production with 152,000 metric tonnes of the Pacific cupped oyster *C. gigas*, 2,500 tonnes of flat oyster *O. edulis*, and more than 60,000 tonnes of mussels *M. edulis* and *M. galloprovincialis*. Moreover, species like the pearl oyster *Pinctada margaritifera* in French Polynesia, and on the Atlantic coastline the scallop *Pecten maximus* and the Manila clam *Tapes philippinarum* contribute significantly to the overall landings.

Since traditional rearing areas are now almost overloaded, new management practices are currently under review to optimise and develop shellfish culture. Besides the products resulting from genetic research (e.g. triploids, tetraploids and disease resistant strains), zootechnical approaches have been developed: semi-intensive and intensive techniques in oyster ponds, longlines to sustain mussel spat recruitment and production.

At the ecosystem level, the need for potential new shellfish areas as well as increasing pressure for integrated coastal management plans prompted researchers to use GIS (Geographic Information Systems) to facilitate decision making. Several cases will be presented concerning deep water oyster culture experimentation and constraints related to the extension of mussel longlines field.

The French Shellfish Industry

The current situation of the shellfish industry in France is presented in Table 1, providing information about the landings as well as their exchange value and the number of packing houses involved. Total landings reached more than 218,000 tonnes in 1997. Oyster culture remains the leading activity within the shellfish industry. More than 4,500 packing houses specialise in mussel and oyster production combined. In the vicinity of the Marennes Oléron Bay alone, the shellfish industry employs more than 10,000 people (Figure 1). To characterise this industry, the difference between oyster and mussel culture must be emphasised: supply and demand is balanced for the former and unbalanced for the latter, since almost half of the yearly mussel consumption is imported (Goulletquer and Héral, 1997):

- Stable oyster production (150,000 tonnes/year) – Supply and demand balanced
- Increasing mussel production (>60,000 tonnes/year) – Supply lower than demand
- Oyster and mussel production based upon yearly natural spatfall (>95%) (Hatchery 5%)
- Scallop and clam production from aquaculture and fisheries industries.

Table 1. Overall Landings, Exchange Values and Packing Houses (n) of the Main Molluscan Species within the French Shellfish Industry in 1996

Species	Landings (metric tonnes)	Exchange values (£ million)	Packing houses (n)
Cupped oyster *C. gigas*	149,629	134.27	
Flat oyster *O. edulis*	2,500	8.89	4,500
Mussels *M. edulis* and *M. galloprovincialis*	61,962	45.19	
Clams *T. philippinarum*	400	1.83	1+50
Gastropods	1,100	1.69	–
Cockles	2,400	1.83	6
Scallops	150	0.3	(70)
Pearl oysters	6	85.38	20 (+500)
Total	218,147	279.39	5,150

( ) = secondary activity

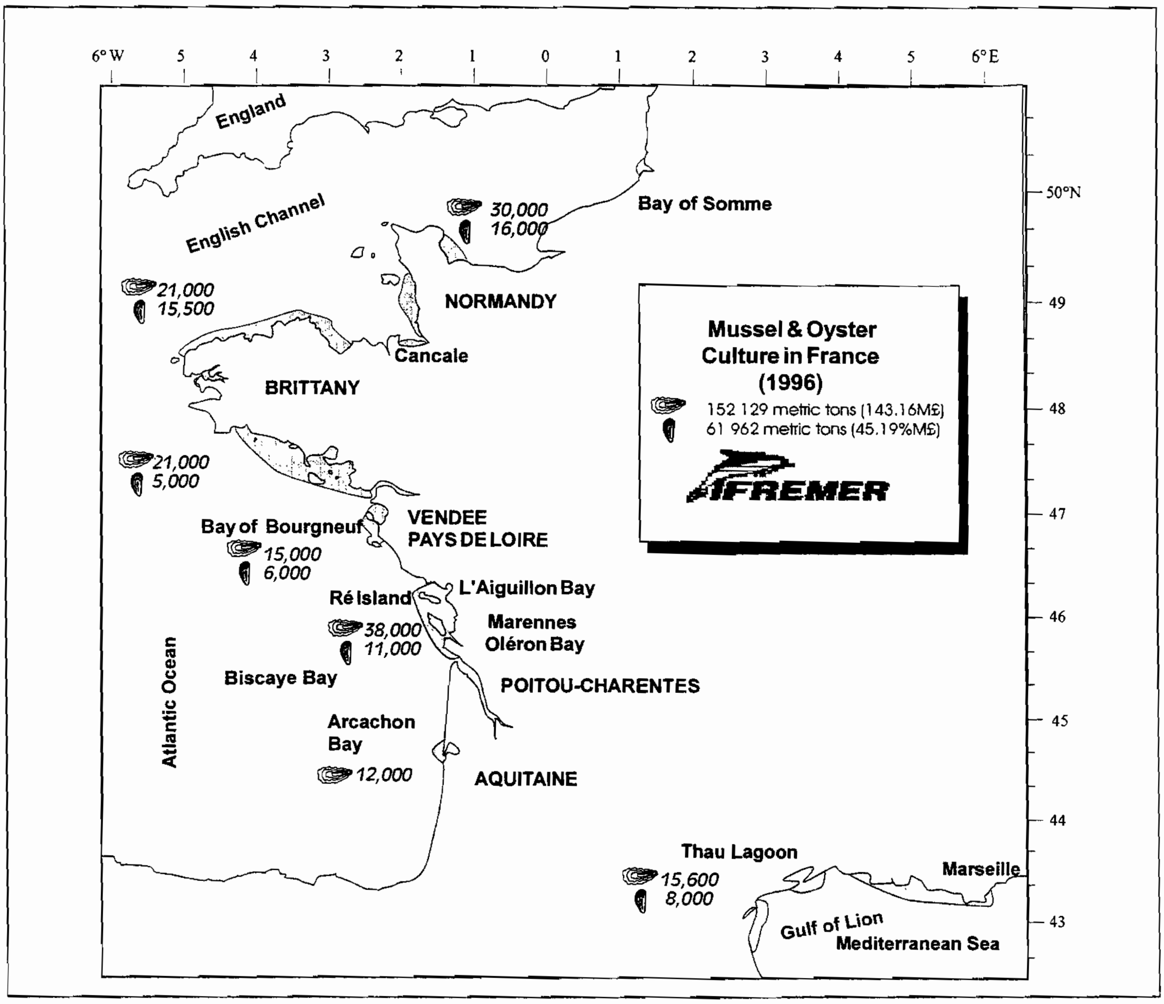

Fig. 1. Mussel and oyster culture in France: geographic distribution and overall landings in 1996

Therefore, strategies for these sectors are obviously different. The fact that most of the production is based on traditional culture, well established since the early part of the century in several areas, must also be emphasised. This is a key point in understanding the present activity which mostly relies on natural spat settlement (oysters and mussels) to sustain overall production (Figure 2). Spat settlement occurs consistently on a yearly basis in specific areas; the spat is then marketed and transported to rearing areas. The side effect of this tradition is that it has been difficult for new and innovative approaches and techniques to emerge and have a significant impact on common production. New approaches have to be incorporated into classical rearing cycles to be really successful. For example, only 600 million spat of *C. gigas*, and 50 million of clams were produced in 1996 by eight hatcheries and 25 nurseries. Their products have to compete with the natural spat which is available on a yearly basis. However, triploids and new genetic strains may change this pattern in the near future. Remote setting practices have been optimised but have been used only in areas located far away from the natural beds.

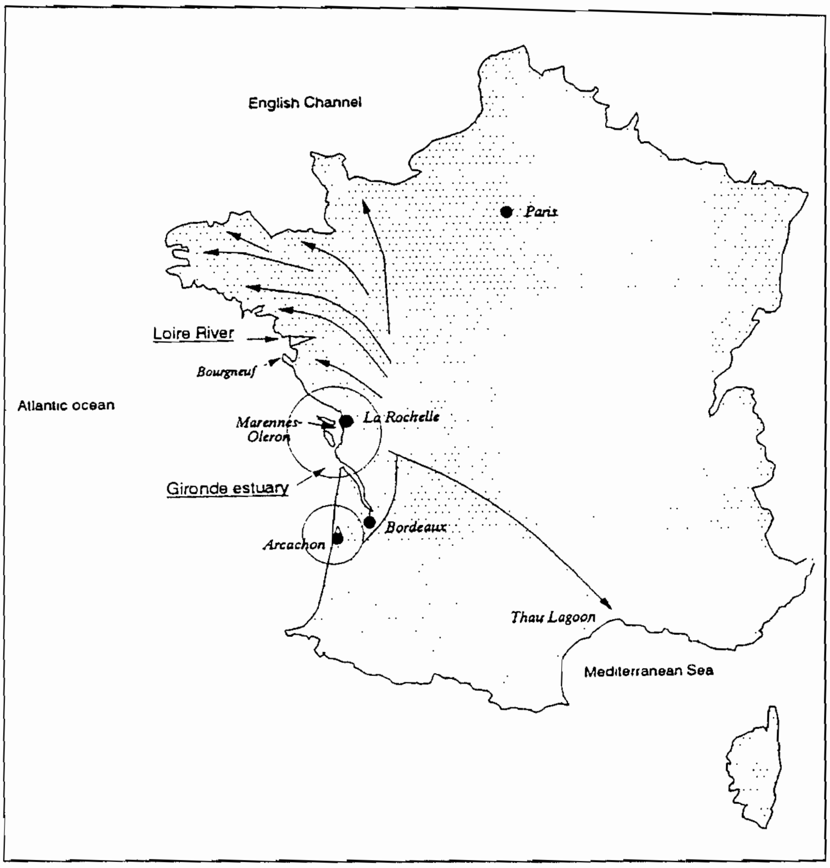

Fig. 2. Natural reproductive areas for the cupped oyster *C. gigas* and spat transplanting operations to sustain regional productions

Table 2. Advantages and Disadvantages of the Current Oyster Culture Industry in France

Advantages	Disadvantages
▸ Natural spat supply ▸ Shellfish industry well established in the coastal area ▸ Product quality	▸ Lack of diversification (monoculture) ▸ Marketing ▸ Overstocking - Production costs ▸ Integrated coastal management (Conflicts for space and resources)

Table 2 shows the advantages and disadvantages for a sustainable oyster culture, besides the obvious risk of disease not evaluated here. The main problems can be listed: poor marketing, overstocking which affects production costs and the increasing pressure over coastal management. The variability of the oyster selling price is characteristic of the difficulties at the marketing level, with a lack of recognition of the variations in shellfish quality (Figure 3).

With regard to mussel culture, the key point is that supply is below demand and increasing production is still one of the major priorities (Table 3).

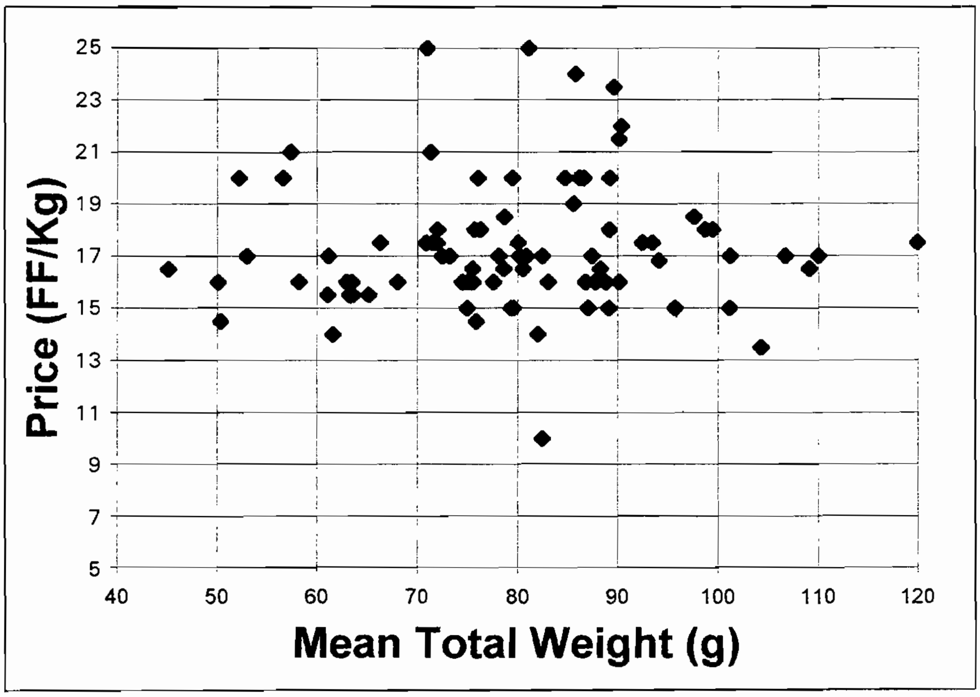

Fig. 3. Variability of oyster selling price during the 1997 winter season. The wide price variation demonstrates the marketing difficulties of the oyster industry *vs* production costs

Table 3. Advantages and Disadvantages of the Current Mussel Culture Industry in France

Advantages	Disadvantages
▸ Natural spat supply ▸ Mussel industry well established in the coastal area ▸ Demand > supply ▸ Product quality	▸ Marketing ▸ Yearly spatfall variability Production costs ▸ Seasonal supply ▸ Integrated coastal management (Conflict for space)

However, the supply is still seasonal with difficulties to expand throughout the year. Moreover, we have seen irregular spat recruitment during recent years.

How to address the current problems?

To address the marketing issue, the oyster and mussel industries have recently developed a major initiative in organising several 'OP', a professional organisation recognised by the EU. Its aims are to sustain and organise supply; facilitate market extension and advertise the products; recognise quality marks (label, certification, trademarks, etc); to sustain market prices. Besides that, we have seen also four new techniques to facilitate oyster shucking and therefore extend public consumption (e.g. perforated shell then waxed).

From a zootechnical point of view, three recent approaches can be presented resulting from R&D:

- ▸ Semi-intensive technique in traditional oyster ponds (fertilisers)
- ▸ Intensive technique for shellfish nursery - pre-growing and growing (underground seawater)
- ▸ Longlines to sustain mussel spat production, increase production and extend the market.

Semi Intensive Technique in Traditional Oyster Ponds ('Claires')

About 60,000 tonnes of oysters are marketed yearly following a stay in oyster ponds which can last one to three months. In the Marennes Oléron Bay, there are about 3,000 ha of such oyster ponds. This aims to improve the taste as well as the fattening of oysters in winter, before the marketing season. Unfortunately, the stay in ponds might affect the meat condition if temperatures are inappropriate and too high. A carrying capacity problem might emerge in these half closed ponds. With 20 oysters/m^2, and a seawater exchange every ten days, food might be rapidly depleted. To guarantee the oyster meat quality and an appropriate yield, several oyster farmers have developed a new technique by inducing phytoplanktonic blooms using fertilisers in winter time (Figure 4) (Le Moine et al, 1997; Hussenot et al, 1998).

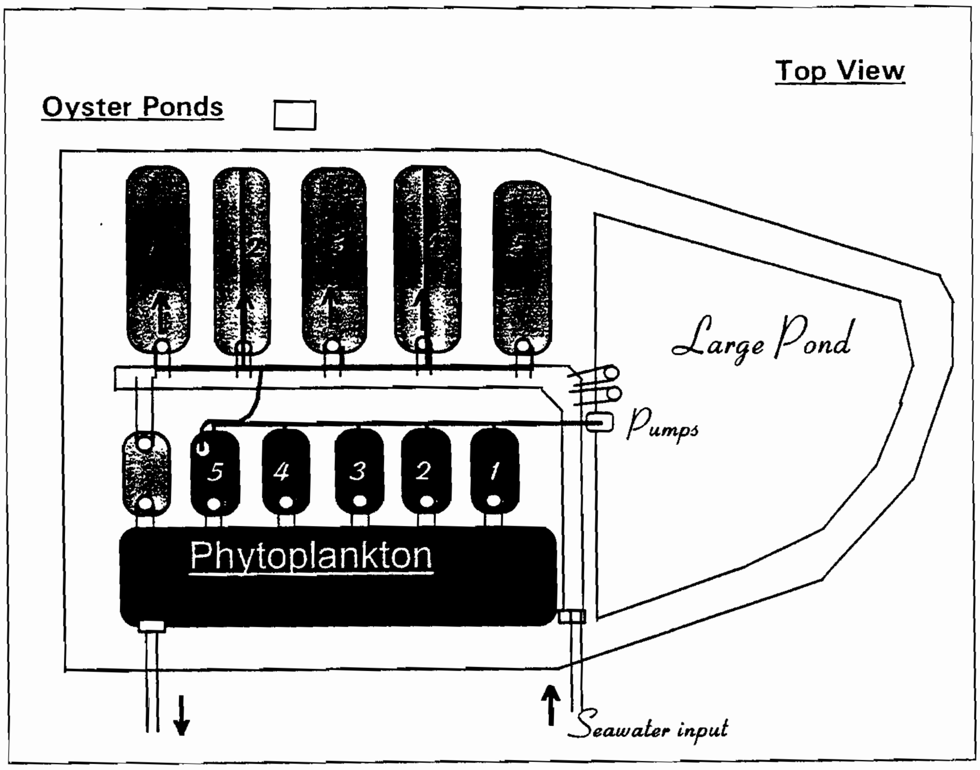

Fig. 4. Characteristics of optimised oyster ponds (top view)

This can also be used for developing the diatom *Haslea ostrearia* responsible for oyster gill greening (Turpin and Robert, 1998). The market value peaked when greening occurred. Phytoplankton is distributed by gravity. R&D has provided the optimised nutrients formula to induce the blooms without side effects on the environment (Table 4).

Table 4. Fertilisers for a 100m³ Phytoplankton Culture (500,000 cells/ml)

▸ Ammonium chloride	808 g
▸ Tri Potassium phosphate	240 g
▸ Sodium metasilicate	1,591 g
▸ Iron chloride	41 g
▸ Manganese sulphate	27 g

Culture can reach a concentration greater than 1 million cells per ml and a total volume of plankton of several 100m³ a day (Figure 5). Phytoplankton distribution has a significant effect on improving oyster meat quality (Figure 6) (Le Moine et al, 1997).

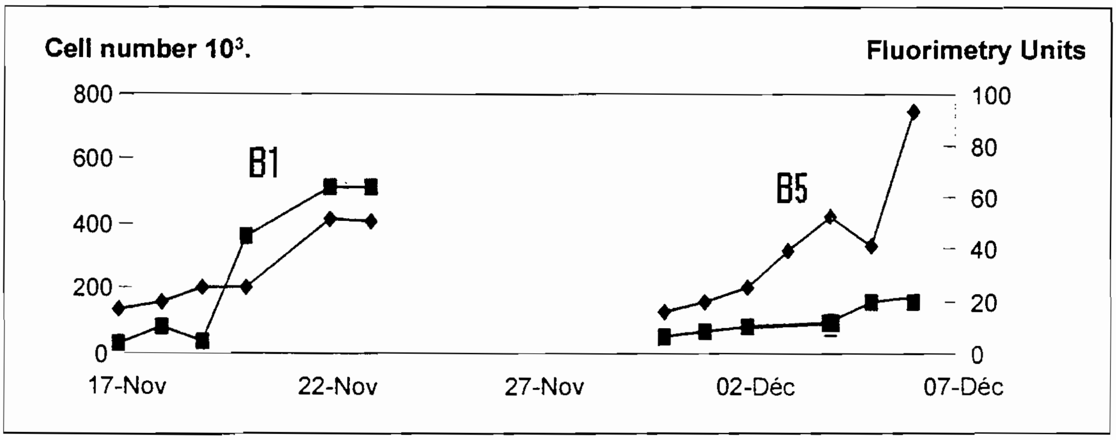

Fig. 5. Example of phytoplankton culture obtained in winter time

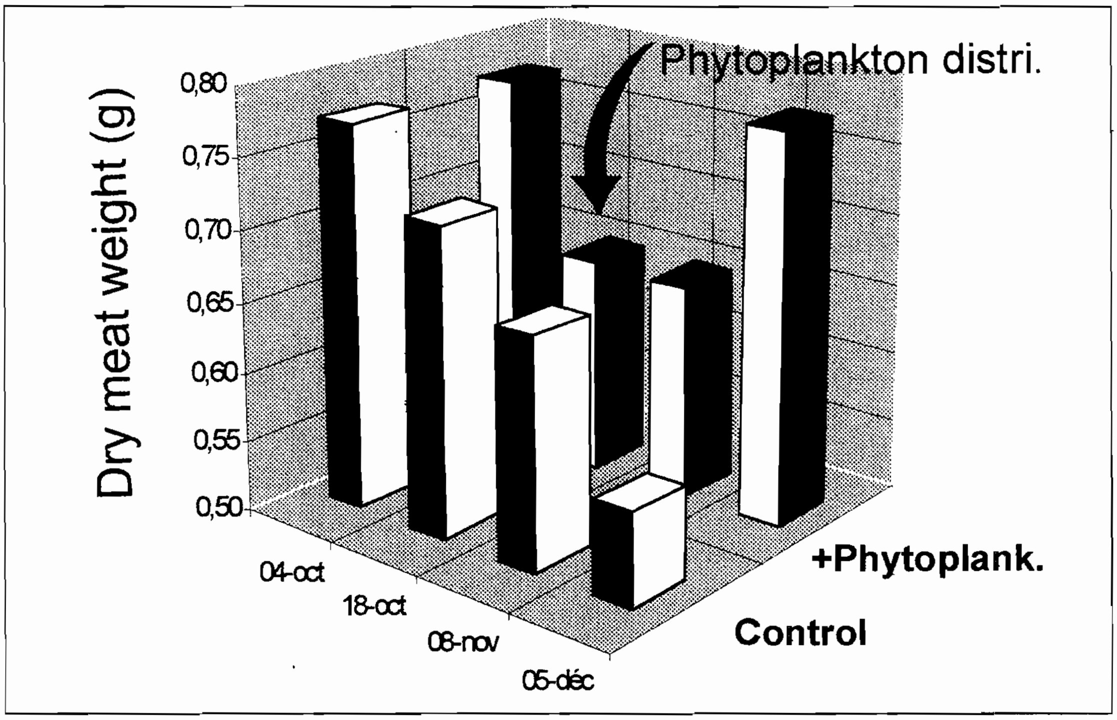

Fig. 6. Effect on oyster dry meat weight of added phytoplankton in ponds

Intensive Technique for Shellfish Culture

Table 5. Characteristics of Fossil Underground Seawater

- Temperature 13.5°C
- Salinity 30.4 ppt
- pH 7.25
- NO4+ 307.5 NO2 - 0.2 NO3 - 0.3 μmole/l
- PO43 - 24.6 Si03 - 178.9 μmole/l
- total Fe 3.3 mg/l

This intensive technique for shellfish nursery, pre-growing and growing, is based on the use of underground fossil seawater which has constant characteristics, high temperature, high nutrient loads, no bacteria (Baud et al, 1995) (Table 5).

This seawater can be used for several purposes including heat exchange, and as a medium for phytoplankton culture.

Several companies, hatcheries and nurseries have based their production on that technique. Primary production can be maximised and a large volume can be produced for a very limited cost (Table 6). One company can produce about 200m^3 of phytoplankton a day.

Table 6. Characteristics of Phytoplankton Culture

▸ Cell number	1,476.10^3/ml
▸ pH	8.51
▸ Partic. organic matter	40.25mg/l
▸ Chlorophyll a	601.5μg/l
▸ Pheopigments	119.2μg/l
▸ Proteins	14.6mg/l
▸ Lipids	4.8mg/l
▸ Carbohydrates	10.9mg/l

It takes about three days to reach the plateau (1.4 million cells/ml) between March and November and five to six days in winter. The large volume allows a food distribution in concrete tanks with high shellfish densities. Rearing stages for clams, flat and cupped oysters are under controlled and well defined standards.

The Use of Longlines for Mussel Spat Production

Table 7. Traditional Spat Settlement Techniques in France

- ▸ Use of coconut fibre rope within the intertidal area (only source of spat)
- ▸ Deployed in March/April for spat settlement in May/June
- ▸ Average settlement density = 6,000 ind./m
  - range: 30 to 14,000 mussels/m
- ▸ Present trends:
  - Decline and irregular natural spat settlement
  - Stocking biomass drastically reduced by limited spatfall in 1989, 1990, 1991, 1992

Commonly deployed in March within the intertidal area, kilometres of coconut fibre rope represent the supply for the whole French blue mussel production (Table 7). Following decades of sustainable spat supply, this production decreased at the end of the '80s, followed by a drastic decline in stocking biomass and mussel production along the European coastline during the '90s. To address the problem, mussel farmers have developed offshore culture using longlines (Table 8).

Table 8. Longlines to Sustain Mussel Spat Settlement and Production

- ▸ The case of L'Aiguillon Bay
  - Climate changes have affected mussel spat settlement within the intertidal area
    - temperature+wind+sunshine+moisture
- ▸ To address the problem
  - Subtidal culture in a more stable environment
  - Since 1991:
    - 241 longlines offshore (each 100m long)
    - 431 km of rope for spat settlement
    - 1 longline=1.93 km rope=4.88 tonnes spat
    - 2 spat recruitments a year (instead of 1)
    - + 1,000 tonnes of marketable size

This approach limits the environmental impact on spat since they are always submerged in a more stable environment. Since then, spat production has increased and represents a steady and more reliable supply for local farmers. Besides that, pre-growing can be done directly on longlines, improving the stock rotation and biomass (two spat settlements a year). Since the growth rate is particularly high, marketable size can be reached within a year and has prompted farmers to develop a second market. The marketing season starts earlier with these products (the gain is about one month), therefore expanding the seasonal supply. This technique has not replaced the traditional one, but has been incorporated into the traditional rearing cycle.

Research and Development

There are several ongoing research programmes to sustain the shellfish industry, particularly genetic projects focusing on studying the genetic variability of *C. gigas* worldwide populations to select 'better' strains (assimilation rates, temperature), to assess relationships between growth rates and genetic characteristics, and also to develop triploids and tetraploids (Gerard, 1998). The latter ones were recently obtained at the IFREMER laboratory (La Tremblade). These programmes are critical when considering the problem of overstocking, carrying capacity and therefore management issues. A comprehensive research programme has been developed on shellfish quality (Grizel, 1998). Ongoing programmes focus also on the disease resistant flat oyster strain *O. edulis* (against *Bonamia*) as well as on the life cycle of *Marteilia* sp, and the search for intermediate hosts. Great improvements against *Bonamia* have been obtained which might facilitate a future production rebound for this oyster species.

Similarly, ecosystem modelling remains one of the critical research programmes to optimise shellfish production, especially when considering the stocking biomass around the bays and the feasibility of new developments. By way of example, 'freshwater inputs' modelling at the Charente River provided information to decision makers to build a dam on the watershed so as to sustain the fluxes of nutrients in summer time, then to facilitate primary productivity and spat settlement.

Table 9. Current Research Programmes Related to Summer Mortalities of the cupped oyster *C.gigas*

- ▸ Concomitant approaches to address the issues
  - Physiology
    - relationship with reproduction status
    - effects of stressful conditions (temperature) - (juveniles selection at the nursery level)
  - Ecophysiology
    - environmental parameters/mortality rates/*in-situ* monitoring of oyster activity (multifactorial)
  - Pathology
    - Monitoring network (> 12,000 analyses in 1997)
    - PCR probe development (Herpes like virus)
    - Experimental contaminations

A comprehensive research programme has been developed to focus on cupped oyster *C. gigas* summer mortalities at juvenile and adult stages (Table 9). First of all, on that matter, it is important to develop sampling strategies to assess quantitatively the mortality rates. This is challenging since we do not see extensive mortality but small patches which might cause variations in the farmers' yield. Last year the mortality rates were limited, probably resulting from less stressful environmental summer conditions. In addition to the previous aspect, the monitoring pathology network has increased the efforts in terms of spatial coverage and analysis number. More than 12,000 analyses have been carried out so far. Several approaches have been developed to study these mortalities which are in almost all cases related to stressful conditions for oysters. Sub-projects include assessments of the relationships between physiology and temperature stress, and the reproductive status which is a critical factor (Soletchnik et al, 1997). The cupped oyster ecophysiology focuses on the relationship between environmental factors and population status (Figure 7). In these cases, *in situ* and continuous monitoring of environmental parameters as well as population activity (valve activity) are performed to provide a multifactorial assessment. With regard to pathology, an Herpes-like virus (HLV) has been detected since the early '90s in several rearing areas sometimes but not systematically concomitant to abnormal mortality rates.

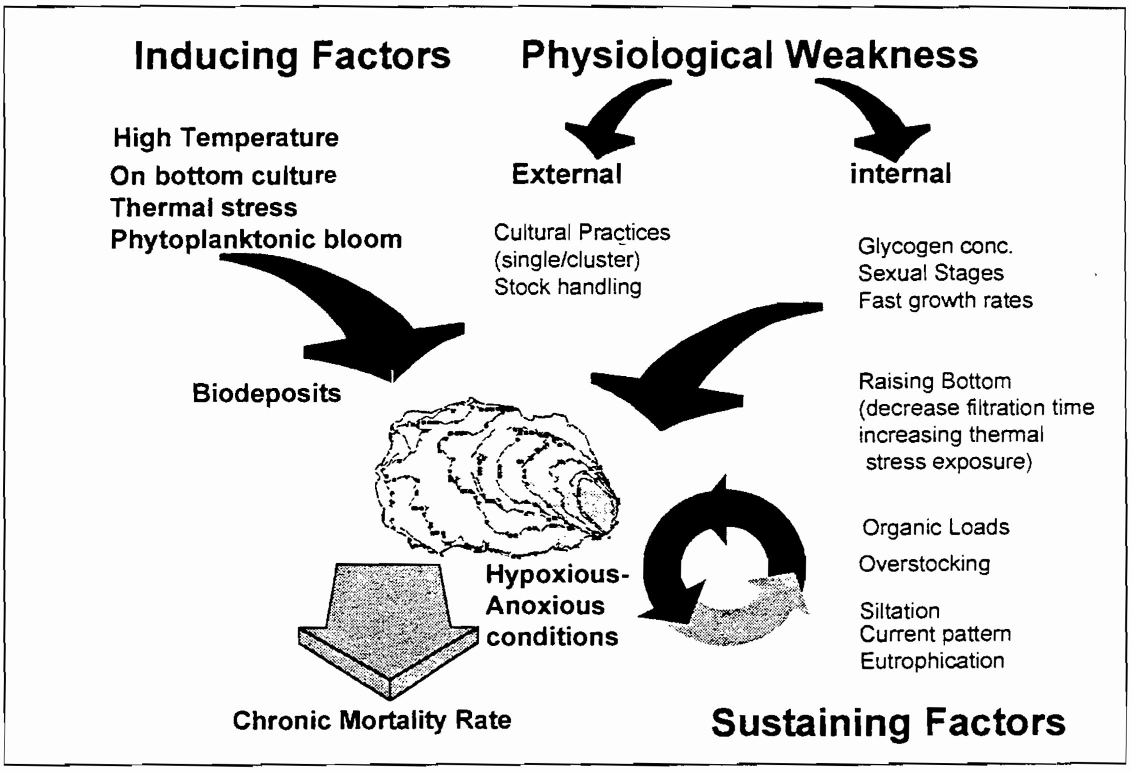

Fig. 7. Variables included in the monitoring programme on the cupped oyster *C. gigas* summer mortality (LCPC La Tremblade 1998)

Experimental contaminations have been carried out successfully at the larval stage, but no effect has been observed at the juvenile stage. PCR probes have been developed and improved at IFREMER La Tremblade for several years to assess more effectively the presence of this HLV. As the European reference laboratory for shellfish pathology, a workshop was organised last fall in La Tremblade to train and provide the tools to union members (nation reference labs) to assess the status at the European level. It must be emphasised that HLVs had already been observed in other countries such as New Zealand and Korea.

Integrated Coastal Management

To improve the ecosystem management and production costs it is critical to assess and develop new rearing areas. By way of example, it seems logical to optimise spatially the distribution of rearing areas while decreasing the overall stocking density. However, it has to be done in a way limiting the impacts on the current rearing beds. To do that, Geographic Information Systems are under development to provide insights where and how new rearing beds can be developed. By way of example, the case of the deep water oyster culture near the Bay of Marennes Oléron required an overlay of more than 25 layers of information (e.g. environmental, biological, regulatory, fishing activities) to assess new potential areas. Similarly, a request to extend the longline field in the Breton Sound was made by the farmers. Potential sites were assessed similarly and carrying capacity models are under development to assess the quantitative shellfish potential. In other words how many additional longlines can be deployed and at which location? However, by developing such projects we have seen the emergence of conflicts for space mainly with the fishermen. They are systematically opposed to new development, even though they might be incorporated into the process, as was done in Brittany for pectinid culture. This is one critical problem in terms of development showing that shellfish farming must now compete with other users for space.

The emergence of new users' conflicts is obvious such as, for example, freshwater use in the Charente River where we have seen increasing acreage of irrigated land in the watershed, therefore limiting the nutrient fluxes in summer time in the coastal areas. All these potential or existing conflicts require effective coordination among users to expect a sustainable aquaculture. This may be done by coastal management plans. This is probably the most challenging issue in the near future for the shellfish industry (Table 10).

Table 10. Main Challenges for the French Shellfish Industry in the Near Future

- Within the Industry
  - Organising supply - Marketing improvements and recognition of quality product marks
  - Decrease of production costs likely to occur (deepwater, longlines) but should be made without increase of the oyster production and with increase of the mussel production
- Outside the Industry
  - Maintaining seawater quality, especially if additional constraints were to be adopted
- All the improvements can only be obtained by integrating coastal management
  - Conflicts for space likely to occur if rearing areas were to extend spatially (tourism, environment, fishery)
  - Conflicts for freshwater use (quality and quantity) likely to occur (agriculture)

References

Baud J P, E Brisset and M Cardinal, 1995. Affinage contrôlé en bassin de l'huître creuse *Crassostrea gigas*. RI DRV-95.17 RA, Bouin, 35p.

Gerard A, 1998. Rapport d'activité du Laboratoire GAP (Genetique-Aquaculture-Pathologie), IFREMER La Tremblade, 54p.

Goulletquer P and M Héral, 1997. Marine Molluscan Production trends in France: from fisheries to aquaculture, p 137-164. In: US Dep. Commerc., NOAA Technical Report, NMFS 29.

Goulletquer P, P Gras, P Geairon and S Taillade, 1998. Grille Nationale de l'huître creuse *Crassostrea gigas*. Regional Report of Poitou-Charentes, IFREMER La Tremblade, 31p.

Grizel H et al, 1998. Qualité des Mollusques. Synthèse des résultats: propositions et applications. IFREMER Sète, 21p.

Hussenot J, N Brossard and S Lefebvre, 1998. Mise au point d'un enrichissement de l'eau de mer pour produire en masse des microalgues diatomées comme fourrage pour les claires à huîtres. In: Marais maritimes et Aquaculture: préservation et exploitation des zones humides littorales, Buchet V & J Hussenot eds, Actes de Colloques 19, IFREMER Brest, 280p.

Le Moine O, P Geairon, D Razet, P Soletchnik, N Faury, S Taillade and P Goulletquer, 1997 Optimisation de l'affinage en claires traditionnelles: effet d'une complémentation alimentaire en algues 'fourrage' sur l'affinage: ressource trophique et potentiel de croissance. Rapport Contrat de Plan Etat-IFREMER-Conseil Régional de Poitou-Charentes, année 1996, 38p.

Soletchnik P, D Razet, P Geairon, N Faury and P Goulletquer, 1997. Ecophysiologie de la maturation sexuelle et de la ponte de l'huître creuse *Crassostrea gigas* : réponses métaboliques (respiration) et alimentaires (filtration, absorption) en fonction des différents stades de maturation. *Aquat. Living Resour.*, 10(3): 177-185.

Turpin V and J M Robert, 1998. Fertilité potentielle des eaux de claires ostréicoles de la région de Marennes-Oléron pour *Haslea ostrearia* Simonsen. en période d'affinage. In: Marais maritimes et Aquaculture: préservation et exploitation des zones humides littorales, Buchet V & J Hussenot eds, Actes de Colloques 19, IFREMER Brest, 280p.

DISCUSSION

David Jarrad *(Chairman)*

Philippe, thank you very much indeed. As I said in my introduction, as an industry we are very envious of the support IFREMER gives to the French industry. We do not have a lot of time but we can take just a couple of questions.

Alan Howard *(CEFAS, Weymouth)*

Your early table showed us pearl oyster production. Can you tell us a little more about it?

Philippe Goulletquer

Pearl oyster production located in French Polynesia is increasing. We have seen a large increase in shellfish farming and there are new management plans for this type of production. For example, several years ago we had problems with growth rates. We had to relocate several shellfish farms in order to optimise spatially this type of culture. We are also developing GIS to optimise the location of these farms. We are developing models and a monitoring network in terms of growth rate and settlement. You have seen the output and the exchange value on the table I showed. It is now the second production in terms of value, and is still increasing.

Caroline Poultney *(Seafare Ltd, Kingsbridge, South Devon)*

One of our speakers yesterday talked about the classification of shellfish production areas. He made a rather sweeping statement to say that all the areas in Holland and France are classified as 'A'. I wonder whether you could comment.

Philippe Goulletquer

Not all the areas are classified as 'A'. For example, in the Bay of Marennes-Oléron we have two areas classified as 'B'. Actually it is not really a major problem for the oyster farming industry because they are already well equipped for that. The key issue, for example, in the northern part, in the Breton Sound is the longlines, because the last classification provided a 'B' near this location. Mussel farmers have an agreement on their boats which means if it is classified as 'B' they are not allowed to market that product from their boats. They invested a lot of money two or three years ago building this type of boat. Now, we are talking about building land based facilities to do a light depuration for mussels. That is a tough issue right now. Actually, the industry is divided on this. Some mussel farmers are looking to the future and want to develop the land based facilities anyway to address the issue quickly. Others are totally against it because they are only looking for seawater quality improvement. So, in this case again, we need integrated coastal management because the main pollution coming from the watershed results from agricultural activity. We need all the people concerned to get round the table and discuss these problems.

Wim Verwijs *(Krijn Verwijs Yerseke bv, Holland)*

I have a question on the flat oysters. You say you have overcome the problems with *Bonamia*. Have you done this by producing tetraploid and triploid oysters, and does that mean that the spat all have to come from nurseries?

Philippe Goulletquer

With regard to flat oysters, we are not really working on the polyploids in flat oysters. The main research programme focuses on the genetic selection programme. We have been working on that for more than ten years. We have the capacity to concentrate *Bonamia* and then perform intensive inoculation of broodstock. For several generations we have selected a strain which is resistant to the *Bonamia* disease. This means we have had a considerable improvement in terms of survival rates and it can now be transferred to the industry. The key issue is how we can sustain the selection programme. It is not the business of IFREMER but at the present time the industry does not have any facility to maintain the selection breeding programme. So it is still an ongoing process. But with regard to triploids and tetraploids, it is done mostly on cupped oysters. Last year we obtained tetraploids at the research hatchery (La Tremblade) and now we can expect to produce 100% triploids by using these tetraploid techniques. So probably the commercial hatcheries in France will be using these types of techniques in the near future. Actually, several of them are already using the triploid method. But the French industry is still not entirely convinced of the advantages; they want to see whether it is really efficient. However, I can tell you that last year during the national agricultural fair, the two gold medals went to triploid oysters. So, that means it is a good product.

David Jarrad

On that note I will say thank you very much indeed and ask our President to present an Association tie to Philippe as a memento of his visit here.