ECASA Study Site Report

Site n° 5
The Pertuis Breton (Bay of Biscay)
France

ECASA Partner n°12:IFREMER

Alain Bodoy, Jean-Louis Martin, Cédric Bacher
Anne-Gaelle Haubois, Pierre-Guy Sauriau,

IFREMER

Non Technical Summary

1. This report presents the results of a field study conducted in the ECASA test site n°5 in the Pertuis Breton, France. The site is located on the Atlantic West coasts. It is open to the bay of Biscay, but is slightly protected against westerly winds. The bay has been exploited by intertidal mussels culture for centuries.

2. Within the bay, mussels (*Mytilus edulis*) are cultivated either by the traditional pole technique, around the bay or on longlines in the centre of the bay. The area occupied by these longline s represents 250 ha, and the resulting annual production is 1 000 tonnes of mussels. The average depth at mid tide is of 13.8 m. The sediment is sandy, with a small fraction of mud.

3. The site is subject to several regular monitoring through the local implementation of national networks aiming at protecting the environment and marine resources, on pollutants (RNO), microbiological quality of the waters (REMI), phytoplanktonic toxic species (REPHY) and growth and mortality of molluscs (REMORA). Benthic macrofauna was studied in 1976.

4. Five sampling sations were chosen along a line, starting under the longlines, and at distances of 50, 100, 200, and 400 metres from the area cultivated. A reference station was chosen in a different direction at 2 300 metres of the cultivated area. Sampling methods are described in the text.

5. Sediments were sampled for different analyses: grain size, content in organic matter, total organic carbon and nitrogen, and phytic pigments (chlorophyll a and phaeopigments). Redox were measured in cores. The macrofauna living into the sediment was also sampled. The water column was sampled for physical (temperature, transparency) and chemical parametres, including oxygen content, salinity, organic matter, dissolved nitrogen forms, phosphates and silicates.

6. Results from benthic macrofauna surveys indicate that there were no significant differences between the different stations and the reference station, all being classified as slightly disturbed. The bay is submitted to freshwater runoffs from two adjacent rivers.

7. The sediment is slightly modified by the culture of bivalves. Total organic carbon, total nitrogen, Eh values and pheopigments were significantly higher under the trestles than in any other stations. Other stations often did not differ from the reference station.

8. The effects of shellfish culture on the water column were. However, it was observed a small decrease of the food available to the molluscs near the rearing

9. The DEB model was able to describe and predict adequately the growth of oysters, both in the Baie des Veys and in the Loch Creran. The parametres for its use in other environment are given, but a tuning of one parametre should be performed with the help of authors.

10. Among the indicators and models for use in areas of intertidal bivalve culture, it is recommended to use the sediment quality index, TOC (Total Organic Carbon), redox and pheopigments, in surficial sediment, AMBI for the macrofauna, chlorophyll a contents and nitrogen forms in the water column, and models describing the carrying capacity, filtration rate of molluscs, and a DEB model to predict the growth of molluscs.

Contents

1 Introduction to the aquaculture operation

1.1 background

- The study site is a field of mussels longlines, located offshore at a distance of 4 kilometres from the shore. This public area is leased to shellfish culturists by the French State. As the area is homogeneous, and the rules for the exploitation are common for all farmers, it was considered that the study should include the whole area as a large farm, in which several farmers participate. This is also based on ecological backgrounds. All the longlines are contiguous, and the resulting impact of the shellfish culture therefore results from the biological activity of the whole area

- This report was prepared by a team from IFREMER, ECASA partner n° 12, with technical help from the CRELA (centre de recherche sur les ecosystemes marins anthropisés) http://www.ifremer.fr/crema/, a laboratory commonly established with IFREMER and CNRS, and from other IFREMER scientists, from the laboratories at Brest (France)

- The main information sources were gathered from colleagues, involved in monitoring activities, with informal talks with stakeholders (mainly the professional exploiting the site).

- The site was visited both at sea and in the facilities, the 14th and 15th September 2006. Samplings were performed at the same date. Other informations were obtained from the Administration for Marine Affairs, in charge of legal aspects.

- The methods used were those described in ECASA documents: book of protocols, indicator sheets, and model descriptors.

- The main difficulties encountered were linked with rough weather conditions during the sampling performed with divers. Some cores were lost during the sampling, and the very high turbidity did not allow to recover them.

- The present report aims at selecting indicators and models for use in Environmental Impact Assessment and site selection. It should not be viewed as a comprehensive ecological study of the relations between shellfish culture and environment, nor as a research report on all the aspects of shellfish impacts on the surrounding ecosystem.

1.2 Summary statement

1.3 Information of farmer's environmental strategy:

1.3.1 Current regulatory status

The farmers are required to maintain their leases (grounds, parks and longlines) in proper productive conditions, under specifications linked with the lease contract. The environmental monitoring is performed by IFREMER and national monitoring networks (such as the RNO for contaminants). Sanitary controls have been recently transferred to the farmers themselves, for the quality of the product. The farmer is responsible for the quality of its products. The environmental controls, allowing to classify the areas of production according to their sanitary status, are performed by IFREMER.

1.3.2 Key regulatory controls for the shellfish culture in France

1.3.2.1 National regulatory status

The shellfish culture in France may occur either in public leases, located in the intertidal, public area and offshore, or in private grounds, in marine ponds. All the regulatory aspects are controlled at the state level, by means of the administration of Maritime Affairs. The public leases are rented to farmers against the payment of annual fees. The farmers must use their parks or longlines for production, while maintaining them in proper conditions. At the end of the agreement, that is after 30 years, parks should be returned in a virgin condition. In theory, the parks should not be exchanged, but the administration let some exchanges of parks to occur, when a farmer stops the exploitation. This has conducted to an unofficial market, based on the productive value of the parks.

1.3.2.2 Sanitary monitoring.

The principles of the sanitary monitoring are given into the european rule EU/854/2004. The microbiologic, phyco-toxic and chemical risks are taken into account by the regular monitoring of the production areas.

The areas are classified according to the fecal contamination into 3 classes (A, B, C) by the competent authority, in order to obtain shellfish good for human consumption. No tolerance is permitted by the rules when interpreting the data allowing to classify the areas. However, specific decisions can be taken when duly argued. The shellfish organization, acting at national and European level, brings the arguments for the use of particular tolerances.

1.3.2.3 Sanitary rules

As from the 1st January 2006, a new rule comes into force , and complete the existing European legislation (EU n°178/2000). This one sets the general principles of the sanitary legislation, for the producers of alimentary products. The rules for the tracking, Withdrawal and recall of batches are defined. Two other European rules are also into force:

- The general rules for the hygiene of alimentary products (rule EU n°852/2004),
- The specific rules applicable to the alimentary products of animal origin (rule EU n°853/2004). The specific provisions for the mollusks and echinoderm are given here.

1.3.2.4 Microbiologic criteria

These criteria to be considered for the alimentary products of animal origin, are given into the rule EU n°2073/2005. They are based on the assessment of the number or germs (Escherischia coli).

1.3.2.5 Environnemental aspects

At EU level, the main directives on EIA are Council Directive (EEC) No.337/1985 on the Assessment of the Effects of Certain Public and Private Projects on the Environment, and European Parliament and Council Directive (EC) No.42/2001 on the Assessment of the Effects of Certain Plans and Programmes on the Environment.

The water framework directive also contributes to the definition of environmental requirements which are applicable in areas where the shellfish culture develops.

At national level, the Environmental Impact Assessment system is regulated in Book I of the Environmental Code and in Decree No.77-1141 implementing article 2 of Law No.76-629 on the Protection of Nature (Décret No.77-1141 pris pour l'application de l'article 2 de la loi No.76-629 du 10 juillet 1976 relative à la protection de la nature) (1977, as amended).

With regard to marine aquaculture, Decree No.77-1141 implementing article 2 of Law No.76-269 concerning the protection of nature provides that an EIA is only required for farms considered as classified installations. Decree No.53-578 establishing the categories of classified installations (Décret n° 53-578 du 20 mai 1953 modifié relatif à la nomenclature des installations classées pour la protection de l'environnement) (1953, as amended) specifies that shellfish farms are entirely exempt from the procedure, whereas marine aquaculture facilities with a producing capacity over 5 tonnes of fish per year are subject to the classified installations regulations. Consequently, the EIA process is only applicable to the latter.

A bulk of environmental laws and decrees, transposed from the corresponding European legislation, also applies in marine coastal waters (Natura 2000, Bird directives, sensitive habitats…) where mollusks are grown.

Regarding the import of aquatic animals, this is regulated by the Commission Decision (EC) No.858/2003 laying down the animal health conditions and certification requirements for imports of live fish, their eggs and gametes intended for farming, and live fish of aquaculture origin and products thereof intended for human consumption.

2 2. Site specific regulatory and management background

2.1 The regulatory status of proposed location with respect to fish farming developments.

A framework for the development of the sea (SMVM) was developed during the years 1992-1996. It consists in a spatial planning of the different activities and the protected or reserved areas, under the auspices of the French state. Although it did not come into force, this work is still a reference for the planning of marine activities into the Pertuis Breton. For historical reasons, a large place was given to the culture of bivalves in the area, both in intertidal zones and offshore for the future development of longlines. At the same time, following the European Birds Directive, protected areas are located in the Baie de l'Aiguillon, eastbound of the Pertuis Breton, a large intertidal mudflat were ten of thousands of migratory birds are wintering.

The Pertuis Breton is also concerned by several designated areas, which are all located along its shores, along the Ré Island, and on continental coasts. A natural reserve (L'Ileau des Niges) lies on tidal marshes, on the Ré island, and natural zones of faunistical or floristical interest cover salt marshes and saline ponds both in the Ré island and on the continent. However, the site where the mussels longlines are exploited is not concerned by these protected areas.

The longlines are located 4.5 km of the nearest coasts, and the buoys cannot be seen from the shore. They are also located away of the main marine routes, either for commercial or for leisure boats.

2.2 Site description

In the middle Atlantic coasts of France, two large open bays are facing the West. The Ré island separates the two bays , or “Pertuis. The Oléron Island is the Southern limit of the pertuis d’Antioche. The Pertuis Breton is the northern bay, delimited by the continent in the North. It has a surface of 376 km², of which 99 km² are intertidal areas, including at the East, the baie de l’Aiguillon. The depth decreases from West to East (figure 1).

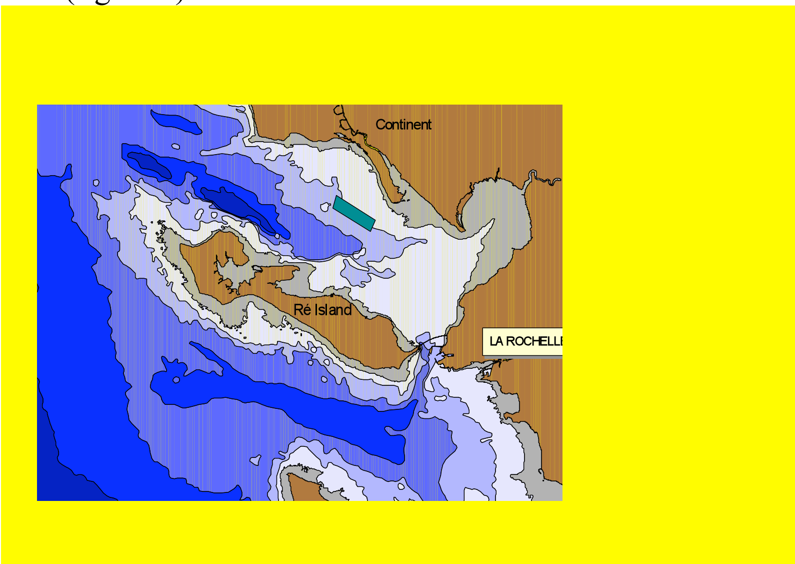

Figure 1 ; Depth and morphology of the pertuis Breton.

Figure 2 . Annual production of oysters and mussels in the two Atlantic bays, the pertuis Breton, in the North, and the pertuis d’Antioche, in the South.

The shellfish production is extensively developed in the two bays (figure 2).Within the pertuis d’Antioche, at the South , the production of oyster predominated, while in the pertuis Breton, the mussel culture is the main activity. Two different techniques are used for the mussel production: the pole technique (or “bouchots” culture) can only be conducted in intertidal areas, around the bay, while in open waters, the longline production is used. The total annual production of the bay is 8 600 tonnes of mussels, of which 1 000 tonnes are produced by the longlines techniques.

2.3 Detailed description of the farm

The study site can only be considered as a common area for mussel culture, which is shared by many farmers. The total area covers 250 ha, and is divided into 2 rows, each of 10 rectangular zones. Four leases or “farms”, each of 3 longlines, 100 metre long, make a zone.

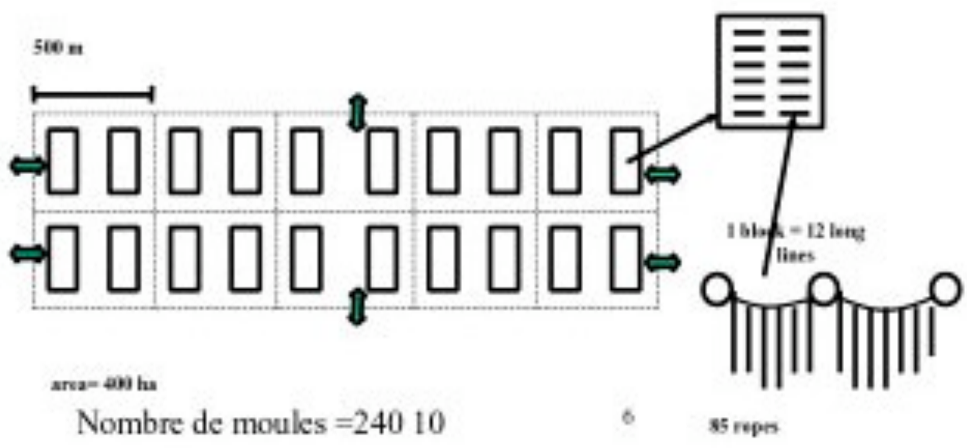

Figure 3 : Schematic représentation of the organisation of longlines in ther pertuis Breton (from Bacher, 2007).

The total number of longlines is then 240. When the site was established, only one lease was given to a farmer. After 14 years of exploitation, several exchanges and buying may allow a farmer to control more then one lease, which may not be contiguous. Therefore, the notion of farm on this site can only be understood as a collective area for mussel exploitation.

More then 100 peoples are employed in the different companies to produce the mussels. The corresponding facilities are dispersed all around the bay, in the continent (North and East coasts) and in the Ré island

2.4 Proposed management strategy: biomass, medicines, chemicals, cycle, feed inputs, growth measurements.

Extensive growth measurements of the mussels grown on near-by bouchots were performed by (Dardignac 2004).

The growth rate of mussels cultivated at this site was compared with the one from pole culture on the shoreline (Garen et al. 2004). Mussels reared on longlines gain 8.24 mg.day^{-1} of dry tissues, while on pole culture, they gain only 7.17 mg.day^{-1}.
The harvest is mainly performed during summer, from May to September.

The food being naturally produced in the surrounding water, a FCR is no generally computed for the bivalve culture. Instead the attention is paid to the carrying capacity

of the site and its compatibility with the size of the rearing installations (Canada 2003).
No chemicals nor medicines are used during all the operations, from the settlement to the harvest.

2.5 Physical farm logistics, type of gear used (Cages, long lines, rafts…), moorings, access, lighting and anti-predator measures.

The mussel longlines used in the Pertuis Breton have been described in details in (Bompais 1991). Most of them are made of a subfloating longline: the main buoys are made of a cylindrical, vertical floater.. When the site is exposed to a swell, which is the case of the Pertuis Breton, this type of floater moves less then a spherical buoy, and the vertical efforts are less intensive. The mussels do not intend to detach themselves as easily as it may be observed with surface longlines.
The mooring is based on a concrete bloc at each end of the longline, weighing 5 tonnes. An auxiliary floater may be included before the longline, in order to reduce the movements due to the wave, currents and swell. The longline itself is 100 metres long. On average, 85 ropes on which the mussels have settled are attached to a longline.

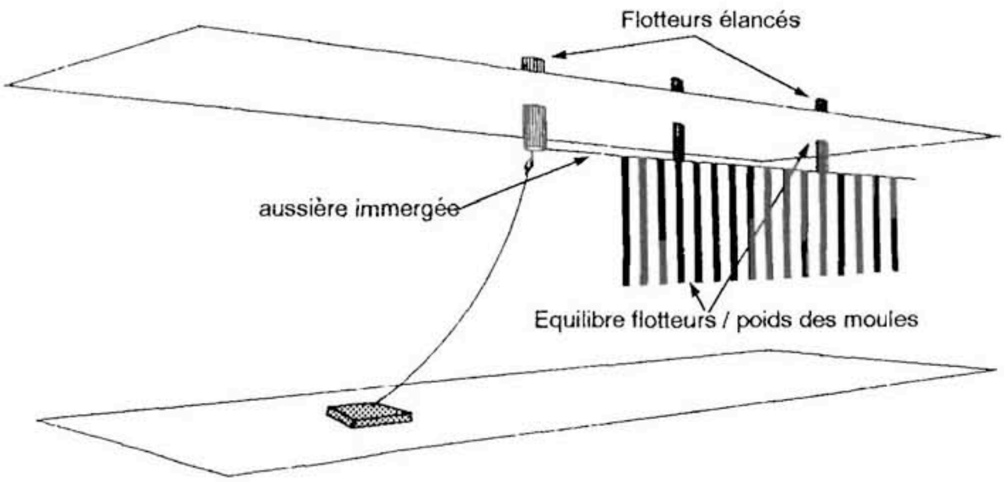

Figure 4 : Structure of sub surface longlines (Bompais, 1991).

These longline are accessed by boat, (see under) from different harbours within the Pertuis Breton. The distance between these harbour and the site varies between 10 and 20 kilometres. At least three different harbours are used by the boats designed for the culture of mussels. All these boats are equipped with hydraulic cranes, which allow to work on the longline inboard, for attaching new ropes or collecting the commercial mussels.

Figure 5: Boats used to collect and process mussels in the pertuis Breton

The whole site is protected by four navigational buoys, at each corner of the site, and navigation inside the area is restricted to the boats specially equipped for the mussel culture. Otherwise, the main channel for navigation is located 2 kilometres south of the area delimited by the buoys.

Figure 6 : Aerial view of the area occupied by longlines in the pertuis Breton (photo A. Bodoy).

Quite interestingly, the predation on mussels remains very low from the beginning of the culture (1992). A different case was observed in the French Mediterranean waters, where a large site of mussel longlines, producing up to 15 000 tonnes of mussels in 1999, almost disappeared few years after, with a mere production of 2 500 tonnes per year (Sanguinède 2001). The reason was the development as from 1999, of a strong predation pressure caused by wild populations of Sea Bream.

2.6 Production and Processing

While they reach a commercial size, around 3 to 5 cm, the mussels are collected: Specially designed boats use a crane to lift up the longlines and the ropes are cleaned of their mussels. These are then washed on board with sea water, to remove most of the fouling organisms, and sieved to reject broken shells, or smaller mussels. They are usually packed on board, on net bag in order to maintain them alive as long as possible. The wastes issued by sorting and cleaning are usually rejected to the sea, on the way back to the harbor. Dead animals are eaten by scavengers identified into the Pertuis Breton (Crustacean and Gastropoda). Since most of the farmers do not have the technical installations allowing them to maintain the mussels in ponds or tanks before sending, the mussels are then transported in refrigerated trucks directly to the selling place, that is fish auction places.

During the rearing cycle, no chemical, drug or food are added. Therefore, the only wastes produced by the rearing and processing are the biodeposits, the discarded fouling organisms and damaged mussels during the cleaning process, and the smoke and burned gasoline produce by the boats. Due to the processing and packaging of mussels inboard, these boats are the only technical installation of the farm. However the farmers may have access to some building on the grounds where they can have buoys, longlines, ropes and mussels bags stored.

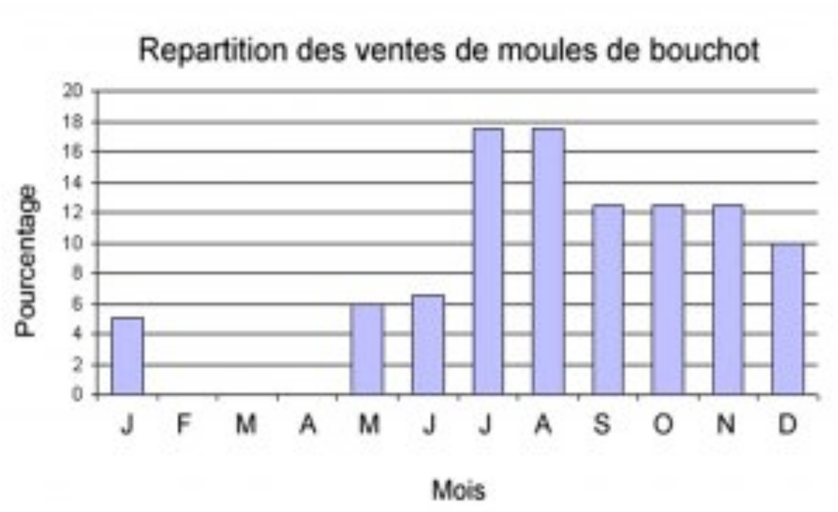

Figure 7: Monthly sells of the mussels produced from the pertuis Breton

3 Description of the site and quantification of effects on the environment

3.1 *Land use, landscape and visual quality (use maps and photographs)*

The site was installed in 1992. It includes 240 longlines, which were fixed at an average distance of 5.2 kilometres from the shoreline. The minimum distance is 4 kilometres. The only visual appearance in the surface are the buoys of the longlines as shown in the figure 7. Being agreed that the largest buoy has a vertical size of 1 metre, these buoys cannot be seen from the shore, and the boats at work are the only signs of mussels culture an human eye can observe, at a distance of 4 kilometres.

Figure 8 : longlines viewed from the sea. The nearest coast is seen on the background.

Another activity consists in the traditional production of mussels on intertidal poles. When the longline were leased to mussel farmers, they were required to stop the exploitation of “bouchots”. They benefited of a better growth, lower mortality, and lower exploitation costs when producing on longlines. The distance between the poles and the longlines is larger then 4 kilometres. Furthermore, the prevailing, tidal currents are oriented perpendicular of the shore in that part of the Pertuis Breton, thus increasing the “biological distance” between the two types of culture.

Figure 9 : Aerial view of an area of mussel culture on poles, near the shore (Photo A. Bodoy).

A fishing activity exists in the Pertuis Breton (Léauté & Caill-Milly 2003). But all fishing are prohibited inside the mussels leases.

3.2 Hydrography and water quality

A hydrodynamic model allows to compute the currents in the Pertuis Breton, from the bathymetry, tide and winds components. The generic name if this model is MARS-2D. The grid for the Pertuis Breton has a mesh of 300m, but larger models covering a coastal part of the Bay of Biscay can give the boundary conditions. The model was validated by current measurements (Doppler currentmetres) performed in ten different sites. The site is a macrotidal bay with average tide heights of 5,4 metres. Therefore it can be considered as highly dispersive.

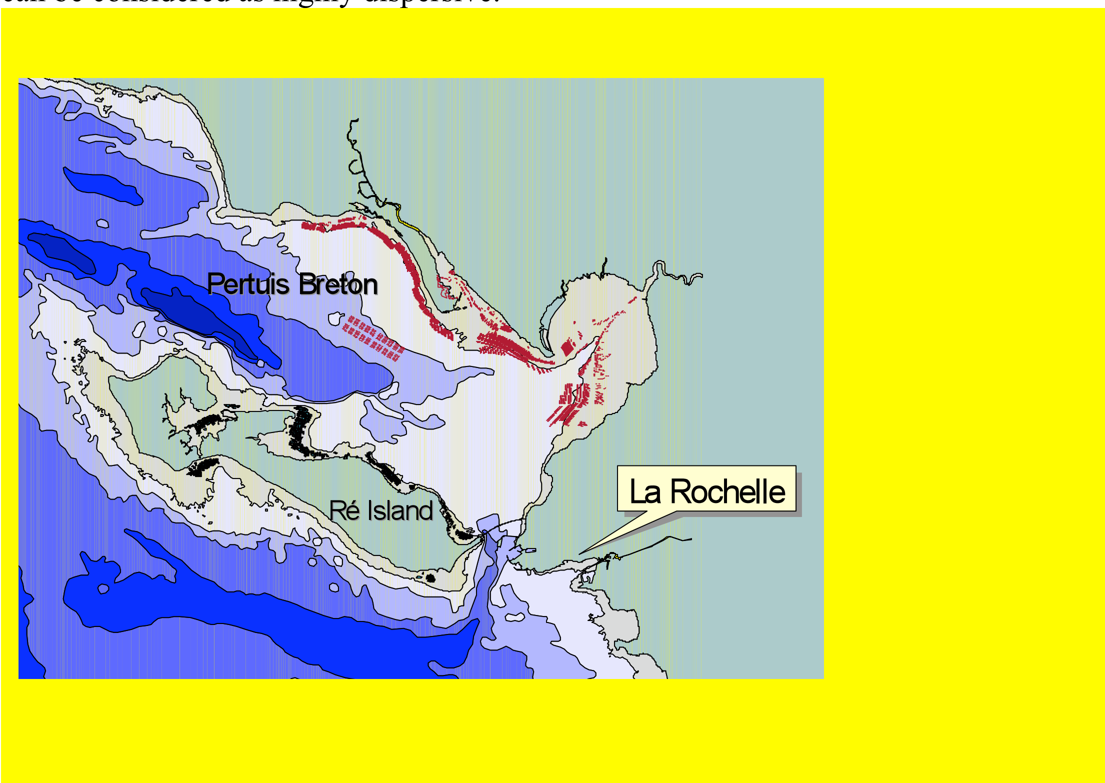

Figure 10 : Bathymetric map of the pertuis breton

The main hydrobiological features were described by (Soulard 1988), and (Barillé 1993b). The last author concluded that the productivity of this ecosystem could be limited by the quantity of Phosphorus rather then by Nitrogen. The carrying capacity towards mussel production has been calculated by two authors (Houze 1997) and (Barillé 1993a). Both concluded that the mussels were depleting e fraction of the available food at each tidal movement, but the primary productivity and turbulence processes would not allow the system to reduce the growth of mussels on longline below that of those on intertidal poles.

Bivalves excrete Nitrogen mainly in the form of ammonia and orthophosphates (Widdows 1978, Qian et al. 2001). The rate of ammonia excretion for Mytilus edulis is of 0.981 $mg.g^{-1}.day^{-1}$ for the flesh (Bayne & scullard 1977). This corresponds to a total of 5.9 tonnes of Nitrogen for a biomasse of 2000 tonnes of live mussels, or 1.47 $g\ N.m^{-2}.day^{-1}$.

At the same time, the residence time of the water body (scale B) is estimated to vary between 80 and 90 days, depending on the tide and prevailing winds. The nutrients produced by the metabolism of the mussels are then rapidly flushed out. The measurements performed during the ECASA campaigns also confirm the high level of turbidity in the Pertuis Breton, which hampers the primary production, thus reducing the risk of eutrophication. (Barillé 1993b) has shown that the fist limiting factor for the phytoplanktonic primary production in the Pertuis Breton could be the Phosphorus. Finally the risk of Eutrophication due to the metabolisms of mussel is perceived as very low.

Calculations on dispersion of dissolved medicines were not performed as the mussel growing does not require any chemicals, nor antibiotics or probiotics.

The pelagic components of the Pertuis Breton have been poorly documented. The phytoplanktonic biomasse was assessed through the measure of chlorophyll a by (Barillé 1993a). The abundance and qualitative composition of the zooplankton in this area have not been described yet. This is unfortunate, as the mussels are known to ingest and destroy zooplanktonic animals ((Davenport et al. 2000), and quantitative data on zooplankton are needed to assess the potential impact of mussels on these populations.

3.3 Bathymetry, geology and habitats.

The Pertuis Breton has a surface of 425 km² and an average volume of 4920 10^6 m^3. A part of it(34 %, or 1650 10^6 m^3) is exchanged by tidal movements.. the average depth is of 13.8 metres, with a maximum depth of metres, near the mouth. The intertidal areas cover 80 km², that is 19 % of the total surface. Two mouths exist, one at the west of the bay, which is 10 kilometre wide a high tide, and the other at the South-East, between the Ré island and the continent, which is only 1 kilometre wide. Two rivers arrive into the bay, the Lay and the Sèvres Niortaise. The surface of their total watershed is of 4074 km².

A substratum map (figure 10) was drawn by (Hily 1976). The same author described the different benthic communities and their specific composition. At the east part of the Pertuis, a small bay (Baie de l'Aiguillon) was studied with more details, as it is a wintering site for many migratory birds. Some of them feed on beds of the Phanerogame *Zostera marina.*

3.4 Benthos and sediments

The physical characteristics of the habitat have been described by (Lorin 1968) and (Hily 1976). This author described the communities, and the nature of the surface sediment, which was presented on a map (figure 11). In the main, the sediment is made of muds and sandy muds in the eastern part of the bay, and below the longlines. Coarser sediments (sands and gravels) re located westbound. A deeper area, locate at the south part of the mouths, is covered with muds, and rocks are found North-West of the Ré island. The fine sediments originate from a small river, the Sèvre Niortaise, which runs into the baie of Aiguillon at the eastern part of the Pertuis Breton.

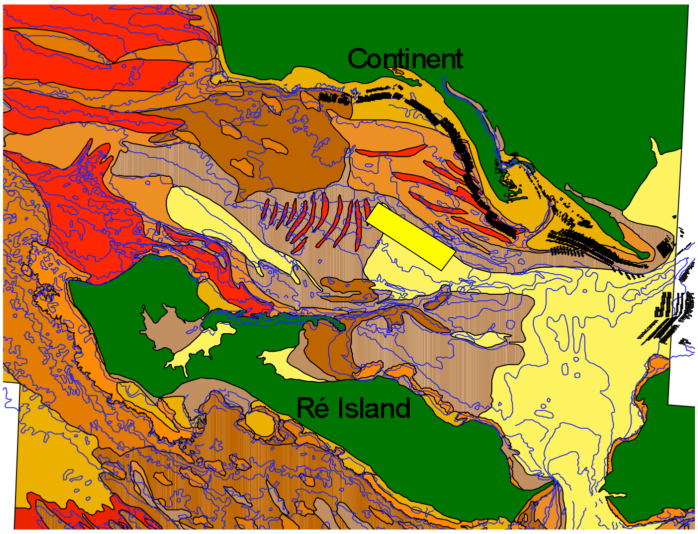

Figure 11 : map of the main sediment coverage in the pertuis Breton (After Hily, 1976).

The macrofauna living in the Pertuis Breton was extensively studied by Hily (1976). This author described the benthic communities. Otherwise, the macrofauna has been sampled on several opportunities, allowing to extend the list of the species living in the area covered by the Pertuis Breton and Pertuis d'Antioche (Montaudouin de & Sauriau 2000). It has not been observed the occurrence of any rare or protected species within the area of longlines. Other studies are performed in the same area to fulfil the requirement of the Water Framework Directive, but the results are not available yet.

3.5 Marine mammals; seals, cetaceans, otters

Marine mammals and birds are known to interfere with the shellfish culture (Roycroft et al. 2004). However, no resident marine mammals, including seals, are observed today in the Pertuis Breton. Some delphinids are occasionally observed, but they are not known to feed on shellfish stocks or even to cross between the longlines.

3.6 Birds

An important area of feeding and rest for the migratory species is located in the Baie de l'Aiguillon, 15 km East of the site of longlines. Most of the species feed on the seagrasses (*Zostera noltii* and *Spartina spp*). The predation of duck on intertidal bivalves has been described (Tyler et al. 2007). Hovewer, these species do not usually interfer with the subtidal mussel culture. A piscivorous fish (cormorant) may be observed on the site at some occasions, but the farmers do not relate about losses related with this species.

3.7 Fisheries and wild fish populations.

A local fishery operating within the Pertuis is described by (Gorichon 1990) and (Tachoires 2003). All the boats are less then 12 metres and are operated by a crew of a single man, or two sailors. Their target species are the common sole, the Sea Bass and less valuable demersal fishing or shellfishes. The main gears are trawls, nets and lobster pots, depending on the seasons and the boats. A nursery for the youngest soles is localised into the shallower, Eastern part of the Pertuis. The interactions between the fisheries and the culture of molluscs were described on the studied site (Bodoy & Biais 2004). The main sources of conflict lay in the competition for space. The biological resources on which each activity rely are quite different: the primary production and phytoplankton for the bivalves, and small demersal fishes or benthic animals for the commercial fishes. The social attitude of each group (fishermen and mussel producers) were analysed, in the context of the existing regulations (Darbon & Deglise 2003).

The site acts as an attractive device for wild fish. However, fishing and angling are prohibited near and within the site. An example of strong predation pressure was observed on mussels on long-lines, by a Sea Bream school (Alléguède 2001). The biomass was reduced from 15 000 tonnes to 2 500 tonnes within 3 years, thus compromising the economic viability of the farms involved in this project (see upper). The main difference between these two sites is the high turbidity observed in the Pertuis Breton (Barillé 1993a), which would hamper the Sea Bream to eat the mussels in a dark environment.

3.8 Noise

Due to the large distance between the site and the shoreline, the activities on site do not produce any perceptible noise for the land based activities and populations, either within daylight hours, or at night-time.

3.9 Transport

Most of the farms renting leases in the Pertuis Breton do not have a permanent shore base, as the product is conditioned in board. In such cases, the furnitures are delivered in the different harbours, La Rochelle, Ile de Ré, and Charron. Some farms have small bases, in the immediate vicinity of these harbours, and the site access is the one of the harbour, that is satisfactory.

3.10 Socio-economic impact

By far, the main activity along the coasts of the pertuis breton is the tourism. Even the agriculture in coastal areas represent more employment then the mussel culture. According to the last professional census in 2001 (Girard et al. 2005), the direct emploiement of the mussel industry could be evaluated to around a hundred of people. Some economic benefits are obtained for the industries building the ships for collecting and processing the mussels, and for those producing the furnitures (ropes, longlines, buoys, bags) and the processing machines (sorting and washing the muxssels).

4 Results of ECASA field studies: Indicators and Models applied and evaluated.

4.1 Sampling operations

4.1.1 Field operations

They were performed in August and September 2006.

The sampling for hydrological parameters was conducted with a small aluminium boat named Salicorne, as the material only consisted in a sampling bottle, a rope and adequate CTD devices and GPS. The sampling dates were the 23rd of August 2006 for the sampling at low tide, and the 6 th of September 2006 for the sampling at high tide.

Another sampling campaign for collecting sediment was conducted the 7th (Boat “Estran” and 8th of September (boat “Tornado”). These sediments were collected by divers, because of the care needed to maintain the vertical structure of the sediment. The Estran is an Aluminium 12 metres long working boat, while the Tornado is an inflatable (6 metre long), allowing to spend a very short time between the different stations and highly convenient for diving operations.

The boats “Estran3 and “Tornado” were rented and operated by a private company (Le Cleach armement ltd). The scientific staffs and divers pertained to IFREMER.

The sampling for infaunal studies was performed the 17th of September with the boat Estran, the only one permitting to operate an heavy grab.

All the sampling operations involved a team of two professional sailors, plus three scientists. Furthermore, the diving operations were conducted with a dive coordinator (one of the scientists) and two divers. All the sampling activities were conducted under the observance of the laws and rules governing the operations at sea.

4.1.2 Sampling scheme.

Because of the size of the site for mussel culture, the initial sampling was performed at the edge of the longline site, on the South east side, just against the longline bordering the site (figure12).

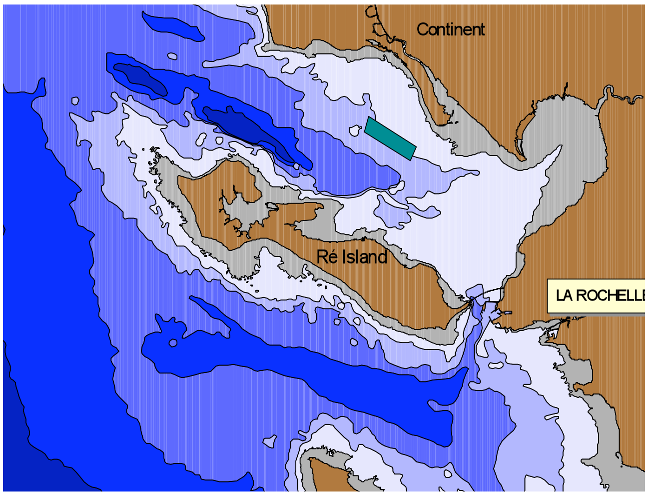

Figure 12 : map of the site of mussels culture

The corresponding station was named 0 (zero), as the distance between the source of impact (the longlines) and the station is equal to zero. Four other stations were located in a transect, and were named as 50, 100, 200, and 400, this number corresponding to the distance in metres, between these stations and the border of the longline site. The direction of the transect was chosen to correspond with the average direction of the tidal currents during flood tide, as it is computed from the hydrodynamical model MARS 2D, that is a bearing of 108 ° (figure 13).

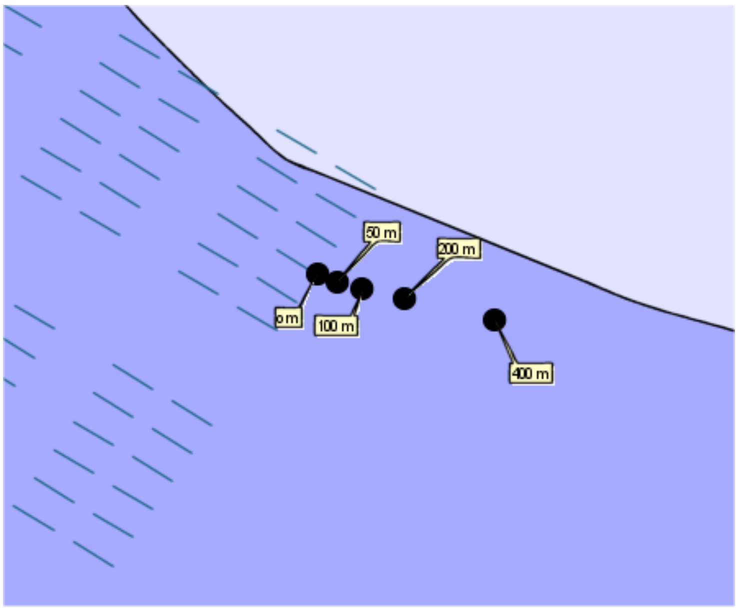

Figure 13 : Location of the transect at the South East part the site of mussel culture

Another station was chosen in a perpendicular direction, as a reference station at a distance of 2300 metres.

The positions of the sampled stations are reported in the table 1. The figure 14 show the theoretical and the true positions of the 5 stations (excepted the reference station), in arbitrary units (tenth of a minute of latitude, or longitude). The distance between these calculated and true positions is due to the difficulty in positioning the boat (and the sampling gear) while facing a strong tidal current. The resulting precision is of less then 15 metres, not considering the GPS error (less then 5 metres in usual DOP conditions).

Table 1: true positions of the different stations sampled in the Pertuis Breton. Geodesic system WGS 84.

Stations	Latitude North	Longitude West
0	46°15.966	001°19.455
50	46°15.958	001°19.414
100	46° 15.943	001°19.389
200	46°15.936	001°19.287
400	46° 15.903	001°19.178
Ref	46°14.727	001°20.764

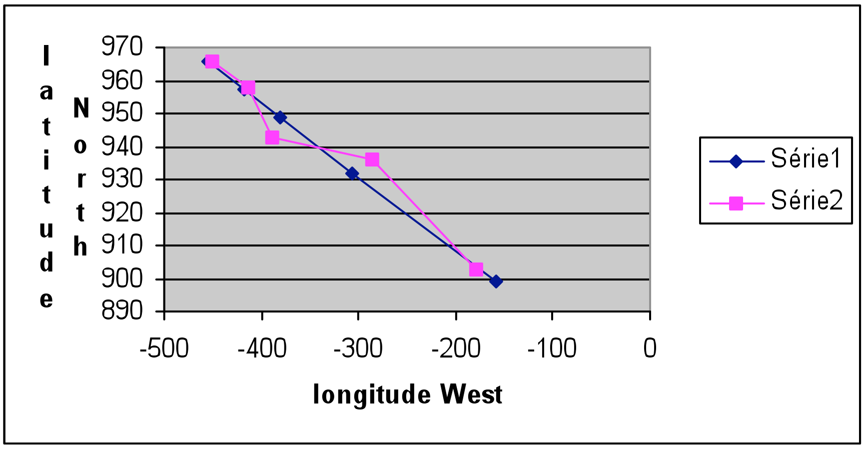

figure 14: Deviations between the theoretical (Serie 1) and the true position (Serie 2) of the stations along a transect in the Pertuis Breton. The unit corresponds to thousandths of minute of latitude or longitude in the geodesic system WGS 84.

4.2 *Sampling methods and materials, analytical methods.*

4.2.1 Sampling techniques

4.2.1.1 sediment

Samples for the analyses of chemical and biological parameters were taken by divers using corer of 4 cm in diameter and 30 cm long. Because of a low visibility, the precise surface place was found by using a GPS and a buoy was installed, in order to drive the diver from the surface to the bottom at the precise location. Three cores were taken at each station (figure 15). Once on board the vessel, these cores were sliced at every centimetre, using a core plunger to push the sediment inside the core (figure 16), and the different samples were conserved in refrigerated conditions on plastic boxes. They were frozen once at the laboratory, after a delay not exceeding 3 hours.

Figure 15 corer used for sampling

Figure 16 :Slicing the sediment and core plunger.

4.2.1.2 redox

Redox measurements were made on special corers, with the same diameter (4 cm), but holes were bored, every centimetre from the bottom of the corer, in two parallel colons. The diameter of these holes was o .07 cm, thus allowing to introduce the special electrode for redox measurements (0.5 cm in diameter). Before sampling by divers, the holes were covered by a thin plastic tape, in order to avoid any linkage after the sample was taken. The operator then could drill the electrode through the tape to access the sediment, starting from the top of the corer.

4.2.1.3 Hydrology

The water column was sampled by bottle sampler at 3 depths; surface, mid-depth and near bottom. A CTD equipment was scheduled, but unfortunately, it ran out of use before the first field campaign. The bottle sampler was a Niskin Bottle (2 litres).

The water was collected in two cleaned flasks of 1litre. Measurements of salinity, temperature and dissolved oxygen were made using a conductimeter WTW 197i, and a oxymeter Hach portable LDO. A stirring time of 30secondes was observed for the salinity and temperature. The oxyègen probe computes by itself the time needed for a stable lecture. The probes were previously calibrated according to their specific procedures and good practices of laboratory. Then the flasks were kept refrigerated. They were frozen once at the laboratory, after a delay not exceeding 3 hours.

A Secchi disk was specially designed according to the recommendations of the ECASA Book of Protocol. It was used following the procedure described in this book.

4.2.1.4 fauna and flora

Samples for the determination of the composition of the benthic macrofauna and macroflora were made according with the general procedures agreed by international organisms (ICES, (Rumohr 1999) and the ECASA Book of Portocol. These samples were performed with a Smith and McIntyre Grab, made of galvanised steel. This grab has a weight of 80 kg, and 20 kilogrammes of additional weight were added to ensure a good penetration of the jaws into the sediment. The closing of the two jaws is obtained by powerfull springs, which are tensed before operation (figure 17). The surface collected by this grab is of 0.1m².

Figure 17 Tensing the springs before operating the grab. A bucket lies under the grab for collectiong the samples before conditioning.

Several samples were taken at each station in order to ensure a good quality of these samples. A particular care was given to the full closing of the jaws, and the entire filling with sediment. The criteria used to accept or reject a sample were those given in the ECASA Book of Protocols. Finally three samples were selected as valid samples for each station. Due to the presence of coarse sediments in higher quantities in the reference station, a total of ten operations was necessary to obtain three satisfactory samples.

Before sending the grab, it was armed on the desk of the boat, and then pre-positioned on top of water.(figure 18). The boat was then localised as precisely as possible with the help of a marine GPS. A light buoy was positioned to help quickly find the true position, with respect of the water currents. On the signal of the captain, the grab was then rapidly immerged to respect the GPS position, and avoid any drift due to the tidal current.

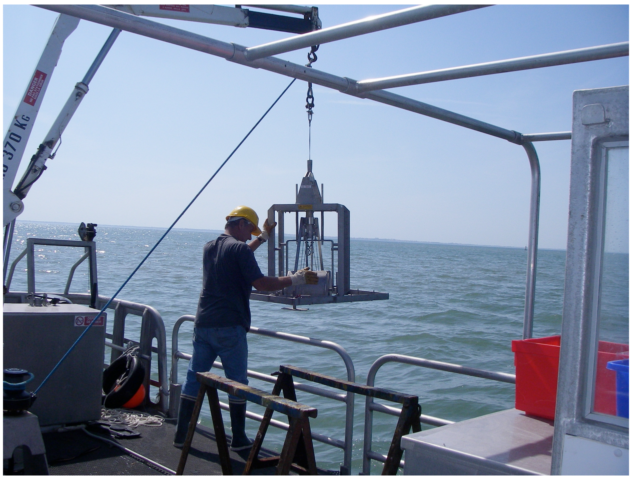

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Figure 18 Positioning the grab before sampling

After sampling, then the grab was positioned on trestles. It was opened, and the sediment was collected into a bucket (figure 17). Each grab was sieved, stored, and documented separately. The sediment was then transferred to stainless steel sieves, of 60cm in diameter, and sieving was made aboard the vessel. The meshes were of 1 mm or 0.5 mm according to the samples. The sample was finally stored into a glass recipient and buffered. A 4 % formaldehyde solution (1 part 40 % formaldehyde solution and 9 parts filtered sea water) was added to preserve living materials.

Special samples were taken for the determination of meiofauna. The divers used cores different to those used for the biogeochemical samples (7.6 cm of diameter and 15 cm high). A particular attention was given to keep the core vertical during the dive and after, during the processing Special bucket were made containing 6 cores in a vertical position. The samples were preserved according to the procedure described in the ECASA Book of Protocol: A narcotic agent (7% Mg Cl2) was added to the samples. After stirring, the sample is fixed after ten minutes with a 4 % formaldehyde solution in adequate quantity to obtain the final concentration of 10%.

In all the samples taken in this site, the macroflora was absent.

4.2.2 Analytical techniques

Biogeochemical analyses were performed according to the ECASA book of protocol
The following parameters were analyzed on the samples:

4.2.2.1 Sediment

Fraction of sediment <63µ was measured by a gravimetric method. The fraction was removed by sieving trhough a 63 µ sieve under a gentle water flow. The corresponding weight wa obtained after drying, by substracting the final weight from the original weight
The content in organic matter(refratory organic matter and labile organic matter) were obtained by Losses On Ignition, according to the ECASA book of protocols.

Total Nitrogen and Total organic carbon in the sediment were measured thanks to a AutoAnalyser Carlo Erba (Nitrogen and Carbon analyser 1500), and according to the ECASA book of protocols.

Chlorophyll a was measured by fluorimetry (Fluorimetre Turner).after axtraction of the pigment contained into the sediment in 90% acetone, according to the ECASA book of protocols. Pheopigments were measured on the same samples, after addition of 100 µl of 1N HCl.

Redox potential measurements were made on board, with a Schotte-Gerate electrode model Pt 5900 A, diameter 5 mm, system Ag/AgCl, electrolyte KCl 3M. Precaution were taken to avoid the interference with ai, (Hinchey & Schaffner 2005), excepted that the holes on the corer were not filled with silicone. Calibration was made by reading the electrode previously to the measures against redox standards, and computing a calibration curve. Measurements were made on board, using a millivoltmetre Knigh Portamess 913 . The lectures were corrected to obtain Eh values according to the constant of the electrode and the temperature at the time of the measure (Hussenot & Martin 1995).

4.2.2.2 Hydrology

All the measurements were performed according to the ECASA book of procedure. Analyses were performed in theIFREMER LAB "Centre de Recherche sur les ecosystèmes marins anthropisés ».

The Depth of diseappearance of Secchi disk was measured before sampling to avoid the excess of turbidityeventually caused by the displacement of the boat.

Temperature and Salinity were measured on board, immediately after sampling, by a CTD conductimetre WTW cond 197i.

Oxygen content was measured on the same sample by a LDO Hach, portable sensor and reader. Results were expressed as the %saturation of oxygen into the water.

Total particulate matter (TPM), Particulate organic matter (POM) and % POM were measured. Standard GF/F filters were used. A control test was made by weighing blank filters, as described in the protocol.

Chlorophyll a was measured by fluorimetry (Fluorimetre Turner).after axtraction of pigments from the filters in 90% acetone, according to the ECASA book of protocols. Pheopigments were measured on the same samples, after addition of 100 µl of 1N HCl.

Particulate OrganicNitrogen (PON), Particulate Organic Carbon (POC), and C/N ratio were measured thanks to a AutoAnalyser Carlo Erba (Nitrogen and Carbon analyser 1500), and according to the ECASA book of protocols.

Nitrates and nitrites, Silicates, Orthophosphates were analyser using a continuous flow analyser Skalar, according to the ECASA book of protocols. All the precautions to sample and store samples wer made according to the ECASA book of protocols.

Ammonium was measured on board, on fresh samples using a phenolate method, in order to avoid the problems linked with the preservation of the samples.

4.2.2.3 Macrofauna

The sediment were sieved through a 1 mm mesh sieve, fixed, stained, sorted and determined according the ECASA Book of Protocols and internationally agreed procedures (Rumohr 1999). Taxa were determined until the species. Abundance and densities were computed for each species.

4.3 Models used and their parameterization.

4.3.1 Available models

IFREMER has built several models which have an interest in the scope of ECASA.

- The hydrodynamic model MARS-2D allows to compute the tidal currents in a given area for given periods of time. It only requires to obtain bathymetric data and boundaries conditions, these being potentially obtained from other models, on a wider spatial scale. Different uses can be made of these models when considering an EIA: They can basically serve as a description of the currents. They can also be use to trace the trajectories of particles, to assess the carrying capacity of shellfish sites (with other informations needed on, available food and productivity, or to compute various indices such the residence time of water bodies.

- A model describe the effect of mussel longlines on the depletion of phytoplankton. This is of a primary interest to assess the effect of a shellfish farm on the pelagic ecosystem.

- A Dynamic Energy Budget model is proposed. It is based on the computation of ecophysiological equations, and the resulting products allows to predict shellfish growth and production in a given environment. Details of the model equations and fundamentals can be found at the following addresse: http://w3.ifremer.fr/aquadeb/

- The Shellfish Production Model allows to compute the shellfish abundance and biomass, according to the quantity of individuals at the beginning, the mortality rate, and the results of DEB model.

4.3.2 Models used in the present study

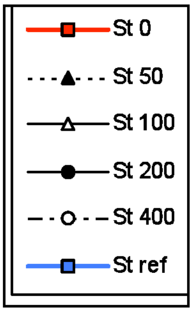
Two models were used in the site, based on the available datas and time availability, the hydrodynamic model MARS 2D (Stanizière et al. 2006) and the depletion model (Bacher 2007).

The model templates are given in Annexe 3, 4 and 5. All the informations required for the use of these models are given there.

4.4 Results.

4.4.1 Sediment

For all the graphs concerning the sediment, a common legend represents in red, the station beneath the mussels and in blue, the reference station.



4.4.1.1 Organic matter

Total organic Matter

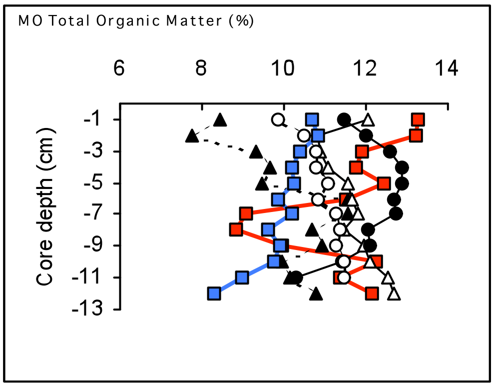


Figure 19: Content of the sediment in total organic matter at the different stations and at different depths within the sediment.

The content in total organic matter of the sediment is generally high in all stations, in slightly decreases with the depth. No clear spatial difference can be observed on the graph, between the different stations: the content in organic matter is higher at the farthest station (400 m) than at the nearest (50 m).

Refractory organic matter

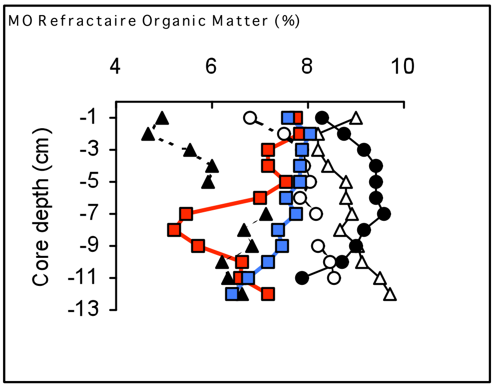


Figure 20: Content of the sediment in refractory organic matter at the different stations and at different depths within the sediment.

The results concerning the refractory organic matter are difficult to integrate in a model of impact of shellfish culture, since both the station under the culture and the reference station, have values quite similar, and the other stations are characterised by values, either lower or higher than these two. Also, the shapes of the curves within the sediment are contradictory. According to the protocol of measure, the contents in total organic carbon and refractory organic matter are not independent.

Labile organic matter

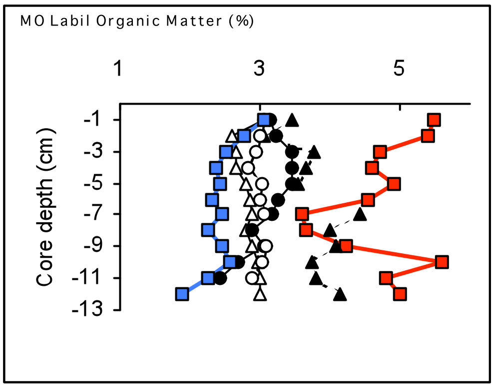


Figure 21: Content of the sediment in labile organic matter at the different stations and at different depths within the sediment.

The content in labile organic matter of the sediment, at the difference of the total organic matter (figure)and the refractory organic matter, shows spatial differences between the stations. Under the culture, the content is the highest, around 5 % depending on the depth into the sediment, while at the reference station, the content is the lowest, at all depths but one. Furthermore, the content of labile organic matter is roughly inversely proportional to the distance from the culture.

Sediment Carbon quality (Rp index)

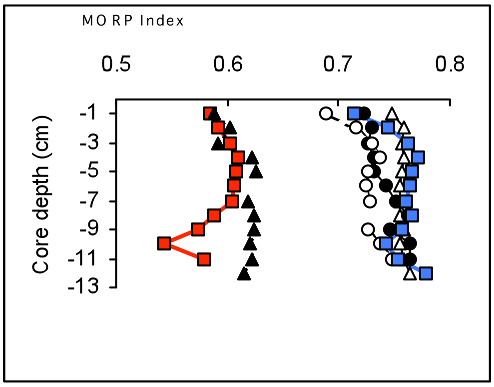


Figure 22: Sediment Carbon quality of the sediment at the different stations and at different depths within the sediment

The sediment carbon quality clearly allows to separate the two stations which are near or under the culture of of mussels, and the other stations, including the reference station, which exhibits among the higher values of this index. The values remain relatively stable with the depth. The upper layers of the sediment may show lower values. The sediment carbon quality seems to be a good candidate as an indicators of the impact of shellfish culture into the sediment.

Organic carbon

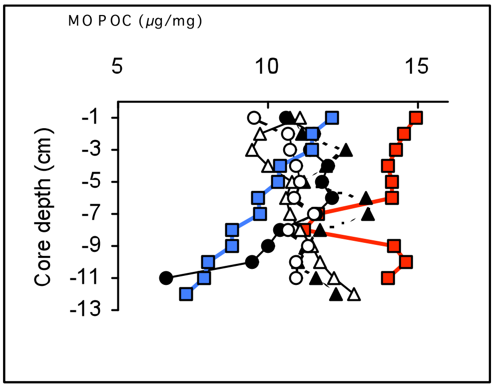


Figure 23: Content in organic carbon at the different stations and at different depths within the sediment

The content in organic carbon is higher at the station under the mussels, but the reference station exhibit values which are not different of those observed in other stations (in particular, station 200 m). A spatial trend is not clarly observed from these results, excepted if it is considered that the impact was spatially limited to the station located under the mussel. and therefore, this parameter is not a good candidate as indicator to describe the impact of shellfish culture on the sediment.

4.4.1.2 Other parametres

Nitrogen

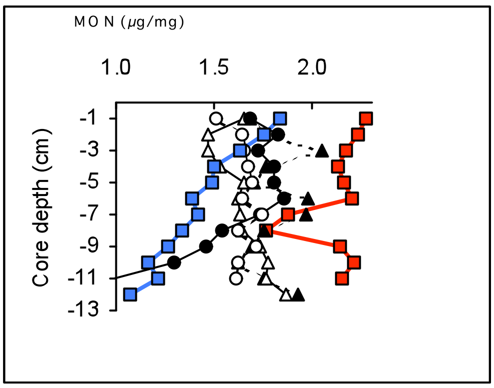


Figure 24: Content in Nitrogen at the different stations and at different depths within the sediment

Similar observations can be made for the Nitrogen content. Except from the station “0 m”, there no clear spatial trend, at least for the five first centimeters. Therefore, the same conclusion applies for this parameter.

Carbon/Nitrogen ratio

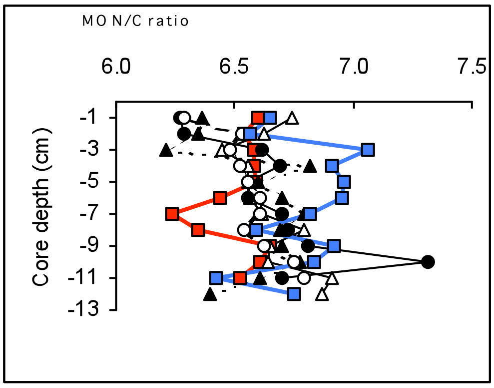


Figure 25: Carbon versus Nitrogen ratio at the different stations and at different depths within the sediment

While the carbon and nitrogen exhibited similar patterns, their ratio does not allows to deduce any spatial or vertical trend, linked with the presence of mussels. Most of the values are included between 6.2 and 7. Therefore the C/N ratio remained quite constant over the spatial and vertical scales, and could not be used as an indicator of the impact of mussels on the sediment.

Silt content (% < 63 µm)

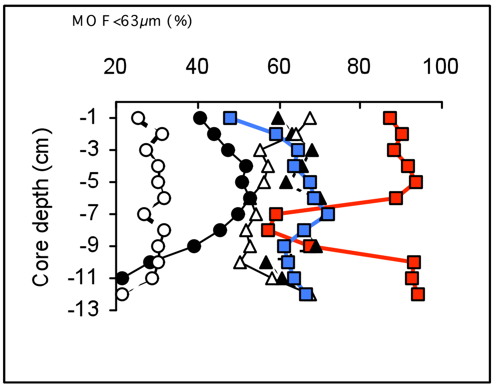


Figure 26:Silt content at the different stations and at different depths within the sediment

The reference station is superimposed with other stations (“50 m”, “100 m” and “0 m”), but there is a spatial trend for the stations located in the transect from the mussels: However, the reference station does not integrate a potential scheme. The silt content, as observed in these conditions may be considered for further considerations as a candidate indicator, being agreed that the results of ECASA studies in other shellfish sites, should be compared in order to elucidate the case of the reference station.

Chlorophyll a content

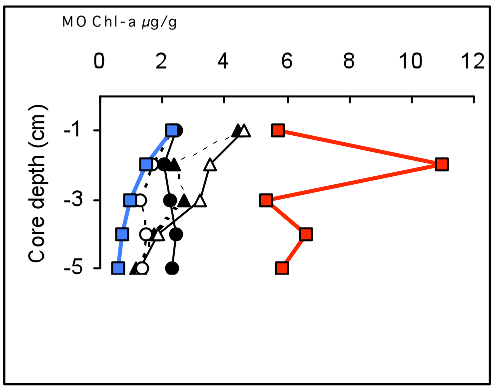
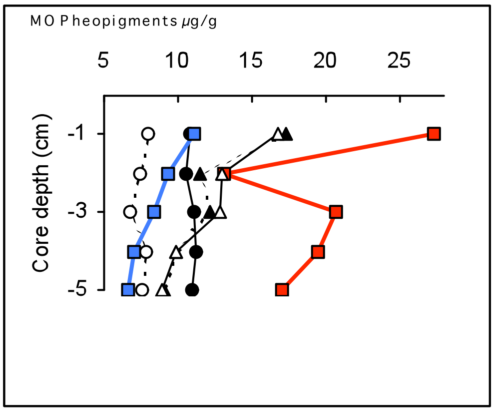


Figure 27: Chlorophyll a content at the different stations and at different depths within the sediment

The Chlorophyll a content of the sediment is clearly higher at the station “0 m”, then at any other station. Furthermore, the different stations are approximately exhibiting Chlorophyll a values inversely proportional to the distance from the mussels, even so if some stations are overlapping. In the surface sediment, the stations “50 m” and “100 m” are slightly impacted, and the other stations of the transect as not impacted if compared with the reference station. A threshold of 5 µg/g of chlorophyll a in the sediment would separate the slightly impacted sediment to those heavily impacted.

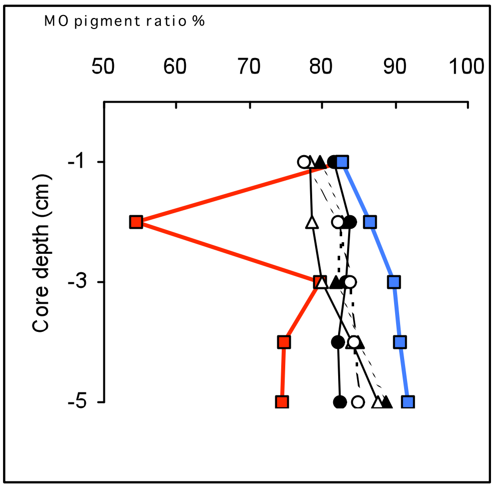
Pheopigments content



The phaeopigments content exhibit patterns somewhat similar to the one for Chlorophyll a, but with more overlapping between the stations and values at the station “0 m” which are less clearly separated from the other stations. The Pheopigments content is less valuable as a potential indicator of the effects of shellfish culture on the sediment

Figure 28: Pheopigments content at the different stations and at different depths within the sediment

Chlorophyll/pheopigment ratio



This ratio is representative of the quality of the chlorophyllic pigments. The higher values are found at the reference station, and the stations performed on the transect overlap. The station “0 m” seems to be characterised by the lowest values , indicating the presence of more degraded pigments, but a doubt exists for the layer “2 cm”, for which the acidification process could have been incomplete. From this, the chlorophyll content would be preferable as indicator of the effect of shellfish culture on the sediment

Figure 29: Chlorophyll/phéopigment ratio at the different stations and at different depths within the sediment

Redox

The different cores sampled for the redox determination were exposed in a inflatable boat to rough conditions. Only two of them were preserved in acceptable conditions. Unfortunately they correspond to the farthest station and the reference station. The values read in the millivoltmetre were corrected with the electrode potential (280 mV) to obtain Eh values.

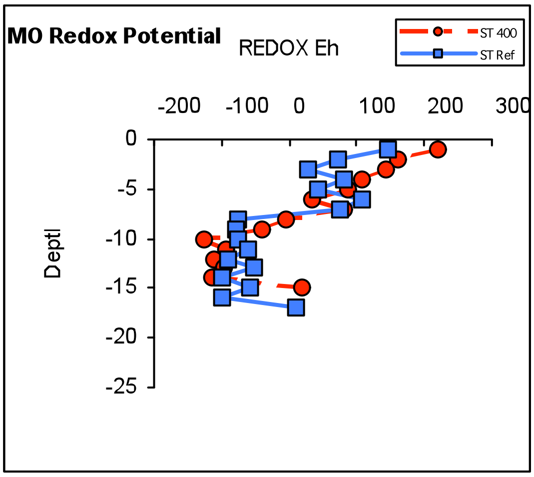


Figure 30: Redox values (Eh) at the different stations and at different depths within the sediment

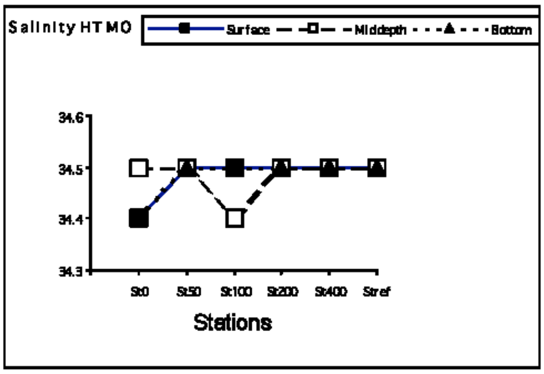
For these two cores, a similar pattern was observed for the Eh values. The Eh remain positive down to a depth of 7cm, and then become negative, both in the station "400 m" and in the reference station. Therefore, no conclusion can be proposed from these partial results, in term of potential indicator of shellfish impact. It is worth noticing that even under the mussels, the surface sediment (from 0 to a depth of 7 cm), had a positive Eh value, corresponding to oxic conditions for the degradation of organic matter (Emerson & Hedges 2007).

4.4.2 Hydrology

Results concerning the measurements made at high tide are presented on the left graph and those made at low tide on the right graph.

4.4.2.1 Physico chemical parametres

Salinity



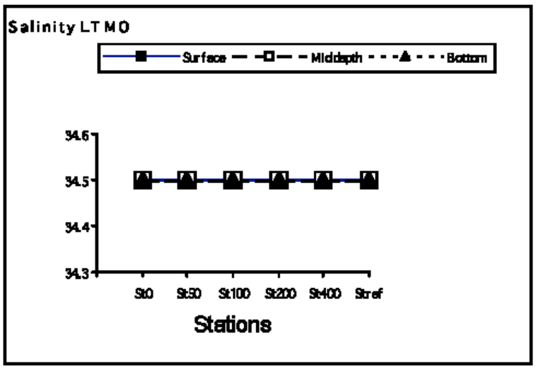


Figure 31 : Salinity measured on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

Either during high tides or during low tides, the salinity remained fairly constant. The salinity probe having an accuracy of 0.1 ppm, the variations observed for two stations during high tides, are barely significant. The values are near of those characteristics of oceanic waters. At the time of the sampling, the climate was dry for the last four months, and the local rivers, the Sèvre Niortaise, and the Lay had a very low flow.

Temperature

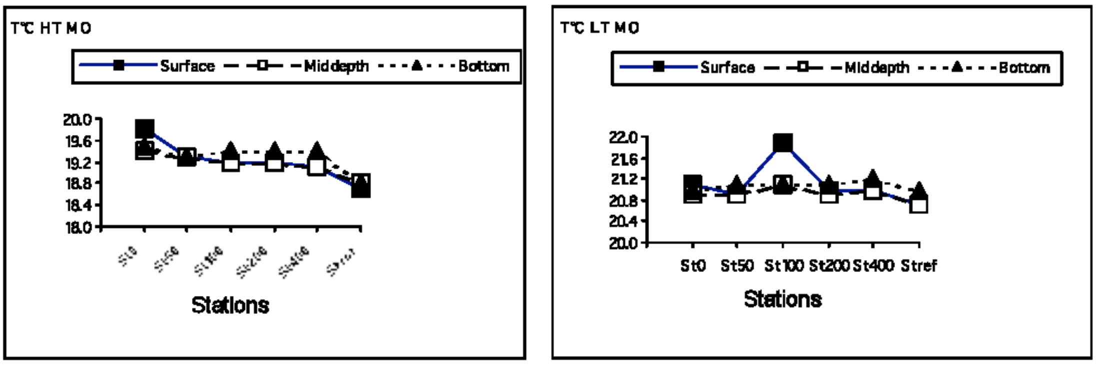


Figure 32 : Temperature measured on the different stations and a three levels,, at high tide (left figure) and a low tide (right figure)

The temperatures measured on the site were characteristics of was is generally observed in August and September, for the Baie de l'Aiguillon (East of the site) and the Bay of Marennes-Oleron (South of the site). Their variations could be related with the presence of different water bodies in the Pertuis Breton, at the time of the measures.

O2, percentage of saturation

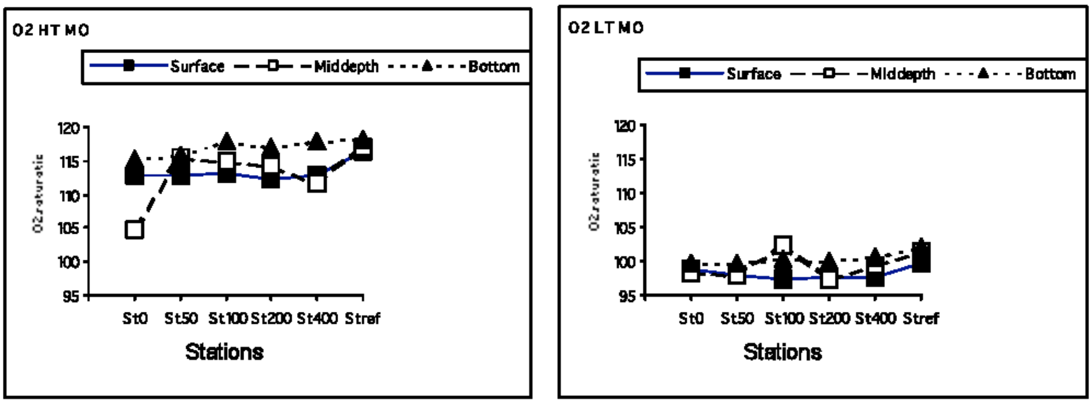


Figure 33 : Percentage of saturation of dissolved oxygen, measured on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

During the field campaign performed at high tide, both a rough weather, inducing short waves, and an intense sunny period resulted in high values of oxygen contents. The percentages of saturation all exceeded 105 % and averaged 115 %. As a result of the intense mixing induced by tidal currents and waves, the upper values were found near the bottom. At low tide, the values were all comprised between 97.3 % and 102.5 %, indicating the presence of good oxygen conditions for the whole water column, and the absence of any depletion in oxygen.

Secchi disk

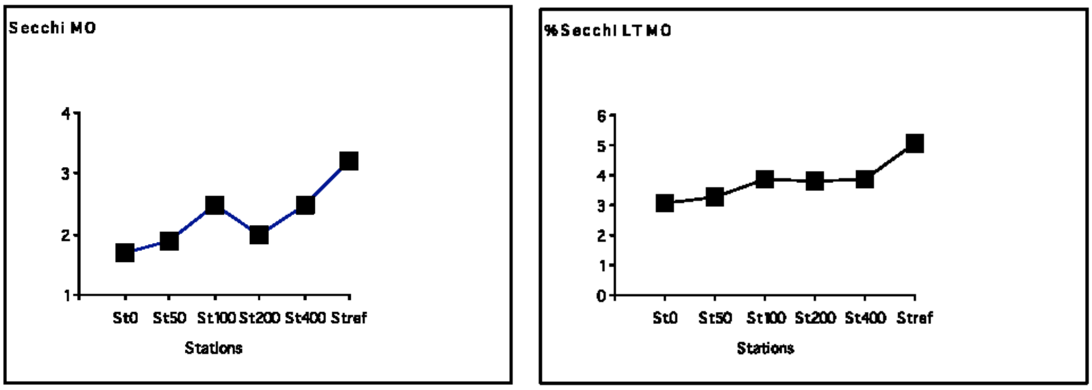


Figure 34 :Depth of disappearance of the Secchi disk, measured on the different stations, at high tide (left figure) and a low tide (right figure)

The very low values found both at high tide and a low tide were characteristic of the site which is turbid. Interestingly, the values were increasing with the distance from the mussels, which may describe a spatial impact ion the turbidity. A visual observation has confirmed that the turbidity was due in the main, to mineral suspended matter, either related to the production of pseudofeces, or to the resuspension of mud in shallow waters. The reference station had in both samplings, values higher then those measured in the transect.

4.4.2.2 Organic matter

Total Particulate Matter

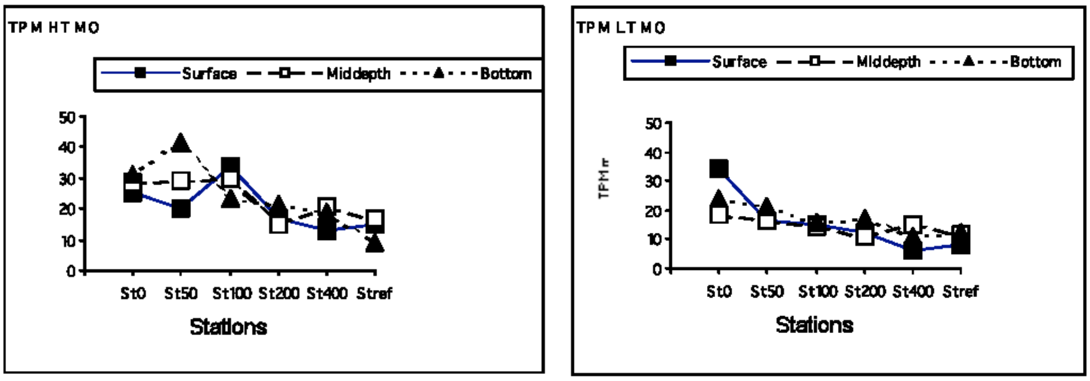


Figure 35: Total particulate matter, or Total suspended solid (TSS), measured on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The total particulate matter also showed spatial trends similar to those observed with the Secchi disk measurements. However, at the reference station, the values were not different from those observed for the last station of the transect. At low tide, the values were slightly lower then at high tide. No significant difference was observed between the different levels, indicating a good vertical mixing in this macrotidal area.

POM

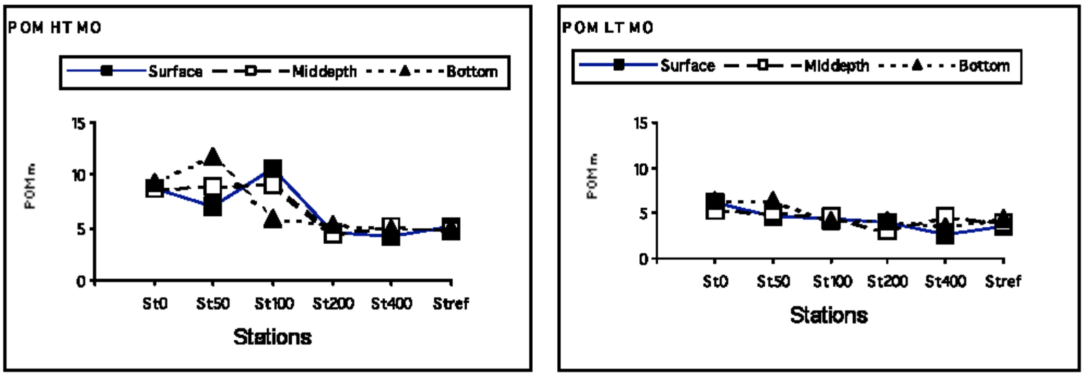


Figure 36 : Particulate organic matter (POM) measured on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The particulate organic matter decreased at high tide from the station 0 M to the farthest station, indicating a spatial trend. The reference station was no different from the two farthest stations. This could indicate that that the spatial impact, as described by this parameter, was limited to the stations located at proximity of the mussels. At low tide, the spatial trend is less clear. Again, the reference station did not differed from the farthest stations. In both samplings, no difference was observed at the different levels.

% POM

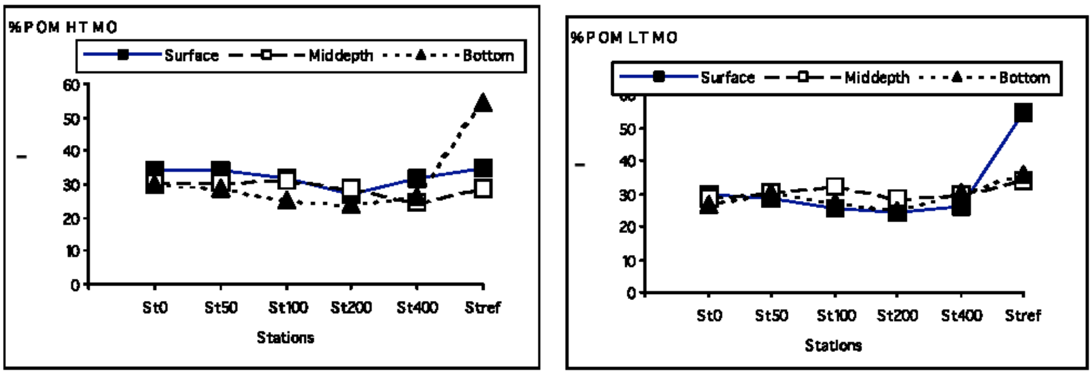


Figure 37 : % of Particulate Organic Matter (POM) on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The content of particulate organic matter in the water was fairly constant in all stations and at all levels, regardless of the tide intensity, excepted for the reference stations near the bottom (at high tide) or near the surface (at low tide). No satisfactory explanation considering the potential impact of mussels culture can be given about these differences.

POC

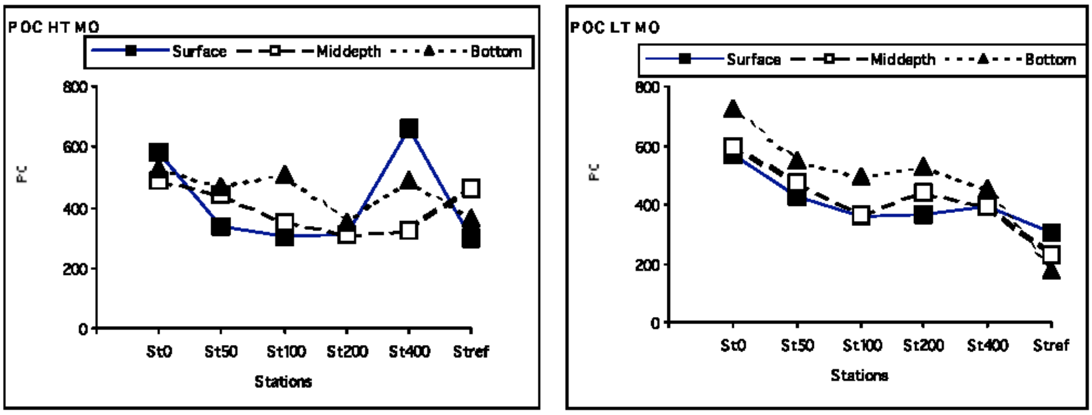


Figure 38 : Particulate Organic carbon (POC) on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The particulate organic carbon (POC) content was higher at the station 0 for the two tidal regimes. It clearly decreased with the distance at low tide, being even lower at the reference station. At high tide, results were difficult to interpret. The higher turbulence, due to stronger currents may have mixed the waters more thoroughly.

4.4.2.3 Other parametres

Total particulate Nitrogen

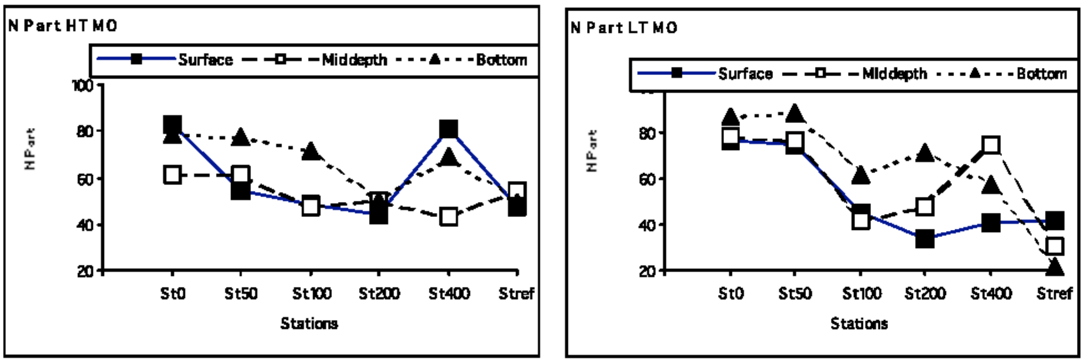


Figure 39 : Total particulate Nitrogen on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The total particulate Nitrogen followed trends very similar to those observed for the POC. But the value measured at mid depth, at low tide, did not correspond to the trend observed. A contamination or mistake is suspected for that value.

C/N Ratio

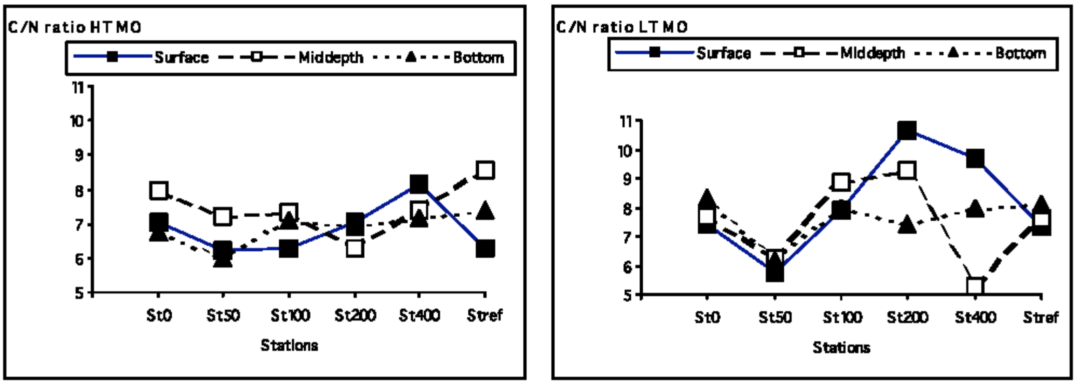


Figure 40 : Carbon versus Nitrogen ratio on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

During the high tide, the higher values of the C/N ratio were found under the mussels, but also at the farthest station and at the reference station. At low tides, the curves were erratic, excepted for the nearest stations. The turbulence may have caused the mixing of different layers, thus perturbing a potential gradient for this parameter, decreasing from the source of organic matter, to the reference point.

Chlorophyll a

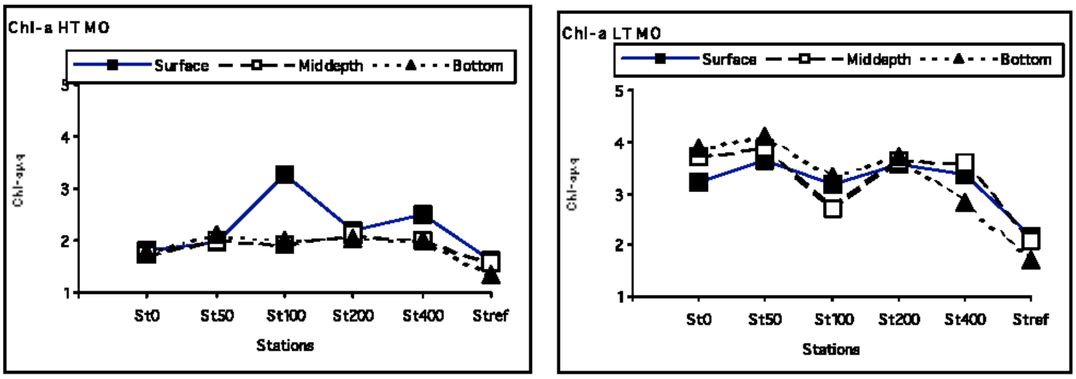


Figure 41: Active Chlorophyll on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The content in Chlorophyll a in the waters is surprisingly lower at the reference station, were they are no mussels filtering the waters. While a depletion of the chlorophyll a in this site has been described from a modeling approach (Houze, 1997), we can only conclude that under the conditions corresponding to the days of sampling, such a spatial effect was not observed for the active chlorophyll. In both cases, the values corresponded to the "low impact" category (Bricker et al. 2003).

Pheopigments

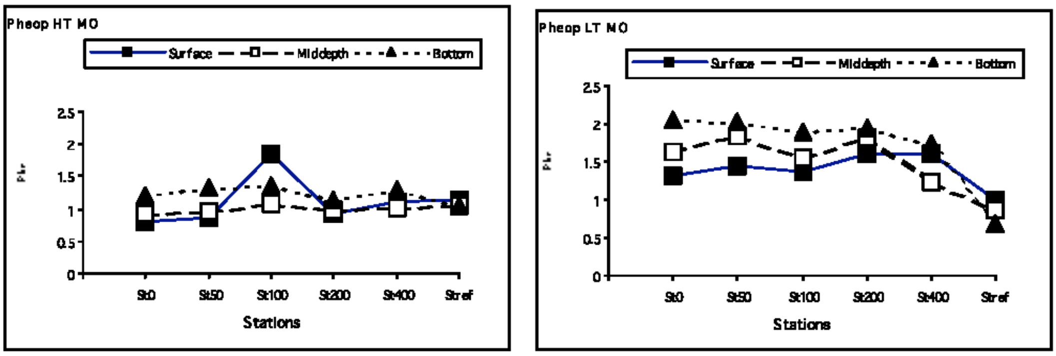


Figure 42 : Pheopigments (degraded chlorophyllic pigments) on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The pheopigments correspond to the degraded chlorophyll, as it may be the case after the passage of phytoplanktonic cells into the gut of filter-feeders. The spatial trends were very similar to those observed for the chlorophyll a and the same conclusions applied. A vertical trend was observed in several stations, where the content in pheopigments was higher at the deeper level.

% Pheopigments

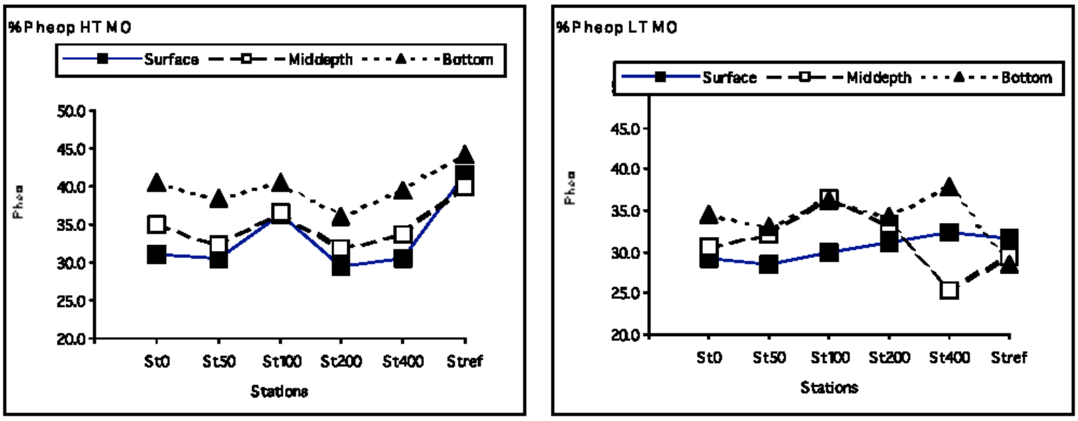
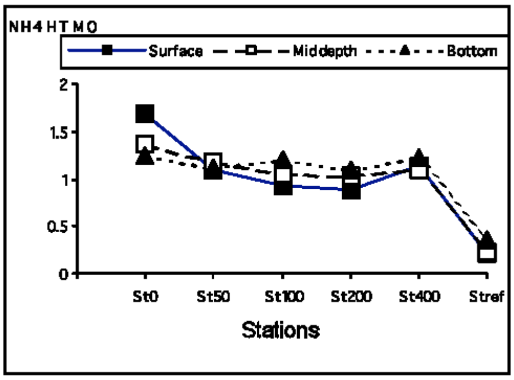


Figure 43 : percentage of Pheopigments (degraded chlorophyllic pigments) on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The values observed for this ratio were lower then those of the chlorophyll a, indicating that the phytoplanktonic cells were in good condition. No clear spatial trend could be observed. However, the ratio is generally higher near the bottom and lower at surface, because of higher contents in pheopigments.

4.4.2.4 Nutrients

Ammonium



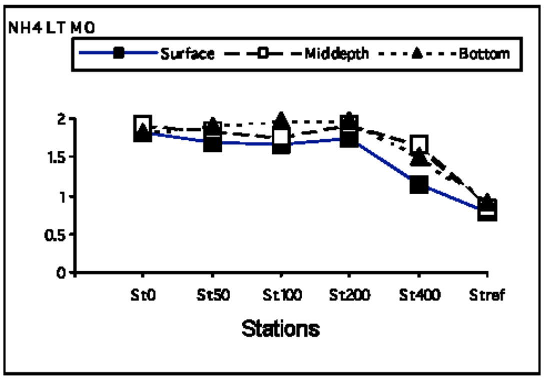
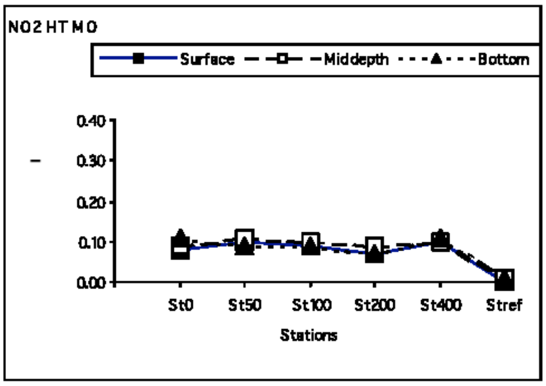


Figure 44 : Content in NH_4 on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The Ammonium content followed at every level a clear spatial trend, declining from the station “0m” through the transect. The reference station was characterized by lower values in both tidal amplitudes. No vertical trend could be detected along the transect.

Nitrites



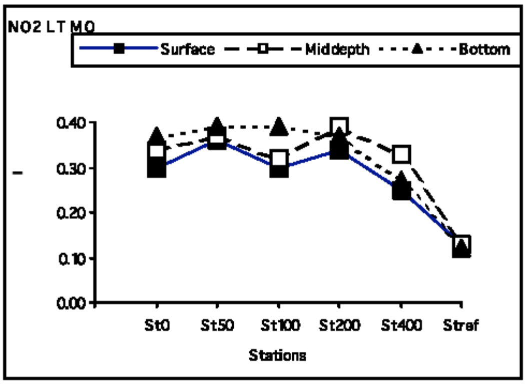


Figure 45 : Content in Nitrites (NO2) on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The nitrites were low and fairly constant at high tide, excepted for the reference station where the values were very low. At low tide, the nitrites contents were much higher, but no spatial trend could be detected. The lower values were still observed at the reference station. The values are low enough to reject any toxic effect of this nutrient on marine life.

Nitrates

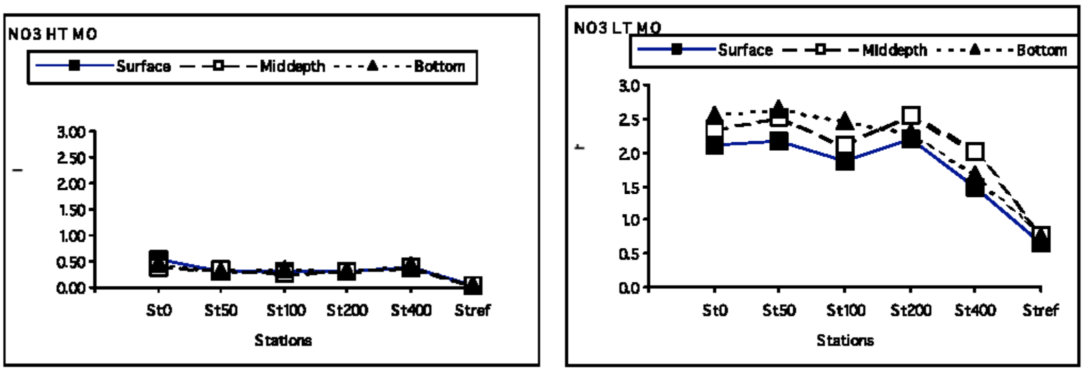


Figure 46 : Content in Nitrates (NO3) on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

The content in Nitrates followed almost identical figures, but with much higher values, as it is usual in coastal waters

Total dissolved Nitrogen

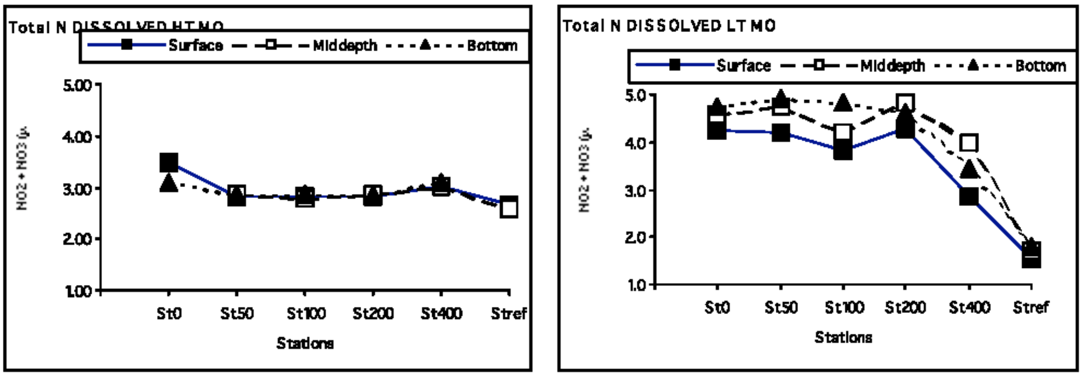


Figure 47 : Content in total nitrogen on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

When summing the different forms of dissolved Nitrogen, the figures were almost identical to what was observed for the nitrates. However, the different contributions were not equivalent, between mainly the ammonium and the nitrates. Under particular conditions, as it was observed at low tide, the dissolved nitrogen is present in quantities able to promote a primary production

PO4

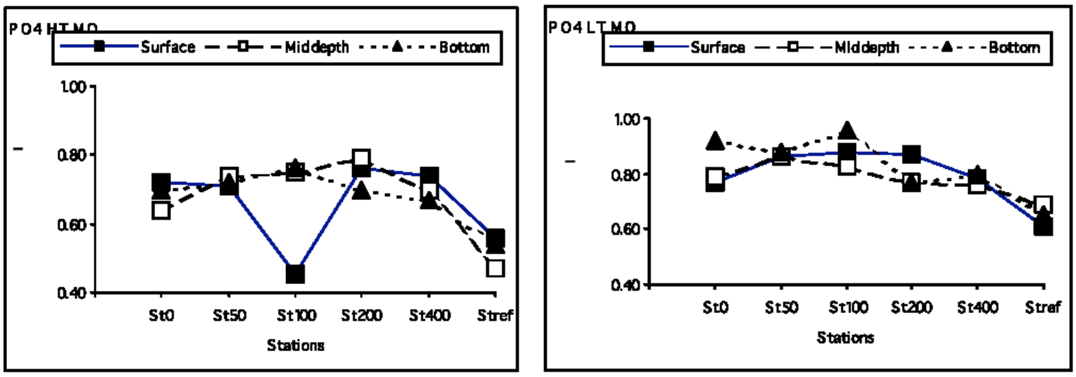


Figure 48 : Content in Phosphorus (PO4) on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

Few conclusions can be drawn in terms of impact of the mussel culture. The values measured along the transect did not exhibited any spatial or vertical trend, but the values were always lower at the reference station, thus indicating that the content in PO4 was higher in the area were the mussels are cultivated. The reasons are not clear.

Silicates

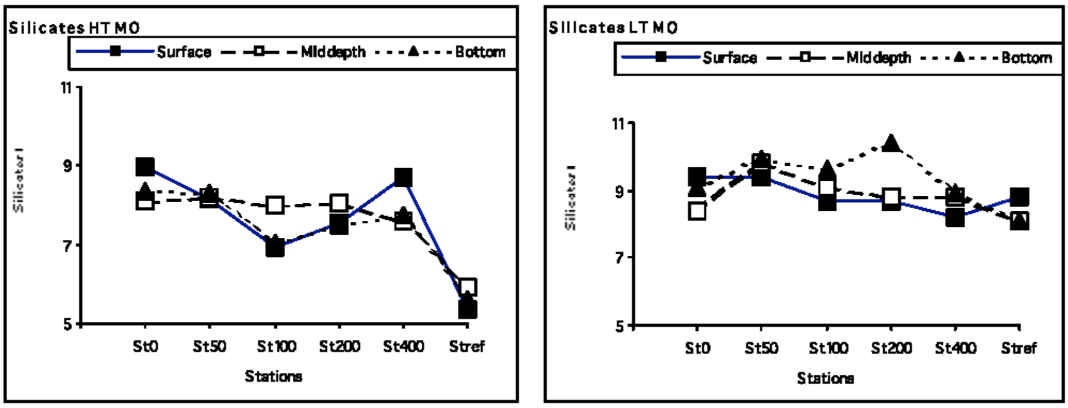


Figure 49 : Content in Silicates on the different stations and a three levels, at high tide (left figure) and a low tide (right figure)

Again, the contents in silicates did not reveal any spatial or vertical trends. The content was still lower at the reference station, but only at high tide.

4.4.3 Fauna and flora

The shellfish culture is well known to produce changes in the structure of the benthic communities where it is practiced (Mattson & Linden 1983, Kaiser et al. 1996, De graave et al. 1998, Stenton-Dozey et al. 2001, Christensen et al. 2003, Hartstein & Rowden 2004, Smith & Shackley 2004), even in intertidal areas (Nugues et al. 1996).

Previous studies on the benthos of the Pertuis Breton have been presented in the § 3.4. The results of the macrofaunal study conducted in 2006 in the Baie des Veys, as part of the ECASA project, are presented here by using a synthetic indicator, AMBI (Muxica et al. 2005). The full list of species and their abundance are in the annexe 2

Figure 50: Repartition of the different species among stations and replica (2) according to their ecological characteristics.

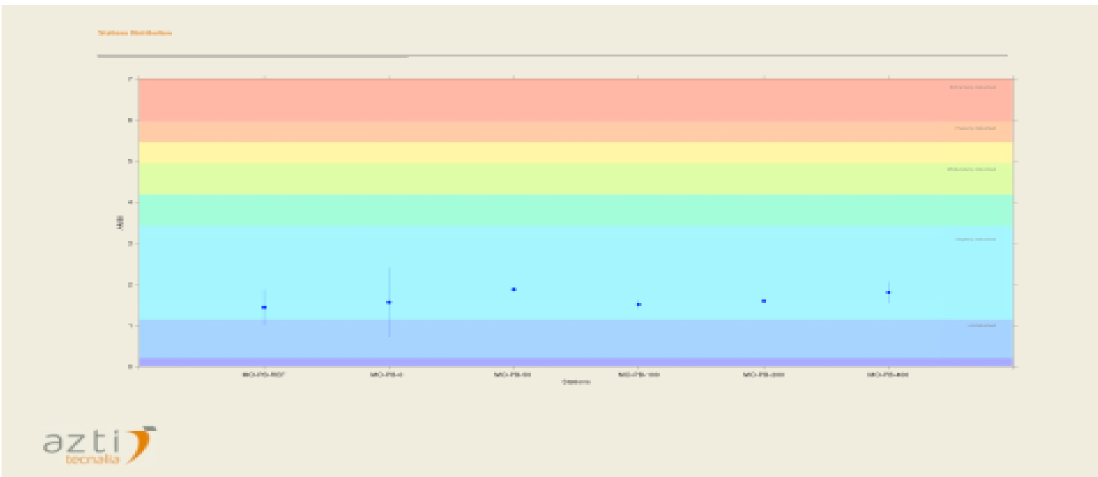


Figure 51 : values of the AMBI index for the different station from the reference station (left) to station 400 (right)

The figures 50 and 51 represent the results of the macrofauna study, on 6 stations with 2 replica[1]. We did not found any species pertaining to the ecological group V (first order opportunistic species), while the larger group was the one of species sensitive to pollution (group I), with a mean percentage of 41.75 %. Values of the AMBI index are allways less then 2, with an average value of 1.63. The reference station was characterized by the lower AMBI value (1.435). The station 0, 100 and 200 had an AMBi value less than 1.6. All the stations including the reference station can be classified as slightly disturbed (AMBI values less than 2). There is no statistical differences between all the stations. From these results, one may consider that the subtidal mussels culture in the Pertuis breton had no significant impact on the macrofauna.

[1] Two other replica per station were sampled, but the full taxonomic determination could not be obtained on time, for unscheduled reasons. A copy of the report with the full results will be added to the ECASA Web site.

4.5 Evaluation of Indicator Performance

From the list of indicator established by the ECASA partners (deliverable n° 10: Report on the relevance of indicators to quantify the impact of aquaculture on ecosystems), several indicators can be computed, by using the data collected during the field trip on sediment, macrofauna, water quality, and coastal zone management

4.5.1 Indicators for sediment

The following indicators were tested, according to the available data in this site of bivalve culture.

Sediment Carbon quality (Rp index)

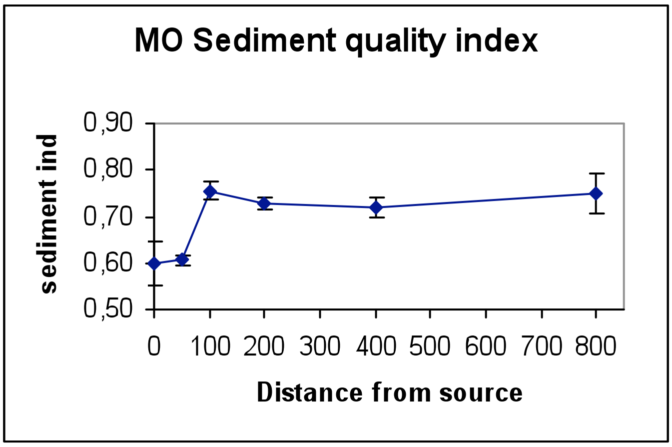


Figure 52: Sediment Carbon quality of the sediment at the different stations and at different depths within the sediment

The sediment carbon quality clearly allows to separate the two stations which are near or under the culture off mussels, and the other stations, including the reference station, which exhibits among the higher values of this index. The values remain relatively stable within the sediment. Lower values were apparently found in the upper layers of the sediment (from surface to 3 cm). To take this into account, it may be useful, when performing low cost studies, to take samples from surfaces to a depth of 5cm. The sediment carbon quality seems to be a good candidate as an indicators of the impact of shellfish culture into the sediment.

Since the stations located at 100 meters and more cannot be distinguished with the reference station, one may conclude that the sediment quality index indicates that the impact of mussels on the sediment was restricted to a distance of 50 meters in the Pertuis Breton.

Total organic carbon in the sediment.

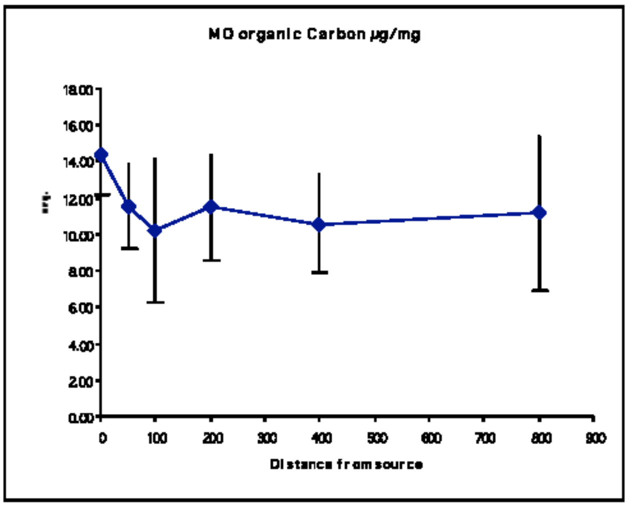


Figure 53: Content in organic carbon at the different stations.

The content in organic carbon is higher at the station under the mussels, but the reference station exhibit values which are not different of those observed in other stations (in particular, station 200 m). A spatial trend is not clearly observed from these results and therefore, <u>this parameter is not a good candidate as an indicator to describe the impact of shellfish culture on the sediment.</u>

Redox potential

Because of the poor quality of data for the stations near the shellfish culture, due to rough conditions during sampling, only two sets of cores gave exploitable results, orresponding to the farthest stations. This is considered as insufficiant to evaluate the interest of redox potential into the 5 surficial centimetres of the sediment, as a candidate indicator for describing the impact of the shellfish culture on the sediment.

Total Nitrogen content into the sediment

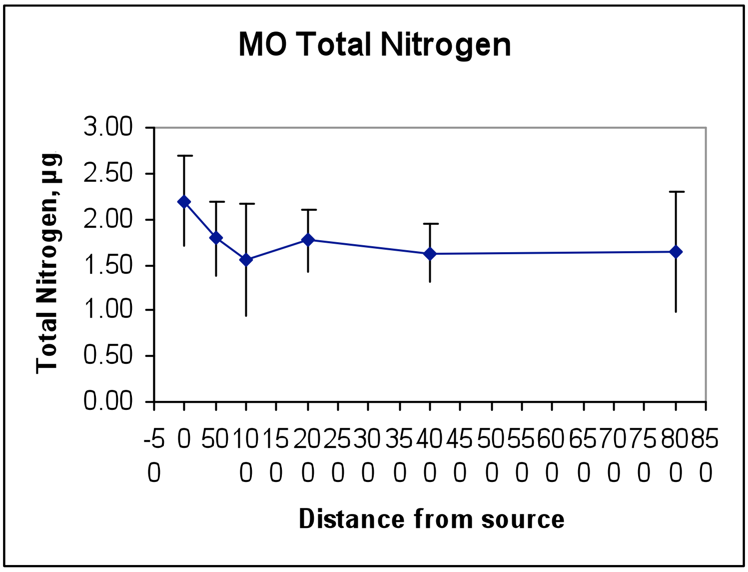


Figure 54: Content in total nitrogen at the different stations.

The nitrogen content into the sediment di not exhibit any significant trend, which could be advocated for demonstrating a clear impact of shellfish culture. <u>This</u>

<u>parametre cannot be selected as an indicator of the impact of shellfish culture</u> into the sediment, for the given conditions (macrotidal environment)

Chlorophyll a into the sediment

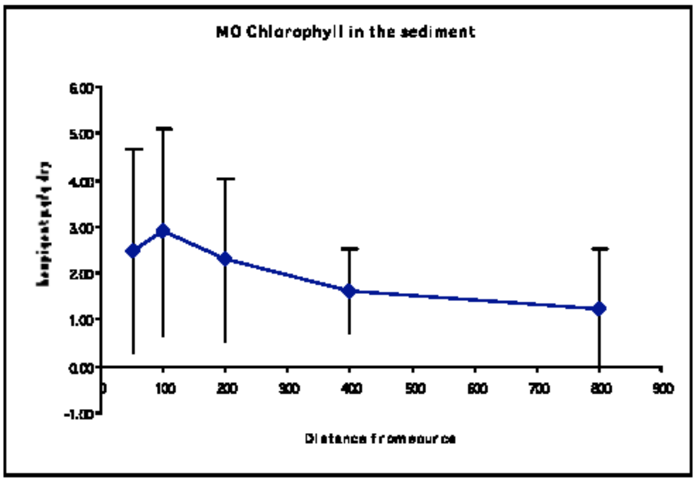


Figure 55: Content in chlorophyll <u>a</u>, at the different stations.

While some differences were observed between the different stations, the highest contents being observed near the source of impact, nos significant differences were found between the different stations. A general trend is observed, showing a decrease in the chlorophyll contents from the source. Considering that the biodeposits may contain a significant quantity of Chlorophyll a (Smaal & Zurburg 1997),

Phaeopigments into the sediment

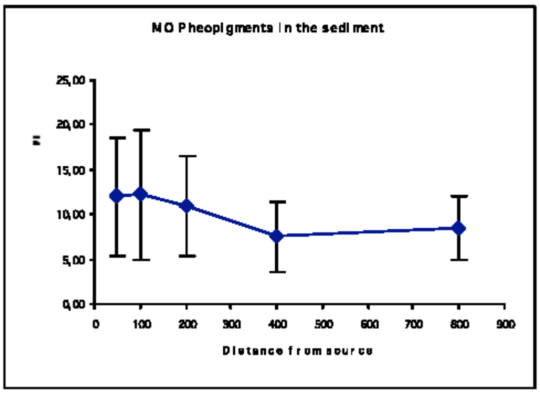


Figure 56: Content in pheopigments at the different stations.

The same remarks can be made regazrding the results of the phaeopigments into the sediment. Furthermore, phaeopigments are more abundants than the Chlorophyll into the biodeposits, since the phytoplanktonic cells serving as food are more or less digested during the gut transit. Therefore, the <u>phaeopigment content of the sediment should not be rejected as an indicator of the impact of shellfish culture</u> into the sediment.

Mud fraction into the sediment

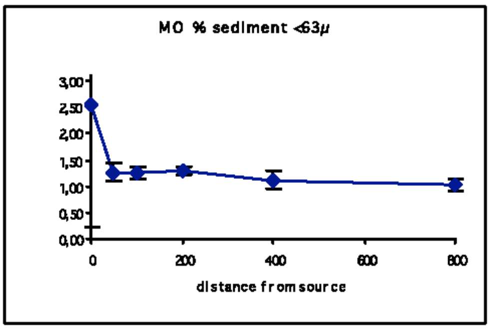


Figure 57: percentage of mud fraction at the different stations.

The fine fraction (or mud fraction) of the sediment exhibited a clear and significant trend,with a high value observed beneath the culture, and much lower values encountered at any other distance. The sedimentation of fine particles was apparently restricted under the longlines.. This parametre is an obvious candidate as an indicator of the impact of shellfish culture into the sediment.

4.5.2 Indicators for water quality and pelagic compartments

Among the different indicators representative of th water quality, some of them do not apply to the shellfish culture. The Maximum production with respect to water quality at farm is an indicator designed for intensive fish farming, as well as the one based on fish growth. The Minimum O2 in bottom water and the winter nutrient concentrations were also originally designed for fish farming. Both could be applied for shellfish culture but for the second one, adequate data were missing during the course of the ECASA contract

Minimum Oxygen content

The results given in figure 33 indicated that there was any depletion in oxygen at the time of the measurements. As far as shellfish culture is concerned, the conditions of the culture can generally (but not always) be considered as extensive. The amount of organic matter that is produced would rarely produces any severe depletion in oxygen. Therefore, the Minimum oxygen content, in such an open and macrotidal environment as the pertuis Breton, could not be considered as a good indicator of bad water quality.

However, special condition of culture can be encountered in confined environments such fjords, lochs and coastal lagons. Cases have been recorded in the thau lagon (Mediterranean Sea), where a phenomenon of eutrophication may occur in summer periods of dead calm. The biodeposits and the molluscs respiration contributed to increase the depletion in oxygen.

This indicator remains of interest for shellfish culture, when it developped in confined areas.

Secchi depth

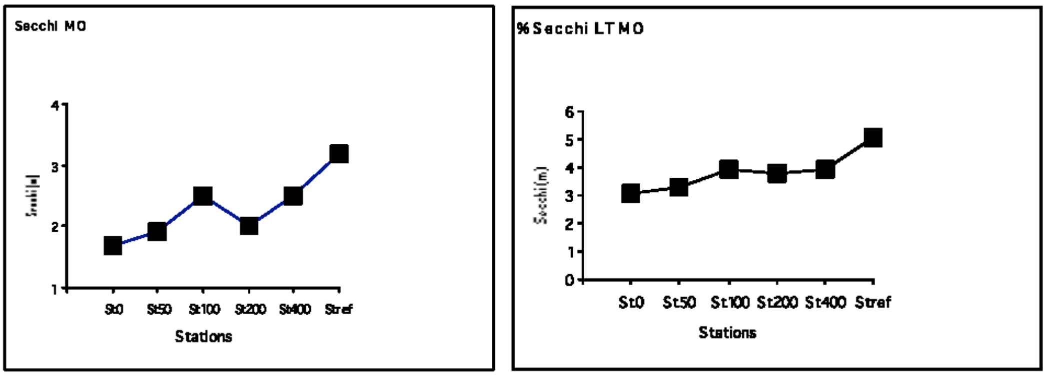


Figure 58: Value of the Secchi disk depth (m) at high tide (left) and low tide (right) in the Pertuis breton

The values measured for the Secchi depth are quite low in the pertuis Breton. This is due to a high turbidity, caused by the terrestrial inputs from the local rivers. As the chlorophyll content do not reach the values for which a state of eutrophication is observed, these low values do not reflect a change in the water status. Despite the low transparency of the waters, the primary production results in a quantity of phytoplankton large enough to support a production of several thousands of tonnes, not considering the mussels which are grown along the shoreline by a pole technique.

Therefore, the Secchi depth, in such an open and macrotidal environement as the pertuis Breton, could not be considered as a good indicator of eutrophication. This can be quite different in semi-enclosed areas, where the use of the Secchi depth for shelfish culture should not be rejected

Chlorophylle a

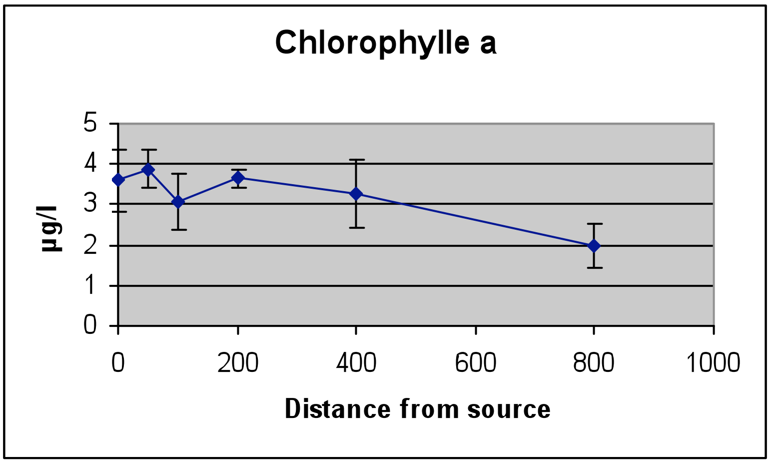


Figure 59: Concentrations of Chlorophyll a, at the different stations, averaged for the different depths (Surface, mid-depth and bottom

The chlorophyll concentration did not showed any clear trend at the vicinity of the shellfish culture. No depletion can be observed at the spatial scale selected for study. However, previous studies, based on a modelled approach (Houze 1997), have demonstrated the role of mussel culture in depleting the chlorophylle a content of the waters in the pertuis Breton. Considering this, and a possible relation at other spatial scale, the chlorophyll a should not be rejected as an indicator of the impact of shellfish culture on the water quality.

Particulate organic Carbon

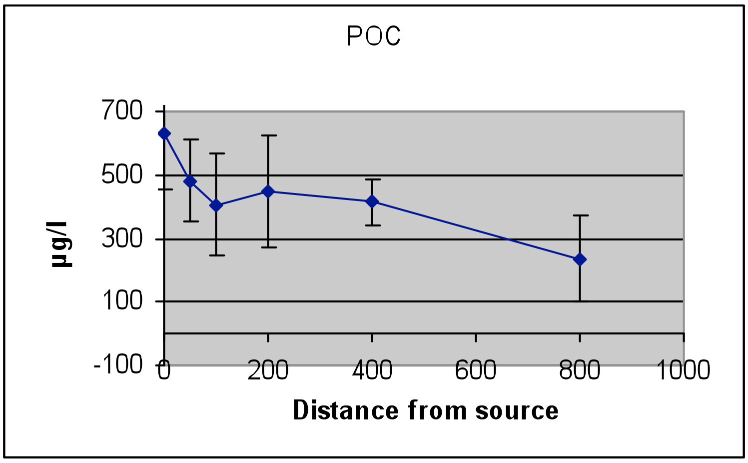


Figure 60: Concentrations of Particulate organic Carbon (COP), at the different stations, averaged for the different depths (Surface, mid-depth and bottom

The contents in Particulate organic carbon are not significantly different between the different stzations. A clear trend is observed along the transect. This was particularly true for the measurements performed at low tide, and the pooling of the results for the two tifal regime did not allow to obtain statistical evidence.Given this, the content of the waters in Particulate Organic Carbon should not be rejected as an indicator of the impact of shellfish culture on the water quality.

4.5.3 Indicators for macrofauna

Macrofauna presence

According to the data presented in annexe 2, there is obviously a presence o f well developped populations of a large number of species, even below the longline. In most of the environments suitable for molluscs culture, the environmentzl conditions would allow the presence of macrofauna under the culture. It may be possible that in deeply confined environments, the organi matter accumulated into the sediment could result in anoxic conditions. Such case was never recorded in normal operating coditins of shellfish culture. Therefore the Macrofauna presence is not a sensitive indicator for shellfish culture.

Indicator AMBI

The Ambi indicator did not seem to react clearly to the impact of suspended mussel on the macrofauna communities (cf. figure 51). However, several studies, including some of the ECASA site studies, have shown the interest of this indicator to describe the relationship between the presence of organic input and changes in benthic communities. It can be concluded that the impact of mussel culture in such a macrotidal environment was low, thus leading to a non significant response of the AMBI indicator. This fact does not allow to reject the AMBI indicator, which can be considered as an interesting tool to identify the impact of shellfish culture on macrofauna, in areas less exposed exposed to strong currents.

4.5.4 Indicators for the coastal zone management issues

Validated distance
The nearest protected area lies within the baie de l'aiguillon, an area of wintering for migratory birds. As such, this is a special protection zone, identified within the birds directive (European Union). The distance between the longlines and the area is of 15 km.

The validated distance as computed from the indicators sheet, is based on the establishment of a safe distance, which is generally considered to be 5 km. In our case, the value is equal to 0 %, corresponding to a "safe" distance. This validated distance appears to be a good indicator of the impact of shellfish culture for the coastal zone management issues. The procedures described in the annotated sheet to modify the safe distance could be usefull to adapt this indicator to the actual conditions of shellfish culture and to the resulting impact.

Aquaculture on shoreline
Most of the East part of the pertuis Breton is occupied by mussel culture on poles, in intertidal areas. While the longlines produce annually from 1000 to 1200 tonnes of mussels, the intertidal area is producing 8200 tonnes. But the growth of mussels is faster on the longlines, indicating better conditions than from the intertidal culture technique. It can be concluding that the longlines are not affected by the larger, intertidal area. On the opposite, the longlines do not significantly alter the growth of these mussels. When designing the use of subtidal areas for longline culture, the main objective was to find fast growing areas, since the growth was already low on the shoreline. The biomasse allocated to the longline was deducted from the intertidal areas, so as to maintain a constant biomasse within the whole bay.

The biomasse of aquaculture production per kilometre of shoreline does not seem to constitute a good indicator of the impact of shellfish culture for the coastal zone management issues. In spite, it is recommended to use models computing the carrying capacity of the site for molluscs culture, in order to assess the consequence of any change in the biomasse of shellfishes, on the resulting growth and production of the molluscs.

4.5.5 Socio-economic indicators

Because of the peculiarities of the shellfish culture in the pertuis Breton, it was difficult to evaluate the socio-economic indicators. As mentionned earlier, the area considered includes more then 100 farms, all different in size and business strategy. Average values could not be considered, since these farms do not follow a linear repartition according to their size. However, two indicators can be considered in this area, because they are general, and they are not obviously related with the size of the different farms.

Public attitudes towards aquaculture
The shellfish industry emploies a large number of people in the coastal cities around the pertuis Breton, from a very long time. Therefore the economic benefits are obvious, while the impacts are less perceived. It is known by the people, that the

mussel culture may contribute to increase the local sedimentation. The visual impact are not perceived, since it is not possible to access the shore around the baie of l'Aiguillon, because of the large areas covered by Spartina species. Some beaches and recreation areas are located north of the longlines area, but the distance of these from the shore (4km) does not allow to see the buoys floating at the surface.

Existence of conflicts

Conflicts were identified between the shellfish farmers and two groups: the fishermen trawling along the pertuis Breton, who did not easily accept to lose a part of their fishing grounds, and yachtmen who do not appreciate having a part of the sea prohibited for cruising along. Some fishermen finally recognised that no clear losses have resulted due to the longlines operations. Some other even consider that the biological productivity was enhanced. But the conflict with the yachtmen is not solved, and has been extended to any project aiming at increasing the areas of shellfish culture. Several trials are currently running. One of them is based on the validity of the environmental impact assessment, for a project of mussel longlines located South of the pertuis Breton, in the pertuis d'Antioche.

4.6 Evaluation of Model Performance (Cedric Bacher)

Since the hazard agent is the extraction of food particles, we first calculated the amount of water pumped by the mussels every day inside the longline area. Considering the number and length of ropes (Figure 3), the number of mussels was estimated to about 240 millions of mussels. If we assume that each adult mussel filters around 3 l.h-1, the total volume of water pumped by the actual standing stock is about 17 106 m3 everyday and results in a filtration time of 1.4 days. This average value has to be adjusted due to environment fluctuations and mussel weight changes. Environmental parameters and mussel growth have been monitored during 1 year and ecophysiological experiments were conducted to assess food availability and use by the mussels. Measurements of Total Particulate Matter (TPM), Particulate Organic Matter, Chlorophyll a in the longline and the bouchot areas showed that trophic conditions of bouchot and long line sites were different (Garen et al. 2004). Chlorophyll a varied between 1 and 11 µg.l-1 with values higher in bouchot than in long lines and mean values of 2.0 and 3.2 for the 2 sites. TPM was also higher in bouchot, and values lay between 5 and 50 mg.l-1 and average values were equal to 13.1 in long lines and 23.1 in bouchot. Temperature varied between 5 (December) and 22 °C (August). Mussel growth showed very similar pattern in bouchot and long lines (Figure 61), but was lower in bouchot. Dry weights increased from March until September and decreased slightly afterwards. Maximum dry weights were equal to 1.3 g in long lines and 0.8 g in bouchot and final dry weights equalled 0.7 g and 0.4 g in the same sites. Shell weights increased during spring and summer and varied only slightly afterwards. Final shell weights equalled 4.7 g in long lines and 3 g in bouchot.

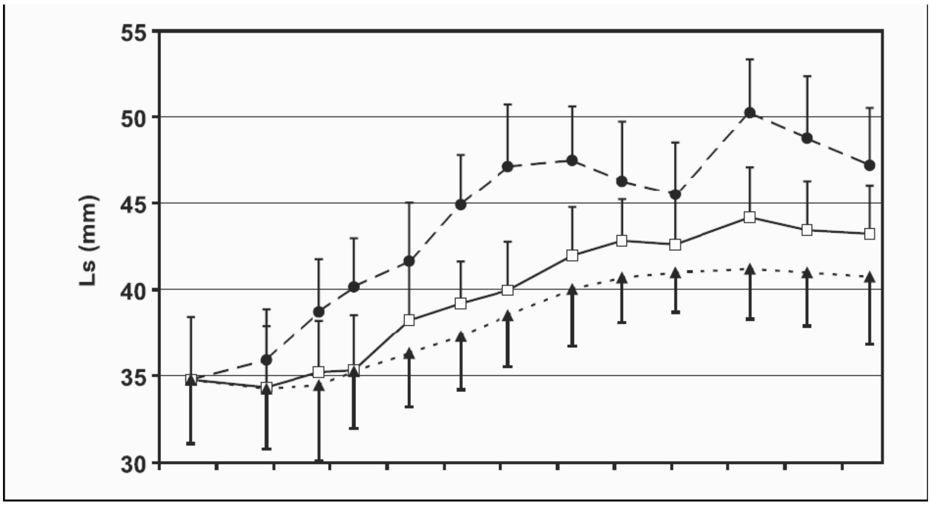


Figure 61 : Monthly progression of shell length of mussels from the 2 locations: longline (dashed line), bouchot (plain and dotted lines). Data plotted as mean+/- S.E. (from Garen et al., 2004)

An ecophysiological model derived from Grant and Bacher (1998) was applied to calculate physiological responses to temperature, particulate organic matter, phytoplankton and total suspended matter concentration. Such processes have been studied in details through experiments and ecophysiology models have been recently published for M. edulis with more or less details on governing processes (Ross &

Nisbet 1990); (Scholten & Smaal 1998); Grant and Bacher, 1998; (Hawkins et al. 1998); (Casas & Bacher 2006). In the model by Grant and Bacher (1998) for instance, clearance rate (1.h-1) of particles is a declining function of TPM. Phytoplankton and POC are both cleared at the same rate, and a proportion of the ingested mass is rejected as pseudofeces in relation to turbidity using a step function : no rejection at 0–5 mg.l-1, 20% rejection at the pseudofeces threshold up to 10 mg.l-1, 40% rejection from 10–40 mg.l-1, and peak rejection (85% of ingesta) beyond 40 mg.l-1. Phytoplankton is selected preferentially to detritus. In terms of ingestion, phytoplankton and POC are maintained as separate quantities, each with an absorption efficiency (AE) value, and absorption rates are summed to calculate total absorption. Phytoplankton AE is assumed to be 80% and AE for detrital POC is set at 40%. As opposed to other models using gut capacity and gut passage time to limit ingestion (Scholten and Smaal, 1998) daily ingestion can not be higher than a constant value defined as the maximum daily ingestion. Net energy balance is determined as the difference between rates of assimilation and respiration, and allocated to somatic tissue and shell, allowing to compute individual growth. One consequence of these series of calculations was that the effective amount of phytoplankton removed from the water column was about 30% of the filtered material we estimated above

Exposure assessment

In carrying capacity assessment, the main route to exposure is related to current velocity, primary production and filtration by cultivated shellfish which can be combined to estimate food availability and individual growth (Smaal et al. 1998). When local effects are first considered, food concentration, current velocity and filtration rate can limit food availability (Bacher et al. 2003) All these factors depend on the studied site and the species characteristics. In Pertuis Breton, current velocity was computed with a hydrodynamical model implemented by (Struski 2005) who predicted water height and current velocity along West-East andSouth-North directions. Water height and tidal currents were simulated for one month to account for neap and spring tides. Maximum current velocity was mapped from this single simulation and showed that long lines were located in a region of intensive water exchange with maximum current velocity over 1 m.s-1. Current velocity generally depends on tidal coefficient and maximum tidal currents varied between 0.5 and 1 m.s-1. In long line area, current direction lies along a northwest/southeast axis and intensive exchange of water occurs at Pertuis Breton straight (Figure 62). Particle trajectories were computed for one tidal cycle during spring tide using current velocity field computed by the hydrodynamic model. They show how particles coming from the inner part of the bay (Aiguillon bay) exit through Pertuis Breton straight in the west or through La Pallice straight in the south. Traj ectories also show that tidal excursion equals almost 10 km which sustains the assumption of strong water mixing in the inner part of the bay and probably minimizes food depletion, as opposed to areas with lower water mixing (Bacher et al., 2003), but also means that particles retained by shellfish in the central part of the bay are longer available for mussels on bouchot.

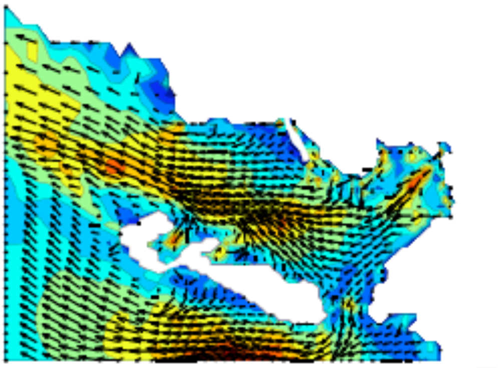


Figure 62 . Map of maximum current velocity (m.s-1, in colours), with arrows representing flow direction during the ebb.

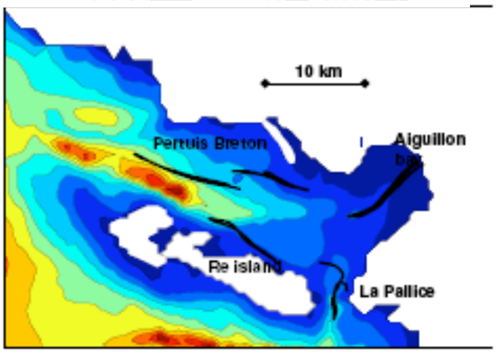


Figure 63. Trajectories of particles simulated with a hydrodynamic model used to compute water mixing in Pertuis Breton

Even though the filtration depends on the lifecycle of the individuals (e.g. temperature, food concentration, individual size and physiology), the high value calculated for the new farm suggests that the exposure must be considered at two different scales – e.g. locally, within the new cultivated area, and globally by assessing the effect of longline onto bouchot areas.

A box model was developed to account for competition for food within the longline areas and to assess whether the farm size and mussel density would affect the carrying capacity. The model is coupling food transport, food consumption by the mussel population and mussel growth at the scale of a cultivated area. The concept is the same as used by Bacher et al. (2003) except that we assumed that food and particulate matter concentrations were homogeneous within the cultivated area which was considered as a single box. The transport equation is a mass budget equation accounting for i) the exchange of water between the box and the part external to the cultivated area ((Bacher et al. 1998); (Raillard & Ménesguen 1994); (Dowd 1997)), ii) sinks of particles due to filter feeders consumption. Food consumption was calculated using ingestion rate of mussels instead of filtration since we assumed that an important fraction of the filtered particles would remain in the water column as pseudofeces and would be reused by mussels with the same efficiency and growth rate was based on the ecophysiology model of(Grant & Bacher 1998). Details of the equations are given in the Annex 5.

The box model for the long lines area with standard values of water exchange, box volumeand number of mussels using environmental data as boundary conditions. It was expected that increasing the number of mussels would decrease food concentration and result in a lower mussel growth. We therefore defined a series of theoretical scenarios combining different mussel densities and lease size. Nominal lease size was multiplied by a factor *l* between 1 to 5. If current speed and mussel density were kept constant, this is equivalent to multiplying cultivation area, volume and total number of mussels by *l2*, while exchange flow and water residence time were multiplied by *l*. We increased nominal lease size and mussel density, by a multiplication factor between 1 and 10.

An exposure indicator was defined from the depletion of phytoplankton computed for the different scenarios of farming extension and averaged over one year (Figure 64). It is shown that a decrease of phytoplankton within the farm area by a factor of 10 % would be obtained when farm size of mussel density would be approximately doubled.

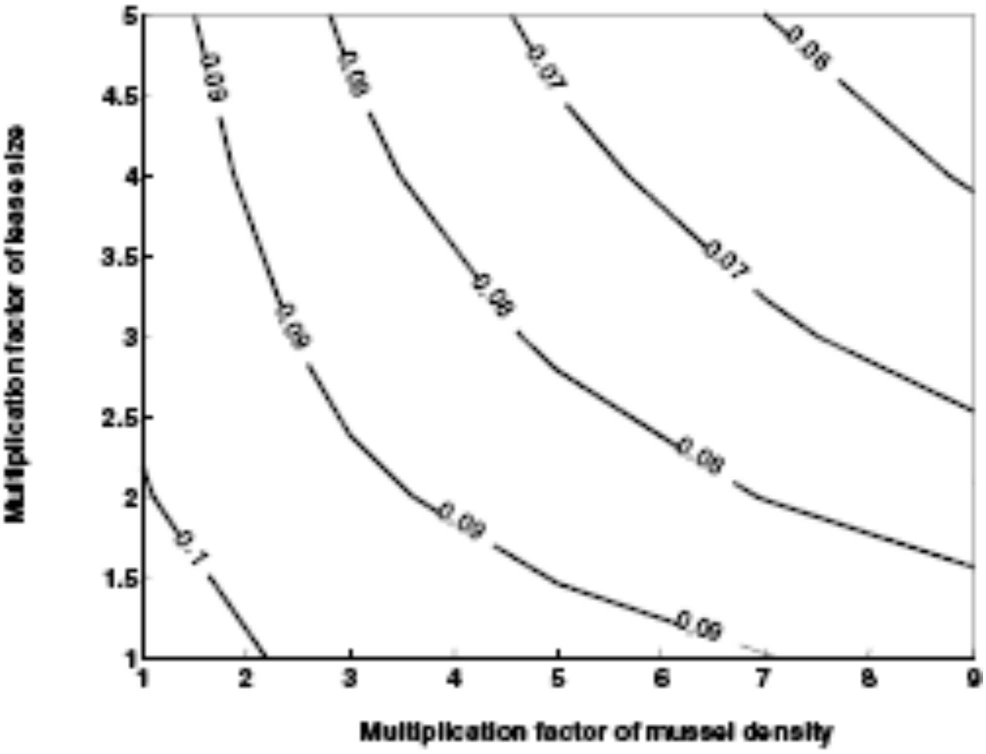


Figure 64 : Phytoplankton concentration (mg C.l-1) shown by the box model with scenarios of increasing density and farm size. The actual situation corresponds to a value of 1 for both multiplicative factors.

Consequence Assessment

Using the same box model, consequences of food depletion on growth were assessed with different scenarios. The standard simulation showed a very small decrease of mussel weight, hardly visible when plotted. It was related to the large flow of POM and chlorophyll a to the lease area compared to the low food use by mussel population. For phytoplankton, computation of annual carbon budget showed that filtration was equal to 0.054, ingestion to 0.048 and inflow to 1.98 mgC.l-1.d-1. For detritus, the same fluxes equalled 0.55, 0.38, 19.4 mgC.l-1.d-1, showing that less than 2 % of the inflow was diverted to mussel population and that food ration was mainly composed of detritus. Increasing lease size or mussel density had similar effects on final mussel dry weight. Minimum final dry weight was less than 0.5 g and was obtained when lease size was multiplied by 5 and mussel density by 10 – to be compared to 0.9 g with actual density and lease size. However, the effects of lease size and mussel density increase were the same and isolines of final dry weight were symmetrical (Figure 65).

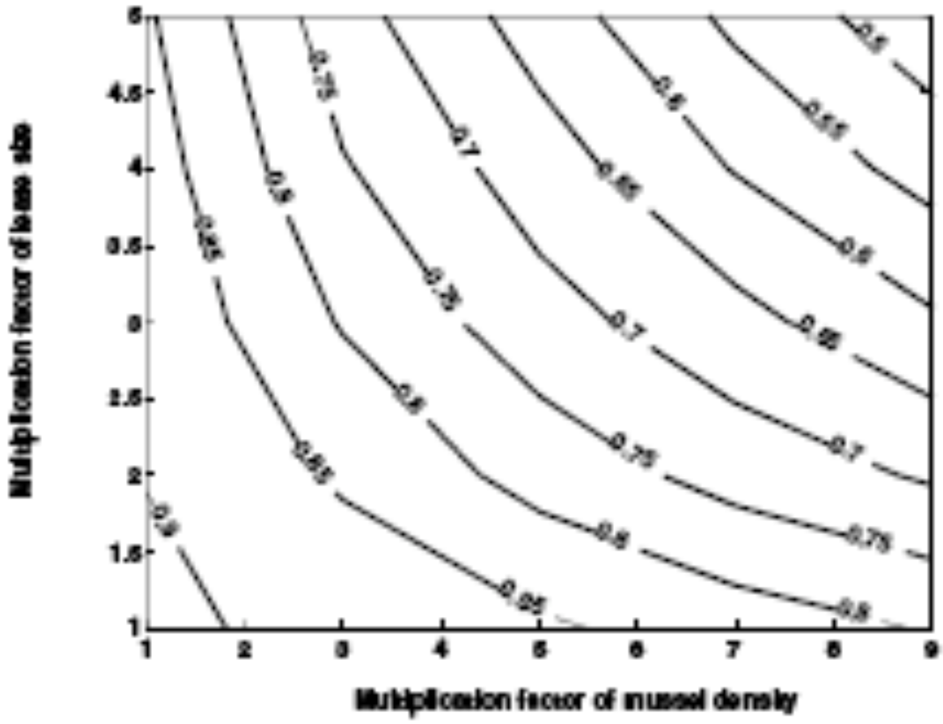


Figure 65. Annual mussel growth as a function of density and size of the mussel farm.

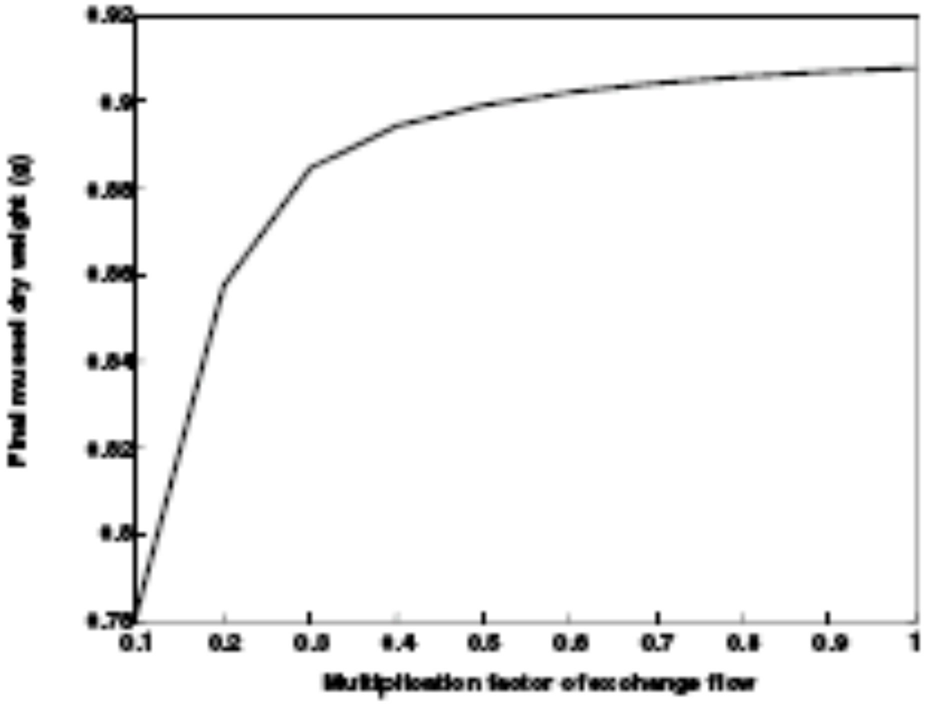


Figure 66. Annual mussel growth as a function of water flow

In a second series of scenarios, we tested changes of exchange coefficient alone, in order to assess the change of mussel growth for areas with lower tidal currents and to make conservative predictions of the effect of flux reduction on mussel growth . In these series, multiplication factor varied from 0.1 to 1, in order to mimick cases with different current velocity and same mussel density and lease size. Compared to the actual situation, final dry weight decreased by 15 % when water exchange was multiplied by 0.1. The decrease was less than 5 % with a multiplying factor above 0.3.

Logic model

The steps of consequence assessment can be deduced from the calculations and available data according to a logic model (Figure 67). At each of these steps, probability, intensity and uncertainty of the effect can been assessed.

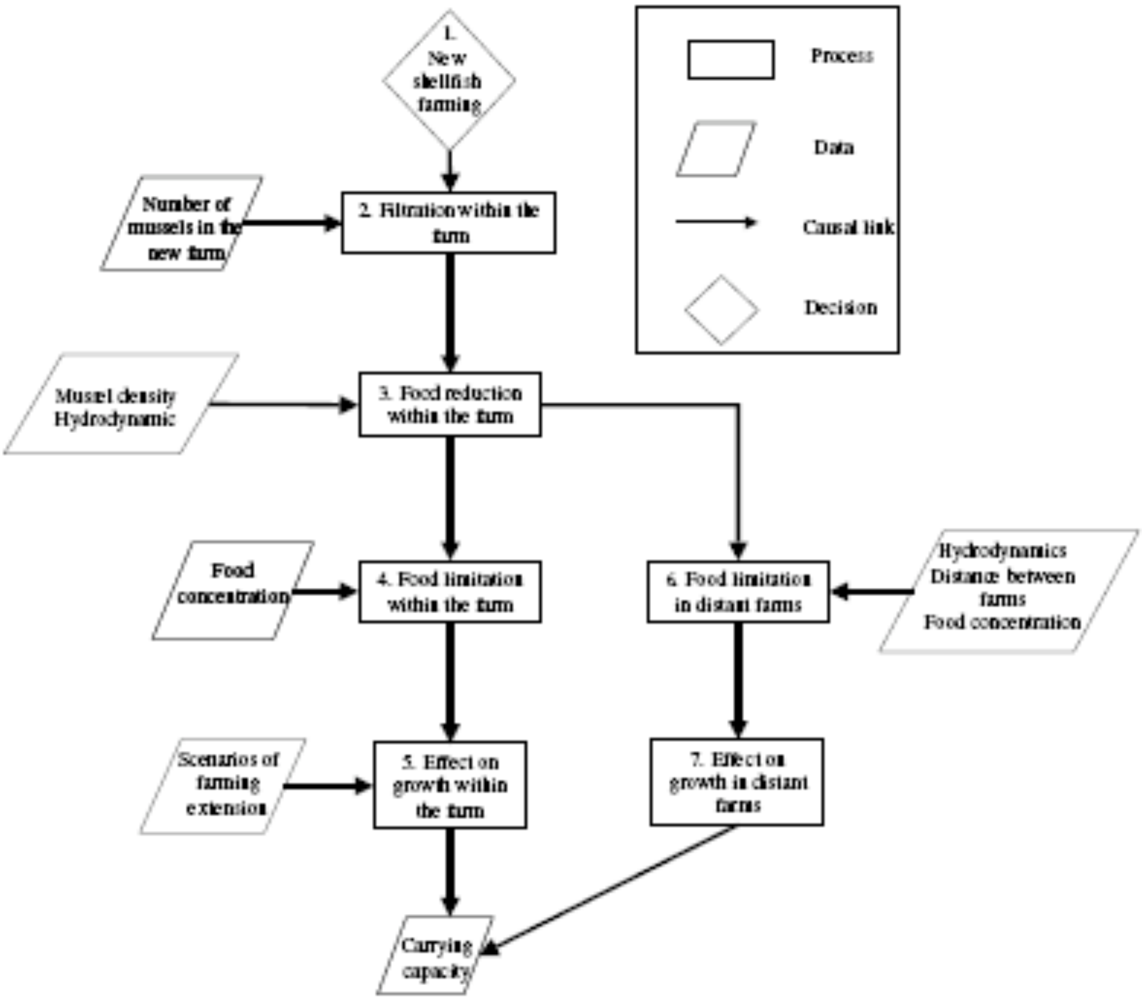


Figure 67. Logical model of the risk assessment procedure representing the different quantification of the different processes (rectangles) in relation with input/output information (squeezed rectangles). Arrows represent causal links. Both local and distant effects of farm extension are considered.

2. Farms will be extended

Extension of shellfish farming is likely. There is already approximately 9,000 metric tons of cultured mussels and 16,000 of cultured oysters in the Pertuis Breton area and carrying capacity is probably partly used, which makes the extension of new areas potentially problematic.**Severity is very High** – bivalves are likely to be one of the largest or the largest group of filterfeeders in the area, they are wide spread and unlikely to entirely disappear over a short period of time. **Probability of occurrence is very High** – for the same reasons given above. **Uncertainty is Negligible** –

cultivated areas are monitored and regulated by Ifremer, as well as environmental parameters

2. Filtration in the farming area is substantial .
The estimation of filtration in the area showed that the amount of particles present in the longline area would be substantially decreased if filtration was considered alone. The increase of filtration would increase with mussel density but, by construction, farm size would not modify the time needed to filter all the particle. The effect at some distance is probable but it will decrease due to dilution and probably be negligible at a distance of a few kilometers. For theses reasons, severity and probability of occurrence are high. Uncertainty related to this calculation is low.

3. Food concentration will be reduced within the farm .
The box model demonstrated that actual mussel density and lease size had a minor effect on flows of particulate organic matter and phytoplankton, and water exchange was high enough to renew water and make phytoplankton food available. Phytoplankton depletion was kept low even under the various scenarios of farm extension and increasing mussel density. **Severity** and **probability** of occurrence are therefore low. Because of assumptions made when the model was used, **uncertainty** is medium.

4. Food limit mussel production in the new farm area
Measurements of food concentration and comparison of mussel growth in two different areas showed that differences in mussel growth could be related to differences in food concentration and other controlling factors which play an important role in ecophysiological responses – e.g. particulate inorganic matter. Food limitation can be deduced from these observations with a high **severity** and **probability** and negligible **uncertainty**.

5. Effect on growth in the new farm area
Though food limitation, the low food depletion implies that standing stock of cultured mussels could be increased by farmers without lowering mussel growth. Mussel production could therefore be increased by extending cultured area and/or increasing mussel density without increasing significantly the cultivation time – that is, the time needed to get marketable size or weight. Both factors would have the same tenuous decreasing effect on growth. If extension of cultured areas was considered, our results on the effect of water exchange on mussel growth indicate that areas with lower water exchange would also be suitable for mussel production – e.g. current velocity twice lower would not yield a significant negative effect on growth and production. **The severity is Low –** The degree of change likely is low and limited to the area of the lease site and immediately downstream. If the production were removed, any effect on the system would not likely occur even a short time later. **Probability is Low –** extension of farming activity will be constrained by external factors (e.g. other activities) which make probability of local effects very low. **Uncertainty is Moderate -** variation in environmental forces that have occurred over the period that data have been collected are expected to be representative of the range of environmental variation anticipated in the forseeable future

6. Food limit mussel production in the other farm area

The same observations as the one mentioned above lead to the high **probability** and **severity** of food limitation in farm distant from the new area.

7. New production will affect other areas

Primary production varies with meteorological conditions which act on the freshwater and nutrients loadings, light intensity, water temperature and sediment resuspension, and interannual variability is probably high. In Marennes-Oléron bay, a comprehensive assessment of primary production showed that primary production is driven by nutrient fluxes, water mixing and light limitation due to turbidity (Struski & Bacher 2006.) and its role on carrying capacity has also been assessed (Bacher et al., 1998). No comparable estimation exists in Aiguillon bay, but it is likely that it behaves in the same way because of the similarities between the 2 ecosystems – e.g. macrotidal bays, input from freshwater and nutrients from rivers, sediment resuspension due to currents and waves. Primary production is therefore thought a limiting factor for the carrying capacity if mussel production is based solely on primary production at the scale of the bay.

One should separate the effect of primary production from the food concentration. There is some evidence of the relationship between phytoplankton concentration and mussel growth on bouchot in Pertuis Breton (Dardignac-Corbeil 2004) and in Marennes-Oléron Bay (Boromthanarat & Deslous-Paoli 1988) and growth of suspended culture mussels has been assessed in Pertuis Breton (Barille 1990). The effect of phytoplankton and turbidity on mussel growth has been assessed by Garen et al. (2003) who compared growth on suspended culture and bouchot and showed that mussels on longlines exhibited the highest growth rate, probably due to differences in immersion time. There is some evidence of the effect of phytoplankton and horizontal water mixing in experimental studies.

Phytoplankton is clearly the first limiting factor of growth, but horizontal dispersion probably acts on food availability through the dilution of food. These factors are varying over space due to water mixing, differences in sediment resuspension, primary productivity in relation with nutrient inputs. They are therefore key factors for site selection and dimension of cultivation structure. However, a detectable effect of this variability on existing shellfish growth and production has not been demonstrated. The hydrodynamical model implemented in Pertuis Breton and Marennes Oléron bay showed that, in Pertuis Breton, tidal currents frequently lie above 50 cm.s-1. Compared to other ecosystems where mussel culture takes place, this intense water mixing favours water and particle renewal. However, water residence time within the bay has not been accurately estimated and is probably much higher than in Marennes-Oléron Bay, where limitation of carrying capacity has been demonstrated.

Calculation of food depletion in the longline case has shown that actual current velocity and mussel density would not generate food depletion even whether the long line area would be extended At the local scale of longlines or bouchots, primary production is negligible compared to the food supply linked to the transport of phytoplankton and detritus by currents. Oceonographic modeling of particle movements and fluxes of bivalve food demonstrated that actual mussel density and lease size had a minor effect on flows of particulate organic matter and phytoplankton, and water exchange was high enough to support the additional mussel production proposed.

Interactions between cultivated areas generally occur when the combination of water residence time, shellfish standing stock and primary production limit food availability (see Smaal et al., 1998; (Guyondet et al. 2005); Bacher et al., 1998). In Pertuis Breton, longlines and bouchots are setup in different areas separated by a few kilometres which minimize the chance of interactions.

The severity is Low – The degree of change likely is low and limited to the area of the lease site and immediately downstream. If the production were removed any effect on the system is not likely to be felt even a short time later. **Probability of occurrence is Low. Uncertainty is Low -** variation in environmental forces that have occurred over the period that data has been collected are expected to be representative of the range of environmental variation anticipated in the forseeable future

8. Effect on carrying capacity
Mortality of mussels has been monitored in longlines and bouchots and always compare to acceptable levels. Increase of mortality is unlikely to occur. The effect of food reduction due to the setup of new farms on mussel growth in the new farm and in distant farm is probably very low. **Probability** and **severity** are low, even if the **uncertainty** is medium

4.7 Site specific conclusions

4.7.1 State of the environment in the pertuis Breton

Considering the results of the indicators presented earlier, the sediment at scale B and C was not affected by the culture of mussels on longline, despite the size of the leases. At scale A, some changes were observed at the immediate vicinity of the longlines. There is a trend towards more labile organic matter, more organic Carbon and lower redox, but the stations at the immediate vicinity of the longlines did not significantly differed from the others. Scale B and Scale C were not different.

The benthic fauna was well characterised by the AMBI index. No significant changes were found at any of the scale considered. It therefore may be concluded that the longlines did not have an impact on the benthic fauna, in such a dynamic, macrotidal environment.

The water quality was slightly modified by the presence of longlines. Total particulate matter, organic matter, organic carbon and turbidity were all higher near the longline, without exceeding thresholds for abnormal values. There is a small effect at scale A, an even smaller effect at size B, and no effect at size C.

Models describing the depletion of food by the mussels on the longlines showed that the potential depletion was always very low, thus allowing to dramatically increasing both the biomasse of mussels and the size of the leases, without compromising the growth of the mussels. Therefore, the carrying capacity of the pertuis Breton far exceeds the quantity of mussels actually reared. Plans are ready to increase the biomasse of molluscs by adding longlines for rearing oysters in the same quantity.

4.7.2 Ecosystem Approach

Although only few indicators on socio-economics aspects are available, because of a lack of aggregated data, some positive economics benefits are obtained from the culture of mussels on longlines. This favourishes the employment in a primary sector, while most of the activity around is orientated towards seasonal, tourism business. Fisheries are declining in the area, and the culture of mussels may have some positive aspects foe species such as the sole. This species was proved to feed on the polychaetes and crustaceans, under the rearing devices. However, the leases have reduced the fishing grounds by forbidding fishing within the longlines (aerial surveys have shown that trawlers may occasionally fish there, despite the difficulties).

Only occasionally after storms, would arrive to the shoreline used equipments from the longlines. Complaints on these aspects are very few.

More developed are the complaints from the yachtsmen associations who see in the presence of longlines at the surface of the sea, an obstacle to a free navigation, or even a danger, with the presence of buoys around to signal the longlines. Channels are signalised around the leases, including in the part nearest to the coast, but the complaints are more based on principles, such as the freedom of movements at sea

In several sites along the French coasts, molluscs cultures in open sea were decimated by the predation of Sea Bream (Mediterranean Sea, Baie de Quiberon). After 20 years of exploitation, not such mortalities were recorded in the pertuis Breton. A possible reason is that the waters are turbid enough to hamper the predation for these carnivorous species. No interactions were observed with birds. The opinion of NGO is that the longlines did not interfere with wildlife.

As a conclusion, it may be noticed that the advantages are large and the complaints are limited to one category of the stakeholders. At the ecosystem level, the impact of mussel culture in the pertuis Breton remains low. This is quite different of what can be observed for the nearby rearing of oysters in huge quantities (120 000 tonnes) in the Baie of Marennes Oléron, 30 km South.

4.7.3 The capacity of the environment

From the study site results, and the running of models on the depletion of mussels, it is noticeable that the carrying capacity of the site is far to be exceeded. The good status of the sediment shows the there only a small accumulation of wastes into the sediment, but the values of the different indicators cannot statistically quantify this. Furthermore, given the nature of the biodeposits of mussels (uneaten algal cells, degraded organic matter from eaten cells and mineral particles), the impact is reversible.

The primary productivity provides food for several thousands tonnes of mussels, while degrading the dissolved waste and the particulate ones. The culture of molluscs dates back from the sixteen century in this area, and became part of the cultural heritage, while this "new technique" of culture as compared with the traditional culture in poles in shoreline, does not interfere with aesthetic aspects: the buoys of the longlines are too small to be seen from the shore and the beaches.

The sustainability of this type of culture remains high. A life cycle analysis should be performed to confirm this; in these times of increasingly expansive energy

At a time when this study was conducted, the decision was taken to extend the culture of molluscs (oysters) in the pertuis Breton, by doubling the surfaces dedicated to the longlines. The prospects for the future of shellfish culture in this specific area are bright, as opposite to the one of finfish culture in French coasts.

4.8 Culture type and environment type conclusions

The use of ECASA tools for the culture of mussels on longlines has shown that this type of culture produces spatially restricted impacts, which remain weak both on the sediment, on the water quality and on the macrofauna. Social impacts are related with the use of space as a resource (at scale C). However, these conclusions are only valid in this type of macrotidal environment, characterised by strong alternative currents flushing the area, and a wide bay where the culture only occupies a tenth of the available surface.

The most appropriate tools and methods for Environmental Impact studies at such sites should consist in indicators of sediment impact (the sediment carbon quality index being recommended for its ease of measurement), indicators of change on the macrofauna (AMBI indicator, and its recent evolutions) and models of carrying capacity (depletion) and sedimentation. While DEPOMOD for shellfish has not been tested yet in this environment, it seems promising where it has been used.

Appropriate monitoring strategies would include, together with the mandatory practices on the sanitary status of the molluscs, a survey of the growth and mortality of molluscs, to identify any decline in the feeding conditions, or the event of any damageable cause (toxic phytoplankton and others sources). These monitoring are already performed in the pertuis Breton.

5 Acknowledgements

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7 Annexes

Annexe 1 Data gathered during the field campaign

Sediment

Sample code	Sampling date	Season	Location	Site	Farm type	Distance (Station)	Depth (m)	Replicate	Layer
2-France-MO-0-mean-(0-1)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	0-1
2-France-MO-0-mean-(1-2)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	1-2
2-France-MO-0-mean-(2-3)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	2-3
2-France-MO-0-mean-(3-4)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	3-4
2-France-MO-0-mean-(4-5)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	4-5
2-France-MO-0-mean-(5-6)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	5-6
2-France-MO-0-mean-(6-7)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	6-7
2-France-MO-0-mean-(7-8)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	7-8
2-France-MO-0-mean-(8-9)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	8-9
2-France-MO-0-mean-(9-10)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	9-10
2-France-MO-0-mean-(10-11)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	10-11
2-France-MO-0-mean-(11-12)	07/09/2006	2	France	MO	shellfish	0	8.10	mean	11-12
2-France-MO-50-mean-(0-1)	07/09/2006	2	France	MO	shellfish	50	8	mean	0-1
2-France-MO-50-mean-(1-2)	07/09/2006	2	France	MO	shellfish	50	8	mean	1-2
2-France-MO-50-mean-(2-3)	07/09/2006	2	France	MO	shellfish	50	8	mean	2-3
2-France-MO-50-mean-(3-4)	07/09/2006	2	France	MO	shellfish	50	8	mean	3-4
2-France-MO-50-mean-(4-5)	07/09/2006	2	France	MO	shellfish	50	8	mean	4-5
2-France-MO-50-mean-(5-6)	07/09/2006	2	France	MO	shellfish	50	8	mean	5-6
2-France-MO-50-mean-(6-7)	07/09/2006	2	France	MO	shellfish	50	8	mean	6-7
2-France-MO-50-mean-(7-8)	07/09/2006	2	France	MO	shellfish	50	8	mean	7-8
2-France-MO-50-mean-(8-9)	07/09/2006	2	France	MO	shellfish	50	8	mean	8-9
2-France-MO-50-mean-(9-10)	07/09/2006	2	France	MO	shellfish	50	8	mean	9-10
2-France-MO-50-mean-(10-11)	07/09/2006	2	France	MO	shellfish	50	8	mean	10-11
2-France-MO-50-mean-(11-12)	07/09/2006	2	France	MO	shellfish	50	8	mean	11-12
2-France-MO-100-mean-(0-1)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	0-1
2-France-MO-100-mean-(1-2)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	1-2
2-France-MO-100-mean-(2-3)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	2-3
2-France-MO-100-mean-(3-4)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	3-4
2-France-MO-100-mean-(4-5)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	4-5
2-France-MO-100-mean-(5-6)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	5-6
2-France-MO-100-mean-(6-7)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	6-7
2-France-MO-100-mean-(7-8)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	7-8
2-France-MO-100-mean-(8-9)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	8-9
2-France-MO-100-mean-(9-10)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	9-10
2-France-MO-100-mean-(10-11)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	10-11
2-France-MO-100-mean-(11-12)	07/09/2006	2	France	MO	shellfish	100	7.9	mean	11-12

Sample code	Eh (mV)	% silt-clay	TOC	TON	LOI	Labil Org Matter	Chl-a (µg /g dry)	Pheopigments (µg/g dry
2-France-MO-0-mean-(0-1)		87.19	14.95	6.60	13.26	5.50	5.72	27.34
2-France-MO-0-mean-(1-2)		90.08	14.56	6.54	13.24	5.41	10.97	13.14
2-France-MO-0-mean-(2-3)		88.04	14.26	6.58	11.88	4.72	5.34	20.76
2-France-MO-0-mean-(3-4)		91.51	13.97	6.58	11.77	4.60	6.60	19.44
2-France-MO-0-mean-(4-5)		93.45	14.14	6.59	12.46	4.92	5.85	17.07
2-France-MO-0-mean-(5-6)		88.52	14.11	6.44	11.52	4.54		
2-France-MO-0-mean-(6-7)		59.03	11.67	6.24	9.07	3.59		
2-France-MO-0-mean-(7-8)		57.32	11.21	6.34	8.84	3.65		
2-France-MO-0-mean-(8-9)		67.60	14.23	6.65	9.94	4.24		
2-France-MO-0-mean-(9-10)		93.10	14.59	6.61	12.25	5.61		
2-France-MO-0-mean-(10-11)		92.68	14.00	6.52	11.38	4.80		
2-France-MO-0-mean-(11-12)		93.90			12.17	5.00		
2-France-MO-50-mean-(0-1)		59.96	10.71	1.68	8.42	3.46	4.44	17.27
2-France-MO-50-mean-(1-2)		63.13	11.15	1.76	7.74	3.06	2.40	11.44
2-France-MO-50-mean-(2-3)		68.13	12.60	2.05	9.32	3.77	2.69	12.22
2-France-MO-50-mean-(3-4)		65.68	11.95	1.76	9.64	3.65	1.76	9.84
2-France-MO-50-mean-(4-5)		61.58	11.21	1.70	9.45	3.54	1.16	9.09
2-France-MO-50-mean-(5-6)		70.00	13.26	1.98	11.56			
2-France-MO-50-mean-(6-7)		71.59	13.31	1.96	11.55	4.42		
2-France-MO-50-mean-(7-8)		65.89	11.73	1.75	10.68	4.00		
2-France-MO-50-mean-(8-9)		69.20	11.29	1.69	10.92	4.10		
2-France-MO-50-mean-(9-10)		57.05	10.99	1.62	9.95	3.74		
2-France-MO-50-mean-(10-11)		60.71	11.57	1.75	10.14	3.79		
2-France-MO-50-mean-(11-12)		67.45	12.25	1.92	10.77	4.14		
2-France-MO-100-mean-(0-1)		67.40	11.09	1.65	12.05	3.05	4.65	16.72
2-France-MO-100-mean-(1-2)		64.11	9.72	1.47	10.82	2.61	3.52	12.97
2-France-MO-100-mean-(2-3)		55.34	9.45	1.47	10.87	2.65	3.21	12.86
2-France-MO-100-mean-(3-4)		57.14	10.01	1.53	11.08	2.67	1.86	9.87
2-France-MO-100-mean-(4-5)		56.22	10.79	1.65	11.57	2.80	1.26	8.91
2-France-MO-100-mean-(5-6)		52.87	10.59	1.62	11.64	2.85		
2-France-MO-100-mean-(6-7)		54.14	10.75	1.63	11.81	2.90		
2-France-MO-100-mean-(7-8)		52.04	11.08	1.63	11.46	2.81		
2-France-MO-100-mean-(8-9)		52.95	11.47	1.73	11.95	2.90		
2-France-MO-100-mean-(9-10)		50.57	11.73	1.77	12.09	2.96		
2-France-MO-100-mean-(10-11)		58.43	12.19	1.76	12.52	3.01		
2-France-MO-100-mean-(11-12)		67.45	12.83	1.86	12.68	2.99		

Sample code	Sampling date	Season	Location	Site	Farm type	Distance (Station)	Depth (m)	Replicate	Layer
2-France-MO-200-mean-(0-1)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	0-1
2-France-MO-200-mean-(1-2)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	1-2
2-France-MO-200-mean-(2-3)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	2-3
2-France-MO-200-mean-(3-4)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	3-4
2-France-MO-200-mean-(4-5)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	4-5
2-France-MO-200-mean-(5-6)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	5-6
2-France-MO-200-mean-(6-7)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	6-7
2-France-MO-200-mean-(7-8)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	7-8
2-France-MO-200-mean-(8-9)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	8-9
2-France-MO-200-mean-(9-10)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	9-10
2-France-MO-200-mean-(10-11)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	10-11
2-France-MO-200-mean-(11-12)	07/09/2006	2	France	MO	shellfish	200	7.3	mean	11-12
2-France-MO-400-mean-(0-1)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	0-1
2-France-MO-400-mean-(1-2)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	1-2
2-France-MO-400-mean-(2-3)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	2-3
2-France-MO-400-mean-(3-4)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	3-4
2-France-MO-400-mean-(4-5)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	4-5
2-France-MO-400-mean-(5-6)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	5-6
2-France-MO-400-mean-(6-7)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	6-7
2-France-MO-400-mean-(7-8)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	7-8
2-France-MO-400-mean-(8-9)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	8-9
2-France-MO-400-mean-(9-10)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	9-10
2-France-MO-400-mean-(10-11)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	10-11
2-France-MO-400-mean-(11-12)	07/09/2006	2	France	MO	shellfish	400	7.7	mean	11-12
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2-France-MO-ref-mean-(0-1)	07/09/2006	2	France	MO	shellfish	ref	9	mean	0-1
2-France-MO-ref-mean-(1-2)	07/09/2006	2	France	MO	shellfish	ref	9	mean	1-2
2-France-MO-ref-mean-(2-3)	07/09/2006	2	France	MO	shellfish	ref	9	mean	2-3
2-France-MO-ref-mean-(3-4)	07/09/2006	2	France	MO	shellfish	ref	9	mean	3-4
2-France-MO-ref-mean-(4-5)	07/09/2006	2	France	MO	shellfish	ref	9	mean	4-5
2-France-MO-ref-mean-(5-6)	07/09/2006	2	France	MO	shellfish	ref	9	mean	5-6
2-France-MO-ref-mean-(6-7)	07/09/2006	2	France	MO	shellfish	ref	9	mean	6-7
2-France-MO-ref-mean-(7-8)	07/09/2006	2	France	MO	shellfish	ref	9	mean	7-8
2-France-MO-ref-mean-(8-9)	07/09/2006	2	France	MO	shellfish	ref	9	mean	8-9
2-France-MO-ref-mean-(9-10)	07/09/2006	2	France	MO	shellfish	ref	9	mean	9-10
2-France-MO-ref-mean-(10-11)	07/09/2006	2	France	MO	shellfish	ref	9	mean	10-11
2-France-MO-ref-mean-(11-12)	07/09/2006	2	France	MO	shellfish	ref	9	mean	11-12

Sample code	Eh (mV)	% silt-clay	TOC	TON	LOI	Labil Org Matter	Chl-a (µg /g dry)	Pheopigments (µg/g dry
2-France-MO-200-mean-(0-1)		40.68	10.62	1.68	11.46	3.15	2.45	10.75
2-France-MO-200-mean-(1-2)		43.99	11.51	1.83	11.99	3.24	2.04	10.58
2-France-MO-200-mean-(2-3)		47.58	11.38	1.72	12.61	3.45	2.24	11.11
2-France-MO-200-mean-(3-4)		52.02	12.02	1.80	12.86	3.45	2.42	11.19
2-France-MO-200-mean-(4-5)		51.11	11.83	1.81	12.87	3.46	2.32	10.92
2-France-MO-200-mean-(5-6)		52.74	12.11	1.85	12.69	3.27		
2-France-MO-200-mean-(6-7)		49.85	11.62	1.73	12.75	3.18		
2-France-MO-200-mean-(7-8)		45.37	10.38	1.54	12.04	2.87		
2-France-MO-200-mean-(8-9)		38.91	9.98	1.46	12.09	3.07		
2-France-MO-200-mean-(9-10)		28.36	9.44	1.29	11.40	2.68		
2-France-MO-200-mean-(10-11)		21.62	6.61	0.99	10.30	2.43		
2-France-MO-200-mean-(11-12)								
					9.85	3.06	2.31	7.99
2-France-MO-400-mean-(0-1)	128.5	25.48	9.53	1.50	10.51	3.00	1.64	7.48
2-France-MO-400-mean-(1-2)	39	31.10	10.70	1.64	10.79	2.93	1.30	6.74
2-France-MO-400-mean-(2-3)	47	27.35	10.72	1.65	10.77	2.84	1.46	7.86
2-France-MO-400-mean-(3-4)	-3	30.30	10.93	1.67	11.10	3.04	1.37	7.63
2-France-MO-400-mean-(4-5)	10	30.53	11.05	1.69	10.84	3.00		
2-France-MO-400-mean-(5-6)	-65.5	31.56	10.89	1.64	11.25	3.07		
2-France-MO-400-mean-(6-7)	-61.5	26.64	11.52	1.74	11.37			
2-France-MO-400-mean-(7-8)	-74	31.82	10.64	1.62	11.28	3.08		
2-France-MO-400-mean-(8-9)	-90	30.11	11.30	1.71	11.47	3.03		
2-France-MO-400-mean-(9-10)	-99.5	30.41	10.95	1.62	11.45	2.89		
2-France-MO-400-mean-(10-11)	-122	28.89	10.96	1.61				
2-France-MO-400-mean-(11-12)	-62.5	21.55						
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2-France-MO-ref-mean-(0-1)	147.5	48.06	12.15	1.83	10.66	3.06	2.34	11.14
2-France-MO-ref-mean-(1-2)	73	59.07	11.50	1.75	10.82	2.78	1.46	9.37
2-France-MO-ref-mean-(2-3)	27	64.83	11.45	1.63	10.39	2.50	0.95	8.35
2-France-MO-ref-mean-(3-4)	81.5	63.59	10.38	1.50	10.20	2.37	0.73	7.01
2-France-MO-ref-mean-(4-5)	42.5	67.76	10.31	1.48	10.26	2.43	0.60	6.66
2-France-MO-ref-mean-(5-6)	108	68.75	9.66	1.39	9.86	2.33		
2-France-MO-ref-mean-(6-7)	74.5	71.92	9.71	1.42	10.19	2.44		
2-France-MO-ref-mean-(7-8)	-75	66.18	8.80	1.33	9.60	2.24		
2-France-MO-ref-mean-(8-9)	-80	61.40	8.78	1.26	9.93	2.46		
2-France-MO-ref-mean-(9-10)	-75	62.30	8.00	1.17	9.76	2.57		
2-France-MO-ref-mean-(10-11)	-62	63.61	7.85	1.22	8.99	2.26		
2-France-MO-ref-mean-(11-12)	-91	66.86	7.27	1.08	8.29	1.87		

Hydrology

Sample code	Sampling date	Season	Location	Site	Distance (Station)	Depth (m)	Replicate	Layer (m)	Salinity	T°C	$O_{2\,(\%)}$	O2 mg/l	l4 (µmol	PM (mg L	DM (mg L	% POM	ecchi (m
High tide																	
IO-Pertuis Breton-13.9-A-surfa	23/08/2006	2	MO	Pertuis Breton	0	13.9	A	surface	34.4	19.8	113	8.43	1.68	25.560	8.680	33.959	1.7
IO-Pertuis Breton-13.8-A-surfa	23/08/2006	2	MO	Pertuis Breton	50	13.8	A	surface	34.5	19.3	113	8.50	1.1	20.440	6.980	34.149	1.9
IO-Pertuis Breton-13.7-A-surfa	23/08/2006	2	MO	Pertuis Breton	100	13.7	A	surface	34.5	19.2	113.3	8.53	0.92	33.600	10.600	31.548	2.5
IO-Pertuis Breton-13.1-A-surfa	23/08/2006	2	MO	Pertuis Breton	200	13.1	A	surface	34.5	19.2	112.2	8.45	0.88	16.930	4.620	27.289	2
IO-Pertuis Breton-13.5-A-surfa	23/08/2006	2	MO	Pertuis Breton	400	13.5	A	surface	34.5	19.1	112.9	8.52	1.14	13.270	4.220	31.801	2.5
IO-Pertuis Breton-14.8-A-surfa	23/08/2006	2	MO	Pertuis Breton	ref-2300 m	14.8	A	surface	34.5	18.7	116.4	8.85	0.22	14.680	5.109	34.800	3.2
-MO-Pertuis Breton-13.9-A-mi	23/08/2006	2	MO	Pertuis Breton	0	13.9	A	mid	34.5	19.4	104.7	7.86	1.37	28.640	8.760	30.587	1.7
-MO-Pertuis Breton-13.8-A-mi	23/08/2006	2	MO	Pertuis Breton	50	13.8	A	mid	34.5	19.3	115.4	8.68	1.18	29.100	8.900	30.584	1.9
-MO-Pertuis Breton-13.7-A-mi	23/08/2006	2	MO	Pertuis Breton	100	13.7	A	mid	34.4	19.2	114.8	8.65	1.06	29.760	9.200	30.914	2.5
-MO-Pertuis Breton-13.1-A-mi	23/08/2006	2	MO	Pertuis Breton	200	13.1	A	mid	34.5	19.2	114.4	8.62	1.04	15.250	4.370	28.656	2
-MO-Pertuis Breton-13.5-A-mi	23/08/2006	2	MO	Pertuis Breton	400	13.5	A	mid	34.5	19.1	111.7	8.43	1.09	20.800	5.090	24.471	2.5
-MO-Pertuis Breton-14.8-A-mi	23/08/2006	2	MO	Pertuis Breton	ref-2300 m	14.8	A	mid	34.5	18.8	116.9	8.87	0.24	16.765	4.802	28.642	3.2

IO-Pertuis Breton-13.9-A-bott	23/08/2006	2	MO	Pertuis Breton	0	13.9	A	bottom	34.4	19.5	115.3	8.64	1.25	31.100	9.280	29.839	1.7
IO-Pertuis Breton-13.8-A-bott	23/08/2006	2	MO	Pertuis Breton	50	13.8	A	bottom	34.5	19.3	115.9	8.71	1.11	41.460	11.820	28.509	1.9
IO-Pertuis Breton-13.7-A-bott	23/08/2006	2	MO	Pertuis Breton	100	13.7	A	bottom	34.5	19.4	118	8.86	1.19	23.560	5.970	25.340	2.5
IO-Pertuis Breton-13.1-A-bott	23/08/2006	2	MO	Pertuis Breton	200	13.1	A	bottom	34.5	19.4	117.1	8.79	1.09	21.680	5.250	24.216	2
IO-Pertuis Breton-13.5-A-bott	23/08/2006	2	MO	Pertuis Breton	400	13.5	A	bottom	34.5	19.4	117.9	8.85	1.22	19.120	5.000	26.151	2.5
IO-Pertuis Breton-14.8-A-bott	23/08/2006	2	MO	Pertuis Breton	ref-2300 m	14.8	A	bottom	34.5	18.8	118.1	8.96	0.35	8.920	4.860	54.484	3.2
Low tide																	
MO-Pertuis Breton-9.6-A-surfa	06/09/2006	2	MO	Pertuis Breton	0	9.6	A	surface	33.8	16.2	86	6.88	2.87	6.48	1.64	20.20	N/A
MO-Pertuis Breton-9.5-A-surfa	06/09/2006	2	MO	Pertuis Breton	50	9.5	A	surface	33.9	16.2	90.1	7.20	2.39	6.48	1.62	20.00	N/A
MO-Pertuis Breton-9.4-A-surfa	06/09/2006	2	MO	Pertuis Breton	100	9.4	A	surface	33.8	16.3	91.1	7.27	2.44	8.50	1.77	17.23	N/A
MO-Pertuis Breton-8.8-A-surfa	06/09/2006	2	MO	Pertuis Breton	200	8.8	A	surface	33.8	16.4	91.7	7.31	2.45	6.56	1.47	18.31	N/A
-MO-Pertuis Breton-9-A-surfac	06/09/2006	2	MO	Pertuis Breton	400	9	A	surface	33.7	16.3	91.7	7.33	2.54	6.94	3.10	30.88	N/A
IO-Pertuis Breton-10.5-A-surfa	06/09/2006	2	MO	Pertuis Breton	ref-2300 m	10.5	A	surface	33.7	16.4	92.2	7.35	2.61	7.62	2.98	28.11	N/A
-----																	N/A
2-MO-Pertuis Breton-0-A-mid	06/09/2006	2	MO	Pertuis Breton	0	9.6	A	mid	33.9	16.2	86	6.88		7.75	1.83	19.10	N/A
2-MO-Pertuis Breton-50-A-mic	06/09/2006	2	MO	Pertuis Breton	50	9.5	A	mid	33.9	16.4	90.1	7.18	2.40	4.27	1.08	20.19	N/A
2-MO-Pertuis Breton-100-A-mi	06/09/2006	2	MO	Pertuis Breton	100	9.4	A	mid	33.8	16.3	90.9	7.26	2.44	10.07	2.05	16.91	N/A
2-MO-Pertuis Breton-200-A-mi	06/09/2006	2	MO	Pertuis Breton	200	8.8	A	mid	33.8	16.4	91.6	7.30	2.47	5.15	1.86	26.53	N/A
2-MO-Pertuis Breton-400-A-mi	06/09/2006	2	MO	Pertuis Breton	400	9	A	mid	33.7	16.3	91.4	7.30	2.54	5.72	2.71	32.15	N/A
O-Pertuis Breton-ref-2300 m-A	06/09/2006	2	MO	Pertuis Breton	ref-2300 m	10.5	A	mid	33.6	16.3	92	7.36	2.56	6.10	2.36	27.90	N/A
-----																	N/A
-MO-Pertuis Breton-0-A-bottor	06/09/2006	2	MO	Pertuis Breton	0	9.6	A	bottom	34	16.1	90	7.25	2.53	5.87	1.36	18.81	N/A
MO-Pertuis Breton-50-A-botto	06/09/2006	2	MO	Pertuis Breton	50	9.5	A	bottom	33.9	16.4	90.7	7.22	2.49	6.37	1.54	19.47	N/A
MO-Pertuis Breton-100-A-bott	06/09/2006	2	MO	Pertuis Breton	100	9.4	A	bottom	33.8	16.3	91.1	7.27	2.43	8.36	1.64	16.40	N/A
MO-Pertuis Breton-200-A-bott	06/09/2006	2	MO	Pertuis Breton	200	8.8	A	bottom	33.8	16.4	91.6	7.30	2.49	4.16	2.08	33.33	N/A
MO-Pertuis Breton-400-A-bott	06/09/2006	2	MO	Pertuis Breton	400	9	A	bottom	33.7	16.3	91.4	7.30	2.56	4.34	2.42	35.80	N/A
Pertuis Breton-ref-2300 m-A-b	06/09/2006	2	MO	Pertuis Breton	ref-2300 m	10.5	A	bottom	33.6	16.4	92	7.34		4.11	1.94	32.07	N/A

Sample code	CHl-a µg/l	Pheop µg/	% Pheop	Part µg/	COP µg/L	C/N	Silicate	PO4	NO2	O2 + NC	NO3	Org N di	Org PO4
High tide													
2-MO-Pertuis Breton-13.9-A-surface	1.810	0.817	31.1	82.7	584.0	7.1	8.96	0.72	0.08	0.60	0.52	36.57	0.53
2-MO-Pertuis Breton-13.8-A-surface	1.955	0.855	30.4	54.3	338.6	6.2	8.17	0.71	0.10	0.42	0.32	15.27	0.04
2-MO-Pertuis Breton-13.7-A-surface	3.274	1.857	36.2	48.1	303.6	6.3	6.92	0.45	0.09	0.38	0.29	13.10	0.26
2-MO-Pertuis Breton-13.1-A-surface	2.201	0.921	29.5	43.8	308.8	7.1	7.56	0.76	0.07	0.36	0.29	12.04	0.11
2-MO-Pertuis Breton-13.5-A-surface	2.492	1.096	30.5	81.2	660.5	8.1	8.70	0.74	0.10	0.47	0.37	16.94	0.16
2-MO-Pertuis Breton-14.8-A-surface	1.609	1.142	41.5	47.3	296.3	6.3	5.34	0.56	0.00	0.05	0.05	10.61	0.05
2-MO-Pertuis Breton-13.9-A-mid	1.749	0.938	34.9	61.2	489.5	8.0	8.11	0.64	0.09	0.48	0.39	20.82	0.09
2-MO-Pertuis Breton-13.8-A-mid	2.017	0.970	32.5	61.1	439.7	7.2	8.20	0.74	0.11	0.46	0.35	17.06	0.06
2-MO-Pertuis Breton-13.7-A-mid	1.905	1.093	36.5	47.9	351.7	7.3	8.02	0.75	0.10	0.36	0.26	12.62	-
2-MO-Pertuis Breton-13.1-A-mid	2.128	0.994	31.8	49.8	311.9	6.3	8.07	0.79	0.09	0.41	0.32	12.61	0.05
2-MO-Pertuis Breton-13.5-A-mid	2.000	1.016	33.7	43.3	321.3	7.4	7.59	0.70	0.10	0.48	0.38	10.85	0.37
2-MO-Pertuis Breton-14.8-A-mid	1.581	1.058	40.1	54.3	463.5	8.5	5.91	0.47	0.01	0.04	0.03	12.92	0.14

2-MO-Pertuis Breton-13.9-A-bottom	1.777	1.210	40.5	78.8	532.0	6.8	8.35	0.70	0.11	0.57	0.46	15.40	0.02
2-MO-Pertuis Breton-13.8-A-bottom	2.101	1.316	38.5	77.9	467.7	6.0	8.30	0.72	0.09	0.38	0.29	14.70	0.09
2-MO-Pertuis Breton-13.7-A-bottom	2.000	1.370	40.6	71.5	508.5	7.1	7.05	0.76	0.09	0.45	0.36	12.42	0.03
2-MO-Pertuis Breton-13.1-A-bottom	2.028	1.141	36.0	50.3	348.6	6.9	7.49	0.70	0.07	0.37	0.30	11.46	0.34
2-MO-Pertuis Breton-13.5-A-bottom	1.983	1.292	39.5	68.6	489.5	7.1	7.73	0.67	0.11	0.54	0.43	13.03	0.23
2-MO-Pertuis Breton-14.8-A-bottom	1.335	1.062	44.3	49.4	365.6	7.4	5.62	0.54	0.01	0.03	0.02	13.59	0.33
Low tide													
2-MO-Pertuis Breton-9.6-A-surface	0.508	0.670	56.9	0.029	0.302	11.291	10.74	1.26	0.56	8.09	7.53	9.79	-
2-MO-Pertuis Breton-9.5-A-surface	0.609	0.752	55.3	0.028	0.295	10.331	10.19	1.23	0.53	7.45	6.92	8.63	0.25
2-MO-Pertuis Breton-9.4-A-surface	0.609	0.734	54.7	0.020	0.182	9.290	10.68	1.08	0.38	7.58	7.20	9.74	-
2-MO-Pertuis Breton-8.8-A-surface	0.698	0.727	51.0	0.021	0.216	10.494	9.81	1.22	0.49	8.14	7.65	-	0.09
2-MO-Pertuis Breton-9-A-surface	0.760	0.949	55.5	0.023	0.150	6.483	11.23	1.25	0.52	7.79	7.27	11.12	0.09
2-MO-Pertuis Breton-10.5-A-surface	0.816	0.952	53.8	0.037	0.149	4.088	10.66	1.22	0.41	7.20	6.79	9.66	0.19

2-MO-Pertuis Breton-0-A-mid	0.542	0.672	55.3	0.030	0.173	5.558	10.35	1.26	0.53	7.71	7.18	9.57	-
2-MO-Pertuis Breton-50-A-mid	0.626	0.818	56.6	0.034	0.244	9.294	9.96	1.16	0.50	7.03	6.53	8.31	-
2-MO-Pertuis Breton-100-A-mid	0.587	0.709	54.7	0.019	0.235	12.184	10.38	1.22	0.47	6.92	6.45	9.00	0.04
2-MO-Pertuis Breton-200-A-mid	0.732	0.794	52.0	0.018	0.240	13.519	10.66	1.26	0.49	7.52	7.03	8.80	0.09
2-MO-Pertuis Breton-400-A-mid	0.726	0.811	52.8	0.021	0.170	8.018	10.95	1.08	0.40	6.23	5.83	8.18	-
-MO-Pertuis Breton-ref-2300 m-A-m	0.788	0.921	53.9	0.021	0.099	4.702	10.81	1.35	0.45	7.35	6.90	14.12	0.04

2-MO-Pertuis Breton-0-A-bottom	0.564	0.667	54.2	0.026	0.270	10.282	11.32	1.23	0.54	7.55	7.01	8.76	0.05
2-MO-Pertuis Breton-50-A-bottom	0.575	0.738	56.2	0.014	0.180	12.509	10.03	1.35	0.54	7.77	7.23	8.91	-
2-MO-Pertuis Breton-100-A-bottom	0.620	0.764	55.2	0.021	0.195	11.204	10.81	1.26	0.49	7.10	6.61	11.97	-
2-MO-Pertuis Breton-200-A-bottom	0.838	0.806	49.0	0.021	0.233	11.044	11.23	1.18	0.39	6.17	5.78	9.10	0.04
2-MO-Pertuis Breton-400-A-bottom	0.676	0.820	54.8	0.012	0.122	10.456	9.52	1.26	0.44	7.01	6.57	10.29	-
MO-Pertuis Breton-ref-2300 m-A-bott	0.933	0.940	50.2	0.027	0.156	5.751	11.38	1.22	0.39	6.31	5.92	-	-

Annexe 2 Results of macrofauna study

SAMPLING_DATE	SITE	NAME	DISTANCE (m)	STATION	REPLICAT	MESH_SIZE (µm)	TAXONOMY_INSTITUTION	TAXONOMY_SCIENTIST	TAXONOMY_DATE	PHYLUM	Class-ERMS	Order-ERMS	Family-ERMS
14/09/2006	MO_PB	REF	3400	MO_PB_REF	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	REF	3400	MO_PB_REF	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Crangonidae
14/09/2006	MO_PB	REF	3400	MO_PB_REF	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	REF	3400	MO_PB_REF	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Porcellanidae
14/09/2006	MO_PB	REF	3400	MO_PB_REF	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	REF	3400	MO_PB_REF	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Porcellanidae
14/09/2006	MO_PB	REF	3400	MO_PB_REF	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	REF	3400	MO_PB_REF	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	REF	3400	MO_PB_REF	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	0	0	MO_PB_0	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Pinnotheridae
14/09/2006	MO_PB	0	0	MO_PB_0	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Porcellanidae
14/09/2006	MO_PB	0	0	MO_PB_0	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	0	0	MO_PB_0	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Lysianassidae
14/09/2006	MO_PB	0	0	MO_PB_0	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Portunidae
14/09/2006	MO_PB	50	50	MO_PB_50	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	50	50	MO_PB_50	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Porcellanidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Photidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Crangonidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Photidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Cumacea	Diastylidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Photidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Decapoda	Porcellanidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Cumacea	Diastylidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	PGS+PG_SA	13/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Amphipoda	Photidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Stomatopoda	Squillidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Cumacea	Diastylidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Isopoda	Sphaeromatid
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Amphipoda	Gammaridae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Decapoda	Inachidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Amphipoda	Photidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Amphipoda	Atylidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Decapoda	Crangonidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	PGS+PG_SA	14/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	PGS+PG_SA	15/05/2007	Arthropoda	Malacostraca	Amphipoda	Ampeliscidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	PGS+PG_SA	15/05/2007	Arthropoda	Malacostraca	Decapoda	Pinnotheridae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	PGS+PG_SA	15/05/2007	Arthropoda	Malacostraca	Amphipoda	Photidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	PGS+PG_SA	15/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	PGS+PG_SA	15/05/2007	Arthropoda	Malacostraca	Decapoda	Inachidae

14/09/2006	MO_PB		400	400	MO_PB_400	4	1000	CNRS	PGS+PG_SA	15/05/2007	Arthropoda	Malacostraca	Decapoda	Paguridae
14/09/2006	MO_PB		400	400	MO_PB_400	4	1000	CNRS	PGS+PG_SA	15/05/2007	Arthropoda	Malacostraca	Decapoda	Inachidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	AL+PG_SAUI	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Buccinidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Ostreoida	Pectinidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Ostreoida	Pectinidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Bivalvia	Ostreoida	Pectinidae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Veneridae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Bivalvia	Veneroida	Veneridae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	REF		3400	MO_PB_REF	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB		0	0	MO_PB_0	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Mytiloida	Mytilidae
14/09/2006	MO_PB		0	0	MO_PB_0	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB		0	0	MO_PB_0	1	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB		0	0	MO_PB_0	1	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB		0	0	MO_PB_0	1	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
14/09/2006	MO_PB		0	0	MO_PB_0	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB		0	0	MO_PB_0	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB		0	0	MO_PB_0	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
14/09/2006	MO_PB		0	0	MO_PB_0	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB		0	0	MO_PB_0	4	1000	CNRS	RP+PG_SAU	09/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB		0	0	MO_PB_0	4	1000	CNRS	SLN+PG_SAI	09/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB		50	50	MO_PB_50	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB		50	50	MO_PB_50	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB		50	50	MO_PB_50	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB		50	50	MO_PB_50	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB		50	50	MO_PB_50	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae

14/09/2006	MO_PB	50	50	MO_PB_50	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	50	50	MO_PB_50	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	50	50	MO_PB_50	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Gastropoda	Cephalaspide	Cylichnidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Gastropoda	Cephalaspide	Cylichnidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
11/10/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Pharidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Thyasiridae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Semelidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Montacutidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Pharidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	AL+PG_SAUI	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	100	100	MO_PB_100	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Nuculoida	Nuculidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	AL+PG_SAUI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	AL+PG_SAUI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Pharidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	AL+PG_SAUI	10/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	SLN+PG_SAI	10/05/2007	Mollusca	Bivalvia	Veneroida	Pharidae

14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	AL+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Veneridae
14/09/2006	MO_PB	200	200	MO_PB_200	1	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Nuculoida	Nuculidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Semelidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	AL+PG_SAU	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Nuculoida	Nuculidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	SLN+PG_SAU	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	SLN+PG_SAU	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	SLN+PG_SAU	10/05/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	SLN+PG_SAU	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Buccinidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	AL+PG_SAU	10/05/2007	Mollusca	Bivalvia	Nuculoida	Nuculidae
14/09/2006	MO_PB	400	400	MO_PB_400	4	1000	CNRS	AL+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Montacutidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	RP+PG_SAU	10/05/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Mactridae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	SO+PG_SAU	10/05/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	AL+PG_SAU	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	400	400	MO_PB_400	1	1000	CNRS	AL+PG_SAU	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	200	200	MO_PB_200	4	1000	CNRS	SLN+PG_SAU	10/05/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	PGS+PG_SA	10/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	400	400	MO_PB_400	2	1000	CNRS	SO+PG_SAU	09/07/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	400	400	MO_PB_400	2	1000	CNRS	SO+PG_SAU	09/07/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	200	200	MO_PB_200	3	1000	CNRS	MC+PG_SAU	09/07/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	400	400	MO_PB_400	2	1000	CNRS	SO+PG_SAU	09/07/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	400	400	MO_PB_400	2	1000	CNRS	SO+PG_SAU	09/07/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007	Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007	Mollusca	Bivalvia	Ostreoida	Pectinidae
14/09/2006	MO_PB	400	400	MO_PB_400	2	1000	CNRS	SO+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	400	400	MO_PB_400	2	1000	CNRS	SO+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Pharidae
14/09/2006	MO_PB	200	200	MO_PB_200	3	1000	CNRS	MC+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	200	200	MO_PB_200	3	1000	CNRS	MC+PG_SAU	09/07/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	200	200	MO_PB_200	3	1000	CNRS	MC+PG_SAU	09/07/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	200	200	MO_PB_200	3	1000	CNRS	MC+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Lucinidae
14/09/2006	MO_PB	200	200	MO_PB_200	3	1000	CNRS	MC+PG_SAU	09/07/2007	Mollusca	Bivalvia	Nuculoida	Nuculidae
14/09/2006	MO_PB	400	400	MO_PB_400	2	1000	CNRS	SO+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Cardiidae
14/09/2006	MO_PB	200	200	MO_PB_200	3	1000	CNRS	MC+PG_SAU	09/07/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	200	200	MO_PB_200	3	1000	CNRS	MC+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Pharidae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007	Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Solenidae
14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007	Mollusca	Bivalvia	Nuculoida	Nuculidae
14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Montacutidae
14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007	Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007	Mollusca	Bivalvia	Nuculoida	Nuculidae
14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007	Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007	Mollusca	Bivalvia	Veneroida	Cardiidae

14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007		Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007		Mollusca	Bivalvia	Veneroida	Semelidae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007		Mollusca	Bivalvia	Veneroida	Pharidae
14/09/2006	MO_PB	100	100	MO_PB_100	2	1000	CNRS	AP+PG_SAU	09/07/2007		Mollusca	Gastropoda	Cephalaspide	Cylichnidae
14/09/2006	MO_PB	400	400	MO_PB_400	3	1000	CNRS	CP+PG_SAU	09/07/2007		Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	JFB+PG_SAU	09/07/2007		Mollusca	Bivalvia	Myoida	Corbulidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	JFB+PG_SAU	09/07/2007		Mollusca	Gastropoda	Neogastropoc	Nassaridae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	JFB+PG_SAU	09/07/2007		Mollusca	Gastropoda	Mesogastropc	Turritellidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	JFB+PG_SAU	09/07/2007		Mollusca	Scaphopoda	Dentaliida	Dentaliidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	JFB+PG_SAU	09/07/2007		Mollusca	Bivalvia	Veneroida	Montacutidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	JFB+PG_SAU	09/07/2007		Mollusca	Gastropoda	Mesogastropc	Calyptraeidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	JFB+PG_SAU	09/07/2007		Mollusca	Bivalvia	Veneroida	Semelidae
14/09/2006	MO_PB	50	50	MO_PB_50	4	1000	CNRS	JFB+PG_SAU	09/07/2007		Mollusca	Bivalvia	Mytiloida	Mytilidae
14/09/2006	MO_PB	100	100	MO_PB_100	1	1000	CNRS	PGS+PG_SA		13/05/2007	Mollusca	Gastropoda	Neogastropoc	Nassaridae

Annexe 3 ECASA model description template : Hydrodynamic model.

1	Name of model	*Reporter/Institute (email address)*
1.a	***Hydrodynamic model***	C. Bacher / IFREMER (cbacher@ifremer.fr)
1.b	*date this form was completed or updated*	5 September 2007

2	Short DESCRIPTION of model	
2.a	*Main state variables:*	Current velocity, water level, temperature, salinity.
2.b	*Scale to which applicable:*	Coastal sea, Bay, lagoon, estuaries – spatial resolution between 50 and 5000 m.
2.c	*General description.* *NB: if the model is complicated, or has easily distinguishable components (such as a physical and a biological sub-models) that can be, or have been, used separately, it may be easier to complete one form for each of the main components.*	The hydrodynamic model solves the three dimensional Reynolds-averaged Navier–Stokes equations with hydrostatic approximation and free surface boundary condition. Density evolution is allowed and related to temperature and salinity variations through a state relationship. Bottom topography is taken into account via a s-transformation along the vertical axis (10 levels) of a Cartesian mesh. Horizontal computational domain is a regular grid.
2.d	*Key semi-universal parameters and example values (which should apply at least regionally or for at least one type of water body); summarize any restrictions or reservations about these parameters*	All parameters are universal and related to the Navier-Stokes equations.
2.e	*Main forcing data needed - initial values of state variables; boundary conditions; inputs; imposed environmental conditions; generalized loss terms. State whether single values or time-series needed.*	• Times series of air temperature, light, wind • Time series of freshwater discharge • Boundary conditions (water height)
2.f	*Restrictions to use of model*	None.

3	possibly relevant INDICATORS and example EcoQOs	
3.a	***D**river*	
3.b	***P**ressure*	Freshwater discharge.
3.c	***S**tate*	
3.d	***I**mpact*	
3.e	***R**esponse*	

4	**STATUS of model** *NB: refers to scientific theory and equation set; distinguish from implementation*	
4.a	*Origin(ator) of model concept and initial formulation:*	IFREMER (Lazure (1995) on Thau lagoon; Struski (2005) and Stanisière et al. (2006) on Marennes-Oléron).
4.b	*Present status of model, including scientific basis of claimed robustness and key matters still needing study:*	Several publications and applications for IFREMER projects on all types of ecosystem, including ecological applications (eutrophication).
4.c	*Present use:*	On Thau lagoon, assessment of the impact of shellfish aquaculture (anoxia, Chapelle et al., 2001) and impact of watershed on water quality (Fiandrino et al., 2003) and ecosystem functioning (Plus et al., 2003a, b, 2006). On Pertuis Charentais, the code has been applied to assess the extension of mussel longlines culture (see 'longline' template), for ecological and impact assessment studies and simulation of sediment dynamics (Stanisière et al., 2006; Struski, 2005). On Baie des Veys, it is under development to assess carrying capacity with a coupling between DEB, ecosystem dynamics and hydrodynamics
4.d	*Potential use and development in ECASA :*	Local impact of shellfish aquaculture, by coupling with an ecophysiologcal model (see DEB template).

5	IMPLEMENTATION of model	
5.a	*State of implementation :* *(This refers to realization of model theory in numerical algorithms, spreadsheets, computer programs, etc. to provide solutions of the model equations when supplied with appropriate forcing data.*	Fortran code and Matlab tools for post processing.
5.b	*State of documentation (which describes how to use an implementation as well as giving model theory)*	See 2 reports describing the model implementation in Marennes-Oléron Bay (Stanisière et al., 2006; Struski, 2005).
5.c	*Intellectual property concerns - if none stated here,*	IFREMER is the owner of this model and the software supporting it. ECASA participants need an agreement

	model and implementation will be deemed to freely available on request	to apply it for their own needs when carrying the tasks identified within the ECASA contract.

6.	**TESTING of model**	
6.a	*Summary of conditions and measurements needed:* *Refer back to 2.e if necessary. Highlight observations needed for model testing.*	Air temperature and wind, freshwater discharge (when necessary), boundary conditions (water height), bathymetry.
6.b	*Criteria for model rejection*	None.

7	**OTHER models**	
7.a	*Used explicitly or implicitly with this model*	Longline model used to assess the effect of cultured mussels on particles and sediment. Anoxia model by coupling hydrodynamics and biological equations (mineralisation, biodeposition). Impact of freshwater inputs (bacteria, nutrients).
7.b	*Similar models (which might serve roughly the same purpose in relation to mariculture)*	Any 2D or 3D model (e.g. MIKE, COHERENS etc.).

8. REFERENCES cited *show in bold the most important paper describing the model*

Chapelle A., Lazure, P., Souchu, P., 2001. Modélisation numérique des crises anoxiques (malaïgues) dans la lagune de Thau (France). Oceanologica Acta 24, 87-97.

Fiandrino A., Y. Martin, P. Got, J.L. Bonnefont, M. Troussellier, 2003. Bacterial contamination of Mediterranean coastal seawater as affected by riverine inputs: simulation approach applied to a shellfish breeding area (Thau lagoon, France). Water Research 37, 1711–1722.

Lazure, P. 1992. Etude de la dynamique de l'étang de Thau par modèle numerique tridimensionnel. *Vie & Milieu* **42**, 137-145.

Plus M., I. La Jeunesse, F.al Bouraoui, J.M. Zaldıvar, A. Chapelle, P. Lazure, 2006. Modelling water discharges and nitrogen inputs into a Mediterranean lagoon. Impact on the primary production. Ecol. Modelling, 193, 69-89.

Plus, M., Chapelle, A., Lazure, P., Auby, I., Levavasseur, G., Verlaque, M., Belsher, T., Deslous-Paoli, J.-M., Zaldívar, J. M., Murray, C. N., 2003 a. Modelling of oxygen and nitrogen cycling as a function of macrophyte community in the Thau lagoon. Continental Shelf Research, 23: 1877-1898.

Plus, M., Chapelle, A., Ménesguen, A., Deslous-Paoli, J.-M., Auby, I., 2003 b. Modelling seasonal dynamics of biomasses and nitrogen contents in a seagrass meadow (*Zostera noltii* Hornem.): application to the Thau lagoon (French Mediterranean coast). Ecol. Model., 161: 149-252.

Stanisière, J.Y, Dumas, F., Plus, M., Maurer, D., Robert, S., 2006. Hydrodynamic characterization of a semi-enclosed coastal system : Marennes Oleron (France) basin. Ifremer Report, http://www.ifremer.fr/docelec/notice/2006/notice2353-EN.htm

Struski C., 2005. Modélisation des flux de matières dans la baie de Marennes-Oléron : couplage de l'hydrodynamisme, de la production primaire et de la consommation par les huîtres.

Annexe 4. ECASA - Model description template. Depletion model

1	**Name of model**	*Reporter/Institute (email address)*
1.a	***Effect of mussel longlines***	C. Bacher/IFREMER (cbacher@ifremer.fr)
1.b	*date this form was completed or updated*	5 September 2007

2	**Short DESCRIPTION of model**	
2.a	*Main state variables:*	Mussel growth, food concentration, biodeposition.
2.b	*Scale to which applicable:*	Mussel longline area, ca. 5 km.
2.c	*General description.* *NB: if the model is complicated, or has easily distinguishable components (such as a physical and a biological sub-models) that can be, or have been, used separately, it may be easier to complete one form for each of the main components.*	It combines an ecophysiology model and a box model in order to simulate growth of mussels reared in long lines and advise for the appropriate size and mussel density of the cultivated area. The model was applied in Pertuis Breton for mussels. The growth model was adapted and calibrated from previously published model (Grant and Bacher, 1998) and food transport in the long line area was computed using outputs of a hydrodynamical model (see the related template). Simulations were carried out for different mussel densities and lease sizes to assess their effects on mussel growth. They demonstrated that actual mussel density and lease size had a minor impact on flows of particulate organic matter and phytoplankon and would not decrease food concentration for other cultivated areas. A threefold multiplication of either mussel density or lease size would therefore be a conservative recommendation for managers willing to increase mussel production without having deleterious effect on growth. Another application was carried out in China for scallops (*Chlamys farreri*) cultured on long lines. A detailed model of *C. farreri* feeding and growth and a one dimensional horizontal transport equation have been coupled. The model was applied to assess the effect of some environmental parameters (e.g. food availability, temperature, hydrodynamism) and spatial variability on growth, and to assess the effect of density according to a wide range of hydrodynamical and environmental conditions. The model suggests that scallop growth was correlated with maximum current velocity for a given density and current velocity below 20 cm s^{-1}.
2.d	*Key semi-universal parameters and example*	Ecophysiology parameters are not universal (in this case) but a generic version of this model exists (see

	values *(which should apply at least regionally or for at least one type of water body)*; *summarize any restrictions or reservations about these parameters*	related template). Spatial Box Model concept and equation are generic and based on simple mass conservation principle.
2.e	*Main forcing data needed - initial values of state variables; boundary conditions; inputs; imposed environmental conditions; generalized loss terms. State whether single values or time-series needed.*	• Water temperature. • Boundary conditions: food concentration, suspended particulate matter. • Hydrodynamical model or current velocity measurements to assess exchange of water between the longline area and the ecosystem.
2.f	*Restrictions to use of model*	None.

3	**possibly relevant INDICATORS and example EcoQOs**	
3.a	***D**river*	
3.b	***P**ressure*	Number of longlines, density of shellfish, size of the farm.
3.c	***S**tate*	Phytoplankton concentration and shellfish growth.
3.d	***I**mpact*	Shellfish growth and production.
3.e	***R**esponse*	Selection of sites suitable for shellfish culture.

4	**STATUS of model** *NB: refers to scientific theory and equation set; distinguish from implementation*	
4.a	*Origin(ator) of model concept and initial formulation:*	Incze et al. (1980).
4.b	*Present status of model, including scientific basis of claimed robustness and key matters still needing study:*	The ecophysiology model is specific, and must be adapted to site and species. Implementation of the model is also specific.
4.c	*Present use:*	The code has only been used in 2 case studies (see description). One of the case studies illustrated how to assess the risk of affecting carrying capacity due to the extension of mussel farms, using Risk Assessment methods in a panel of experts (GESAMP working group 31).
4.d	*Potential use and development in ECASA :*	Can be used to assess effect of animals density and lease size on food concentration, animal growth and biodeposition in shellfish culture.

5	**IMPLEMENTATION of model**	
5.a	*State of implementation :* *(This refers to realization of model theory in numerical*	Matlab code.

	algorithms, spreadsheets, computer programs, etc. to provide solutions of the model equations when supplied with appropriate forcing data.	
5.b	*State of documentation (which describes how to use an implementation as well as giving model theory)*	Concepts and methods are explained in the literature. Examples of applications are given in Bacher et al. (2003), Bacher (2007).
5.c	*Intellectual property concerns - if none stated here, model and implementation will be deemed to freely available on request*	IFREMER is the owner of the software supporting it. ECASA participants have a free access to these tools, which is restricted to be used when carrying the tasks identified within the ECASA contract. Any other use requires the written consent of IFREMER.

6.	TESTING of model	
6.a	*Summary of conditions and measurements needed:* *Refer back to 2.e if necessary. Highlight observations needed for model testing.*	Hydrodynamic model (see the template on hydrodynamic model), growth data, boundary conditions (phytoplankton, suspended matter), forcing variable (temperature).
6.b	*Criteria for model rejection*	None

7	OTHER models	
7.a	*Used explicitly or implicitly with this model*	Ecophysiology model. Hydrodynamical model.
7.b	*Similar models (which might serve roughly the same purpose in relation to mariculture)*	Model by Ferreira et al. (2007).

8. REFERENCES cited *show in bold the most important paper describing the model*

Bacher C., S. Robert, P. Garen, S. Bougrier, E. Pallas. Using a box model to predict the growth of cultured mussels as a function of mussel density and lease size. Symposium of the American Fisheries Society, Québec, 10-14 août 2003, (summary only).

Bacher C., Grant J., Hawkins A.J.S., Fang C. , Zhu M., Besnard M., 2003. Modelling the effect of food depletion on scallop growth in Sungo Bay (China). Aquat. Living Resour, 16, 10-24.

Bacher, 2007. Risk assessment of the potential decrease of carrying capacity by shellfish farming. http://gesamp.net/page.php?page=24 , case study 6.2.

Ferreira J.G., Hawkins A.J.S, Bricker S.B., 2007. Management of productivity, environmental effects and profitability of shellfish aquaculture — the Farm Aquaculture Resource Management (FARM) model. Aquaculture 264, 160-174.

Grant J., Bacher C. 1998. Comparative models of mussel bioenergetics and their variation at field culture sites. J. Exp. Mar. Biol. Ecol. 219 (1-2) : 21-44.

Incze L.S., Lutz R.A. & Walting L. (1980) Relationship between effect of environmental temperature and seston on growth and mortality of *Mytilus edulis* in a temperate northern estuary. Marine Biology 57, 147-156.

ANNEXE 5

Box model

The box model is coupling food transport, food consumption by the mussel population and mussel growth at the scale of a cultivated area. The concept is the same as used by Bacher et al. (2003) except that food and particulate matter concentrations were assumed to be homogeneous within the cultivated area which was considered as a single box. The transport equation is a mass budget equation accounting for i) the exchange of water between the box and the external part of the cultivated area (Bacher et al. , 1989; Raillard et al., 1994 ; Dowd, 1997), ii) sinks of particles due to filter feeders consumption :

$$\frac{dC}{dt} = \frac{\dot{Q}}{V}(C_e - C) - \frac{N}{V}.f(C,w) \qquad (1)$$

where *C* refers to either phytoplankton, organic or inorganic particulate matter within the box C_e is the outside concentration, *Q* the exchange flow ($m^3.s^{-1}$), *f(C,w)* the individual food consumption, *N* the total number of mussels, *w* the mussel tissue dry weight (DW). Food consumption was calculated using ingestion rate of mussels instead of filtration (see ecophysiology model below) since an important fraction of the filtered particles was assumed to remain in the water column as pseudofeces and would be reused by mussels with the same efficiency. Equation (1) was coupled to the following mussel growth equation:

$$\frac{dw(x,t)}{dt} = g(C,w,T) \qquad (2)$$

where *T* is the water temperature and *g(C,w,T)* is the growth rate established upon the ecophysiology model of Grant and Bacher (1998) (see also Table 1 for details). Briefly, the model provides two food sources, phytoplankton and detrital POC, where detrital POC=total POC-chlorophyll carbon. Clearance rate ($1.h^{-1}$) of particles is a declining function of TPM. Phytoplankton and POC are both cleared at the same rate, and a proportion of the ingested mass is rejected as pseudofeces in relation to turbidity using a step function : no rejection at 0–5 $mg.l^{-1}$, 20% rejection at the pseudofeces threshold up to 10 $mg.l^{-1}$, 40% rejection from 10–40 $mg.l^{-1}$, and peak rejection (85% of ingesta) beyond 40 $mg.l^{-1}$. Phytoplankton is selected preferentially to detritus. In terms of ingestion, phytoplankton and POC are maintained as separate quantities, each with an absorption efficiency (AE) value, and absorption rates are summed to calculate total absorption. Phytoplankton AE is assumed to be 80% and AE for detrital POC is set at 40%. As opposed to other models using gut capacity and gut passage time to limit ingestion (Scholten and Smaal, 1998) daily ingestion can not be higher than a constant value defined as the maximum daily ingestion. Net energy balance is determined as the difference between rates of assimilation and respiration, and the balance is allocated between somatic tissue and shell. The model predicts both dry weight and shell weight changes. The respiration equation was modified from Grant and Bacher (1998) to allow a better fit with observations. Two parameters (r1, r2 – see Table 1) were calibrated using the longline dataset and simplex method (Press et al., 1986). The model was also applied on the 'bouchot' dataset for validation and ecophysiological functions were compared to measured values as a further check.

Computation of exchanges flow

Long lines cover an area of 2.5 km^2. They are arranged in 20 blocks of 12 long lines each. 85 ropes of 6 m length are hanged on each longline and the whole area totals about 240 10^6 mussels. We assumed that mussels were homogeneously spread within the box and that trophic conditions were uniform. Boundary conditions were defined for TPM, POM, Phytoplankton from the field survey. Temperature time series were used as a forcing function.
Current velocity was computed with a hydrodynamical model developed by Brenon and Le Hir (1999) applied to Marennes-Oléron Bay. This model solves Navier-Stokes equations with a finite difference method using a rectangular grid (Struski, 2005) and predicts water height and current velocity along West-East and South-North directions. and the geographic area was extended to Pertuis Breton. Water height and tidal currents were simulated for one month to account for neap and spring tides. To check the validity of the model, we compared simulated water height in La Pallice harbour to available data of water height and we found a good agreement. Maximum current velocity was mapped from this single simulation and showed that long lines were located in a region of intensive water exchange with maximum current velocity over 1 $m.s^{-1}$. Current velocity generally depends on tidal coefficient and maximum tidal currents varied between 0.5 and 1 $m.s^{-1}$. In long line area, current direction lies along a northwest/southeast axis and intensive exchange of water occurs at Pertuis Breton straight.
Particle trajectories were computed for one tidal cycle during spring tide using current velocity field computed by the hydrodynamic model. They show how particles coming from the inner part of the bay (Aiguillon bay) exit through Pertuis Breton straight in the west or through La Pallice straight in the south. Trajectories also show that tidal excursion equals almost 10 km which sustains the assumption of strong water mixing in the inner part of the bay.
Current velocities and water height were used to compute water exchange between the long line area (box) and the outer part of the bay. Average water flow entering and exiting the cultivated area was calculated with the following equation:

$$Q_T = \sum_t \left\{ \sum_{x,y} h(x,y,t) \cdot \left| U(x,y,t) \cdot N(x,y) \right| \cdot L \right\} / n$$

where *U(x,y,t)* is the current velocity vector at the grid node *(x,y)* located at the box boundary, *N(x,y)* is the vector normal to the lease size boundary, *h(x,y,t)* is the water height, *L* is the mesh size used in the hydrodynamics model (500 m), *n* is the number of time steps used for the computation. Due to mass conservation, half of total flow is entering the cultivated area and the exchange flow was therefore given by:
$Q = Q_T / 2$
Box volume was equal to :

$$V = \sum_t \left\{ \sum_{x,y} h(x,y,t) \cdot L^2 \right\} / n$$

where here *h(x,y,t)* is the water height of the grid node *(x,y)* located inside the box. Exchange flow was equal to 5.2 10^3 $m^3.s^{-1}$ and volume to 2.37 10^7 m^3 which yielded a renewal time of 0.05 days.

Simulated and observed mussel growth are shown in the following figure to show the accuracy of the model to reproduce the growth patterns at two different sites.

Table 1 Equations, parameters and variables used in the ecophysiology model of mussel growth.

Equations	description
State variables TPM POM CHL DW SW	 Total Particulate Matter ($mg\cdot l^{-1}$) Particulate Organic Matter ($mg\cdot l^{-1}$) Chlorophyll a mussel Tissue Dry Weight (g) mussel Shell Weight (g)
Forcing functions TEMP	 Temperature (°C)
Parameters chl2c=50 pom2c=0.38 CPHY=CHL·chl2c/1000 CDET=POM·pom2c-CPHY	 conversion from Chlorophyll a to Carbon ($gC\cdot gChl^{-1}$) conversion from POM to Carbon ($gC\cdot gDW^{-1}$) Carbon phytoplankton ($mgC\cdot l^{-1}$) Carbon detritus ($mgC\cdot l^{-1}$)
Clearance rate cr1=1.8 cr2=8.6 10^{-3} cr3=0.67 if TEMP < 5 frtemp=$e^{(TEMP-5)\cdot cr3}$ elseif TEMP >5 & TEMP < 20 frtemp= 1 else frtemp=$e^{(20-TEMP)\cdot cr3}$ end CR=CR= (cr1 – cr2·TPM) ·$(DW/0.7)^{cr3}$·24·frtemp	 frtemp=temperature effect clearance rate ($l\cdot d^{-1}\cdot ind^{-1}$)
Filtration rate FR=CR·TPM if TPM < 5 rej=0 elseif TPM >5 & TPM < 10 rej=0.2 elseif TPM >10 & TPM < 40 rej=0.4 elseif TPM>40 rej=0.7 end	 TPM filtration rate ($mg\cdot d^{-1}\cdot ind^{-1}$) rej = rejection rate (no unit)
Ingestion rate IR=FR·(1-rej) ir1=600 ir2=0.40 IRmax=ir1·DW^{ir2} IRTPM=min(IR,Irmax) fq=0.8 IRPHY=IRTPM·CPHYT/TPM/fq IRDET=IRTPM·CDET/TPM	 TPM ingestion rate ($mg\cdot d^{-1}\cdot ind^{-1}$) TPM maximum ingestion rate ($mg\cdot d^{-1}\cdot ind^{-1}$) TPM ingestion rate ($mg\cdot d^{-1}\cdot ind^{-1}$) phytoplankton enrichment factor PHYTO ingestion rate ($mgC\cdot d^{-1}\cdot ind^{-1}$) DETRITUS ingestion rate ($mgC\cdot d^{-1}\cdot ind^{-1}$)
Absorption rate ARPHY=IRPHY·0.8 ARDET=ARDET·0.4 AR=ARPHY+ARDET	 PHYTO absorption rate ($mgC\cdot d^{-1}\cdot ind^{-1}$) DETRITUS absorption rate ($mgC\cdot d^{-1}\cdot ind^{-1}$) total absorption rate
Respiration rate r1= 6.55 r2= 0.454 r3=0.75 RER=(r1+r2·AR)·DW^{r3}	 calibrated calibrated respiration rate ($mgC\cdot d^{-1}\cdot gDW^{-1}$)
Carbon budget and growth Budget=AR-RER alloc=0.58 w2c=0.4 s2c=0.08 if Budget>0 dDW=Budget·alloc/w2c/1000 dSW=Budget·(1-alloc)/s2c/1000 else dDW=Budget/w2c/1000	 Carbon budget ($mgC\cdot d^{-1}\cdot gDW^{-1}$) tissue allocation rate - calibrated conversion from DW to Carbon ($gC\cdot gDW^{-1}$) conversion from SW to Carbon ($gC\cdot gSW^{-1}$) dDW = dry weight variation (g) dSW = shell weight variation (g)

dSW=0 end	
Integration dt=1 DW=DW+dDW·dt *SW=SW+dSW·dt*	 time step (d) dry weight (g) shell weight (g)