Offshore mollusc production in the Mediterranean basin

Ch. Danioux*, X. Bompais*, C. Loste and Ph. Paquotte*[1]**
*Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER),
B.P. 70, 29280 Plouzane, France
**Centre d'Etudes et de Promotion des Activités Lagunaires et Maritimes (CEPRALMAR),
20, rue de la République, 34000 Montpellier, France

SUMMARY – In the Mediterranean basin, offshore mollusc production takes place mainly in France and Italy. Its recent development stems from the limited potential of lagoons and ponds, and centres mainly on mussel production. Suspension culture technologies are described and compared with those used in the Atlantic. Some information is given on the production systems and a short economic study demonstrates the profitability of these shellfish farming activities, in spite of the many risks involved and their relatively low profit margins.

Key words: Mediterranean, offshore, mussel farming, long lines, technology, economy.

RESUME – *"Production de mollusques en mer ouverte dans le bassin méditerranéen". Dans le bassin méditerranéen, la production de mollusques en mer ouverte se pratique essentiellement en France et en Italie. D'implantation récente à la suite d'une exiguïté des lagunes et étangs côtiers, elle est principalement axée sur la moule. Les technologies d'élevage sur filières sont développées et comparées avec celles mises en oeuvre en Atlantique. Des informations sont données sur les systèmes de production avec une étude économique succincte montrant la rentabilité de ces élevages malgré les nombreux risques encourus, mais avec une marge relativement faible.*

Mots-clés : *Méditerranée, mer ouverte, mytiliculture, filières, technologie, économie.*

Background

Reasons for development towards offshore production

Shellfish production in the Mediterranean has been restricted to coastal lagoons for a long time. These rich, easily accessible but fragile environments were exploited to their maximum spatial and biological capacity. Several risk factors, at times simultaneously, have limited the expansion of the activity in the restricted lagoon environment: (i) the necessary intensification of production in order to reduce production costs; (ii) pollution from industrial and domestic, resulting at times in heavy mortalities; and (iii) the limited renewal of the environment due to a lack of strong tides, inducing risk of dystrophic crisis and anoxia.

It has therefore been necessary to occupy open sea space. Whilst the first installations were set up more than 50 years ago in Italy in the Gulf of Trieste, the most significant offshore endeavour was made from 1976 to 1977 by France. This was undertaken by a handful of pioneers who were aware of the possibilities offered by the sea, and marked the beginning of a great technological and human adventure, rewarded with successes but not without disappointments.

In general terms, the development of maritime shellfish production has taken place at two different points in time:

(i) A phase in which techniques were set up to establish complete production systems (suspension culture), to perfect specialized craft (shellfish boats), and to make offshore systems reliable whilst lowering production costs.

[1]Present address: OFIMER, 11 Boulevard Sebastopol, 75001 Paris, France.

(ii) A phase of economic development, including the organization of definitive production structures (structuring the profession, trade organization, applied research programmes). This phase has been generally marked by the obtaining of subsidies and private loans granted by the regional authorities and the European Union.

Species farmed

Several species are produced offshore. There is a large clam production, especially off Italy in the Adriatic. However, this yield is mainly the result of fishing. *Mytilus galloprovincialis* continues to be the main species farmed. The flat oyster *(Ostrea edulis)* and the Pacific oyster *(Crassostrea gigas)* have undergone a recent and moderate development. Successful trials of suspension culture were carried out in France. These trials were not carried out during the mussel capture season to avoid mussels taking over the site.

Producer countries

France and Italy are the main offshore producers.

In France, the Languedoc-Roussillon region produces between 8000 and 10,000 tonnes of mussels per year in offshore conditions (1996 production: 8000 tonnes), contributing to a total French mussel production of 60,000 tonnes.

Production in Italy was estimated at between 10,000 and 12,000 tonnes per year. It is difficult to obtain accurate figures as marine aquaculture production is not distinguished within the total productions of between 90 and 100,000 tonnes (1996 figures). Offshore production is carried out in the Gulf of Trieste, in the Gulf of Manfredonia (1600 tonnes), Mattinata (500 tonnes) and Taranto.

Other countries have also embarked on offshore farming. In Spain, production in Catalonia in 1996 reached 300 tonnes of mussels on submerged lines, 10 tonnes of *Ostrea edulis* and 46 tonnes of *Crassostrea gigas,* 10% of the Catalonian production taking place on floating rafts. Greece produced 3000 tonnes in 1990 in the Gulf of Thessaloniki and further south, Turkey is also making recent development.

Site characteristics

Topography

Production units are located along the coast in the 3-mile zone (0.3 miles for Trieste, 2 miles for Manfredonia, between 1 and 3 miles for Languedoc-Roussillon). Site depths vary from 10 to 30 m, and seabeds are generally flat, with a gradual slope, and a sand-silt sediment.

Weather and currents

The typical Mediterranean climate is characterized by infrequent but often heavy rainfall. Temperatures are mild in winter and hot in the summer. Frosts and low temperatures are rare and sun exposure good. Winds are generally frequent and sometimes strong, especially in Languedoc-Roussillon. Average salinity is approximately from 36 to 38 g/l with an occasional decrease during rainfall.

The currents generally follow the coast relatively slowly: less than 1 knot, though in storms, they can reach 3 or 4 knots. Waves may be quite strong, with heights from 3 to 4 m and it is not rare to see 8 to 10 m waves in Languedoc-Roussillon. The breaking of this type of wave adds more stress to the materials.

Water quality

The strip of sandy coast appears to be a very appropriate site for shellfish culture due to its chemical and physical characteristics. Waters are clean apart from some localized estuary or port zones that generally do not exceed an extent of 500 m. The supply of nutrients in the given sites (Gulf of Lion, Adriatic) favours a wealth of phytoplankton that may vary according to the season, and is appropriate for the growth of filter-feeeding molluscs.

Technological aspects

Production site structures

The simplest farming system consists of seeding the ground with natural young spat either fished from the sea or hatchery-produced. This is common practice for oysters. The oysters grow and are harvested with bottom drag gear as traditionally used for fishing. This farming system is much used for oysters on the Atlantic coast of France and for clams in Italy (Paquotte and Rey, 1988). However it is very precarious and not easy to control. It is furthermore open to external elements (various predators, sinking into the sand or storm-induced mortalities, etc.). Despite all the drawbacks, production costs are very low.

Production in trays (oysters), on stakes (mussels), or on ropes suspended from rafts built with posts and rails is practised almost exclusively in lagoons or sheltered coastal zones (Antona and Paquotte, 1990). Production has also been developed offshore using suspension culture. This technique, adapted from lagoon production, consists of a floating structure, either on the surface or submerged, from which ropes are suspended. There are two types of suspension culture practised In the Mediterranean (Bompais, 1991): (i) surface suspension line units (in Italy, followed by Greece, Spain and Turkey); and (ii) submerged suspension line units (in France).

Surface units

The typical surface unit comprises (Fig. 1):

(i) A main line, which supports the suspended culture ropes, kept afloat by buoys of various shapes and materials.

(ii) Mooring lines attached to an anchor on the sea bottom (generally a concrete block weighing several tonnes) are also joined to the surface unit, which is fitted with a buoy on each end.

Most of these structures are linked together with fittings such as shackles, mooring eyes and rings.

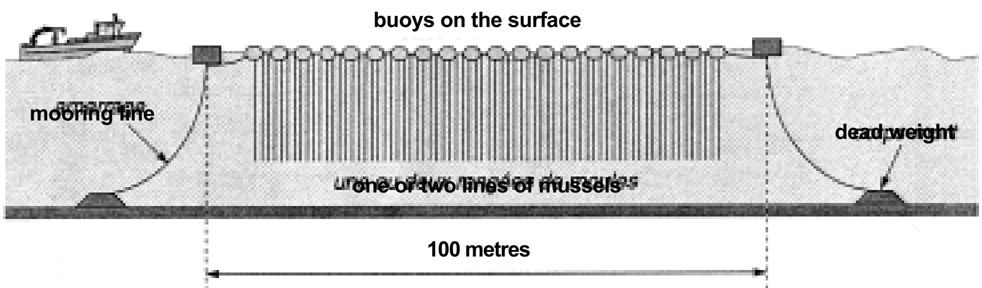


Fig. 1. Diagram showing the main principles of a surface rig.

The unit may be simple: a single support line, which is normally threaded through the floats. This is sometimes called a "pearl/bead unit" (Fig. 2).

Fig. 2. View of the site of a surface unit (IFREMER: X. Bompais).

There are also double "tandem" units: set up with two parallel ropes. The floats keep the two surface lines apart. Triple units can also be used (Fig. 3). The length of the production section of the line varies from 100 to 200 m.

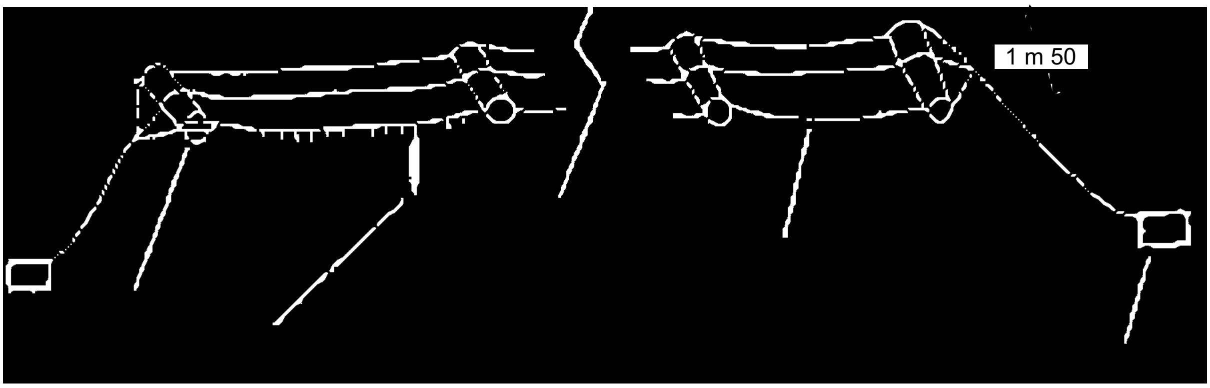


Fig. 3. Type of triple rig used in Italy.

Submerged units

These units were developed in France in Languedoc-Roussillon. They are fixed 5 metres below water level to protect them from bad weather (Fig. 4). The submerged unit consists of:

(i) A supporting line 5 m below water level, equipped with rope floats (60 l) holding the mussels.

(ii) Ropes which tie the bottom of the unit (800 kg dead weight on the sea floor), to the leg floats (300 to 800 l) thus keeping the unit submerged. The legs are between 25 and 50 m apart.

(iii) An 8-m chain links each 800-kg dead weight to a 3-m stake sunk into the seabed. This system does not prevent the unit from being raised to the surface for harvest.

(iv) Two mooring lines keep the unit attached to a dead weight weighing between 1 and 2 tonnes, often fixed with an intermediate float of 150 l, which keeps the mooring taut.

The whole unit measures 200 to 250 m, plus the length of the mooring lines which vary according to the depth of the site.

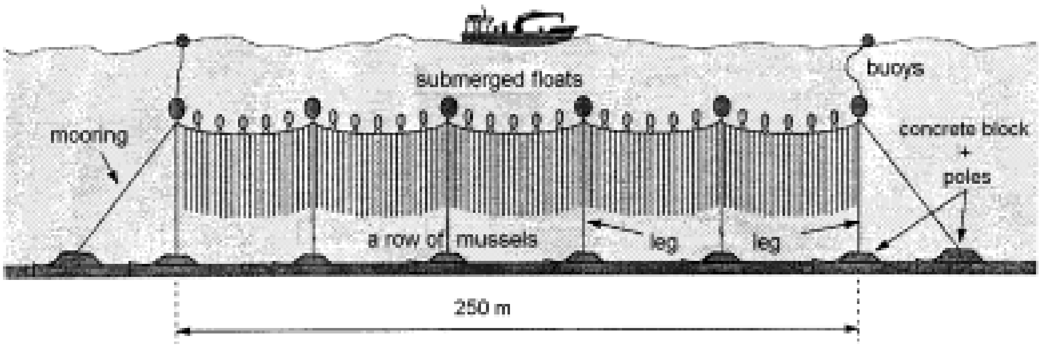


Fig. 4. Diagram of the main principles of a submerged unit.

Material used

Support lines

Polypropylene is essentially used for the main support line from which the cultivation ropes are suspended. The most common diameters vary between 40 and 50 mm. Although the polypropylene line is easy to work with, it does have its defects, as it does not withstand the friction of the propellers, and when new, tends to stretch. The strands take a while to settle into place and therefore the line looses tautness. In order to avoid this problem, the manufacturers sell pre-stretched line.

In most cases, polypropylene eventually becomes slack. The support line begins to droop and the suspended lines can touch the sea floor and rub against the bottom thus detaching the mussels. The best solution is to tighten the line by shifting out the concrete block but this is an arduous task and furthermore, this elasticity is indispensable when working with the submerged lines when they are hoisted up to the surface and onto the workboats.

It is possible to use a mixed material; with a steel core inside polypropylene strands. This is heavier but more resistant and a 30-mm diameter line will suffice. Though this more cumbersome material is also more difficult to work with it does not stretch and is resistant to chafing and fraying. However, the mixed line has only been used in experimental submerged units.

Floats

These are generally made of plastic, steel or polystyrene foam, of variable shapes (cylindrical, spherical, biconal, etc.) They may be new or recycled containers. Their number depends on the expected production, which is approximately 10 to 15 kg per metre of rope (gross yield, including the weight of the small mussels and all the waste).

Buoyancy of around 200 to 250 l is needed to keep 1000 kg gross product afloat. The buoyancy of a line in litres is easy to calculate, it is simply the expected production mass, and the extra weight of the organisms attached to the structure divided by 4 or 5. Qualities to be considered include:

(i) *Robustness and lifespan:* steel is used mostly for large floats. It must be protected against corrosion, either by paint or by another appropriate treatment. Plastic is appropriate for normal-sized floats. They must be thick enough to be robust. Although they are more expensive at the outset, the float will last longer. Its great enemy is UV radiation, which eventually destroys it.

(ii) *Resistance to immersion:* immersed often several metres deep, the pressure should not crush the floats. There are two possible solutions: either filling them with compressed air, which in the long term is not a reliable solution due to possible leaks, or filling them with polyurethane foam, which is a more cumbersome but reliable solution in spite of this making the floater heavier, indispensable for submerged lines.

(iii) *Cost:* floats generally make up half of the total price of the line. It is therefore important to compare costs and in order to do so, calculate the price per litre of buoyancy (Fig. 5).

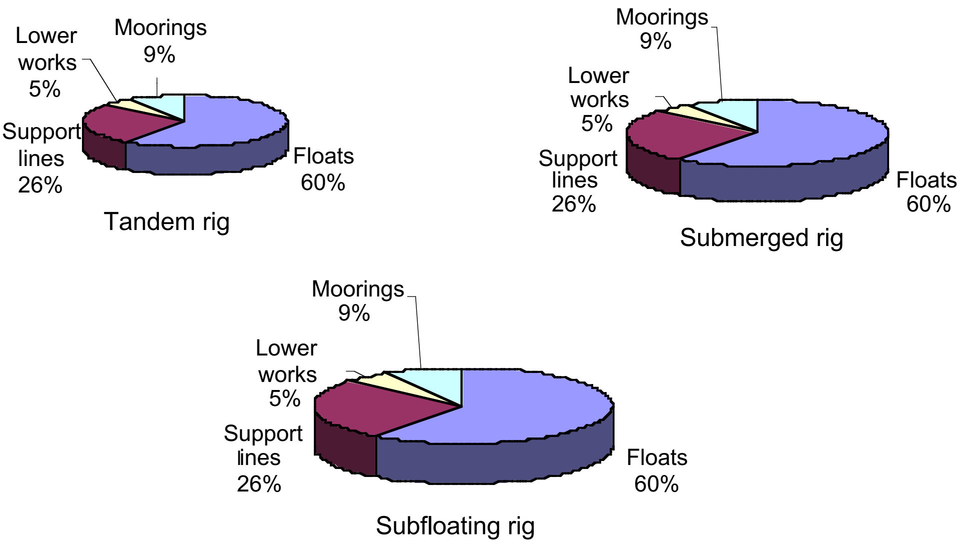


Fig. 5. Breakdown of the unit price.

Anchorage

There are three possible types of anchorage:

(i) Concrete dead weights, which are heavy and solid, are advantageous since they are not very cumbersome to work with. However they need heavy duty equipment to be put in place (boats equipped with hoists or inflatable buoyancy bags, or floats adaptable to pressure changes (Fig. 6). They should adhere well to the bottom: hence, they should be as flat as possible in order to avoid rocking and should have a suction pad on the underside. A ring firmly embedded in the concrete and welded to the steel framework (or a piece of thick chain), keeps the anchoring line firmly fixed to the unit. This ring must be big enough to withstand the wearing of constant friction against the mooring eye of the anchor line.

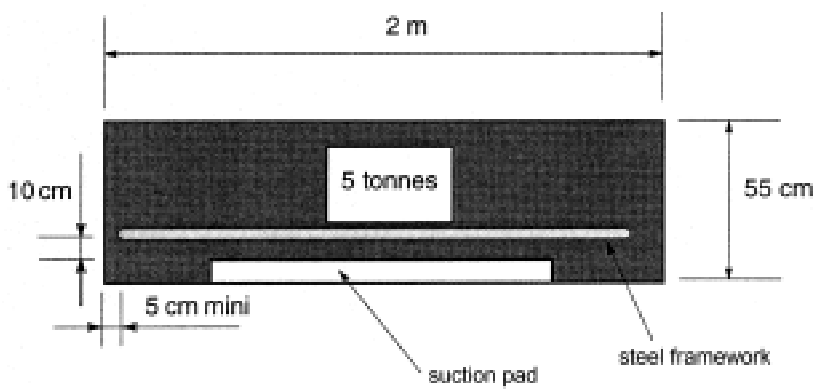


Fig. 6. Example of dimensions to be given to a dead weight of 5 tonnes.

(ii) Stakes are very practical but can only be used in loose ground. They are rarely used on their own, since if they are pulled vertically they will be easily uprooted. However, they are attached to the dead weights of the legs of submerged unit in order to prevent them sliding during storms.

(iii) Anchors: there are several types; plough anchors are most common and are very efficient if the strain is horizontal. In the case of a line, strain is varies across the vertical and horizontal plane depending on the direction of the currents. Moreover, it is not easy to lay the lines as the anchor has to be pulled in order to take hold and settle. For all these reasons, this type of mooring although light is in fact quite cumbersome and is not strongly advised.

Suspension systems for stock

Various types of suspension are used in different regions; ropes are either suspended or pulled down. With lengths varying from 4 to 8 metres, they are fixed under the supporting line every 0.50 m.

Their diameter varies from unit to unit, from a thin line (15 to 20 mm) to a piece of supporting line (40 to 60 mm) (Fig. 7).

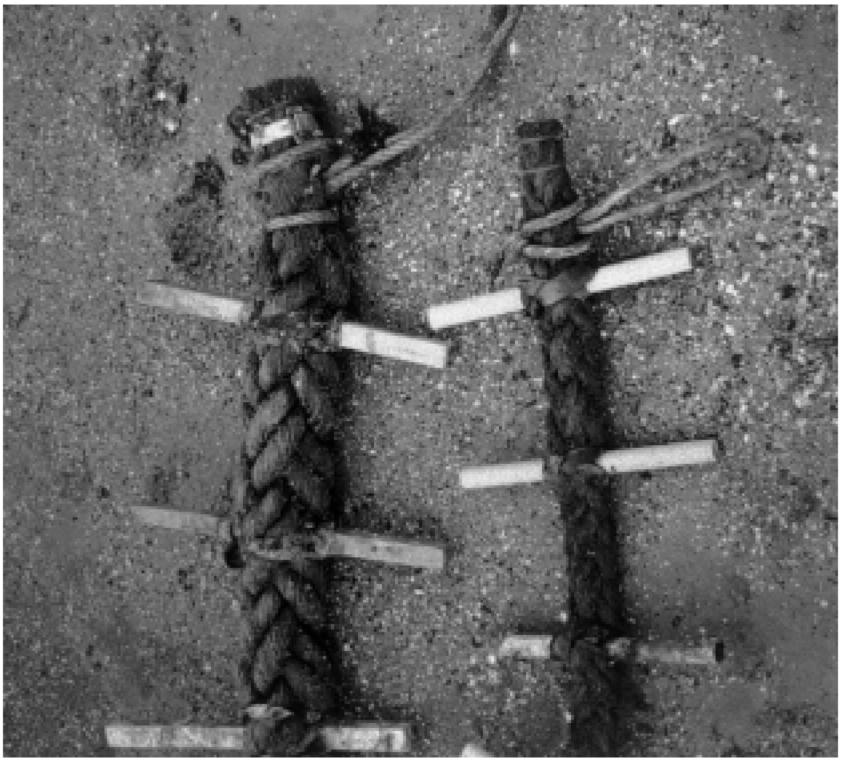


Fig. 7. View of two parts of the suspension lines (IFREMER: X. Bompais).

Thick suspension lines are bulky and difficult to handle. Furthermore, they offer great resistance to the current, which means even more strain on the whole unit.

Thin suspension lines have fewer disadvantages but on the other hand, there is less room for the mussels to attach to and hence less production. However, harvest is facilitated since the mussels are easier to cut off.

All suspension lines are ballasted (5 to 10 kg) when there is a current; seed (spat) collecting lines are normally ballasted as by nature they tend to float.

Differences with structures used in the Atlantic

The surface unit was the first system to be used, in both the Mediterranean and the Atlantic due to its simple implementation and use. This is also easily spotted and affordable. The surface unit is used especially in the protected sites, but at times, it must withstand swells and wave action, which causes considerable movement.

When the line cannot withstand the movements, the mussels become detached and fall onto the bottom thus leading to a loss in production. These sharp movements are made by the floats bobbing up and down on the surface due to the swell. With each wave, the lines slacken and tighten abruptly, suffering a whiplash effect (Fig. 8).

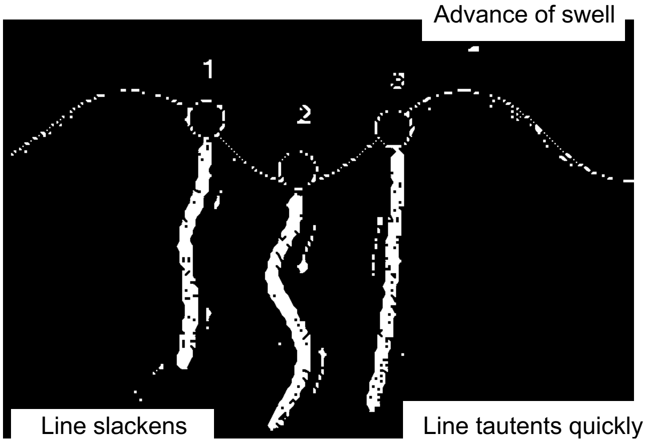


Fig. 8. Whiplash of a suspension line.

Considerable strain may be exerted on the line, as shown in Fig. 9, where it is four times stronger than when at rest position for a period of 5 s. When the whiplash movement is repeated thousands of times, the line becomes weak and eventually breaks the byssus of the mussels. Entire clusters can become detached.

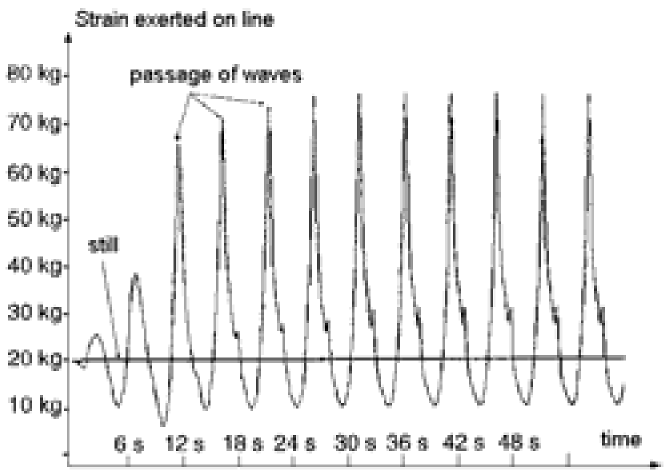
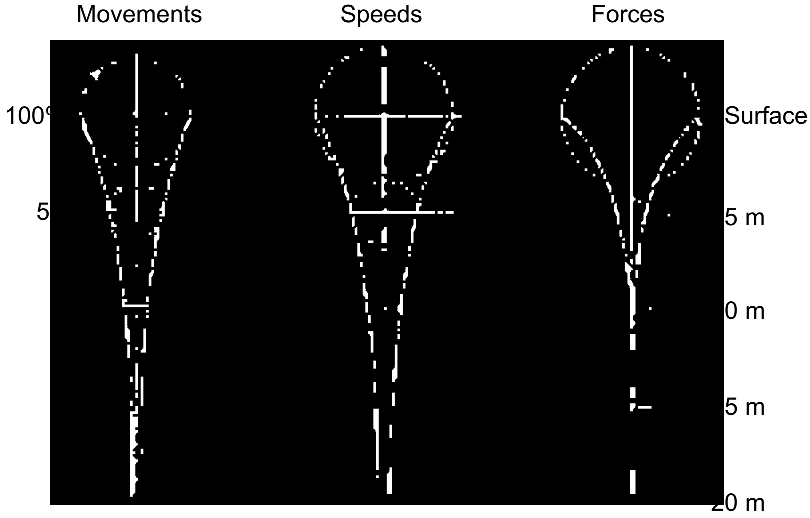


Fig. 9. Passage of a wave over a suspension line.

How can resist the natural elements be resisted? Three solutions can be envisaged:

(i) Submerge the line: surface movements soon diminish with depth, as does strain. For example at a depth of 5 m, movements are divided by 2, strain by 4 (Fig. 10). The lines in Languedoc-Roussillon have applied this principle. Nevertheless, some drawbacks do exist: the height of the unit decreases, the line is less accessible and the floats have to bear the strain.



(2 metre-swell, period of 5 seconds)

Fig. 10. Effects of immersion.

(ii) Limit the number of floats: a float that is not overloaded can bob with the surface water. It moves more freely, particularly in vertical movements, and is buffeted in all directions (Fig. 11). It is therefore necessary to avoid placing too many floats on a line that is not very heavily loaded, for instance, at the beginning of the production season. A certain balance must be kept between the number of floats and the mussel weight. The floats must be added as mussels grow, which, could become bulky.

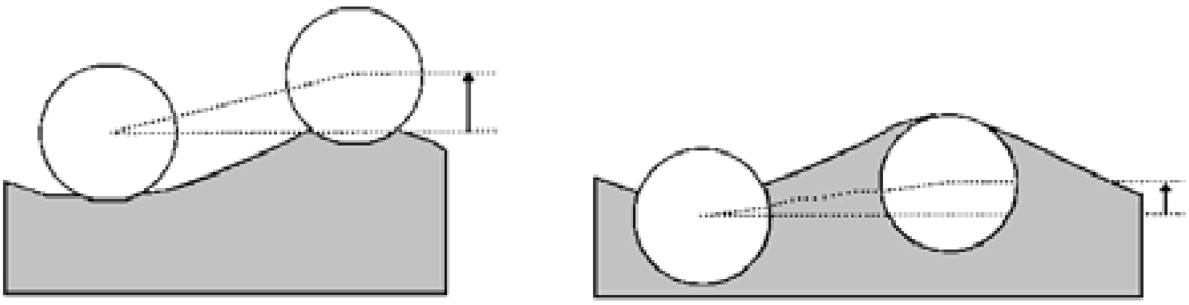


Fig. 11. Comparison of swell effects on a light float and a heavy float.

(iii) Use thin floats: a spherical or biconal floater follows the swell movements constantly. Thin, slender floats (cylindrical, long, with small diameter) called "hanging", or "pencil" floats, ride the swell, which passes over them without dragging them with it. They hardly shift position. The production unit is more relaxed with a submerged supporting line (Fig. 12).

Based on these statements and technical problems observed on the surface lines (detachment, breakage, wearing of material) IFREMER designed and experimented between 1988 and 1991 a subfloating line, a compromise between the floating lines and Mediterranean submerged lines (Fig. 13).

The idea is to keep this line under the sea surface with thin floats that are added as the line fills with mussels (Fig. 14).

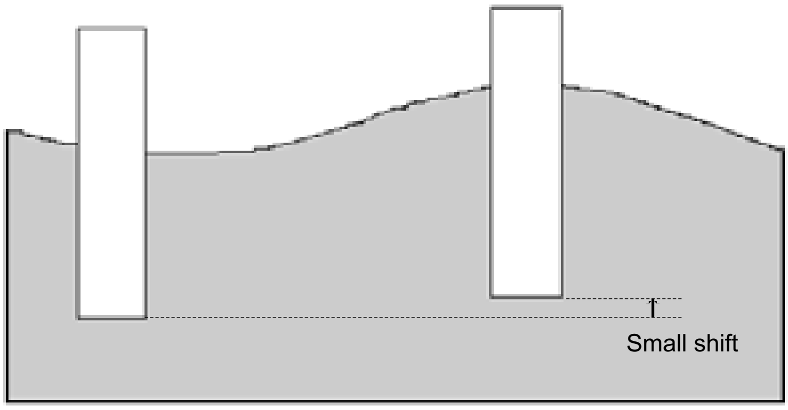


Fig. 12. Movement of a slender float in swell.

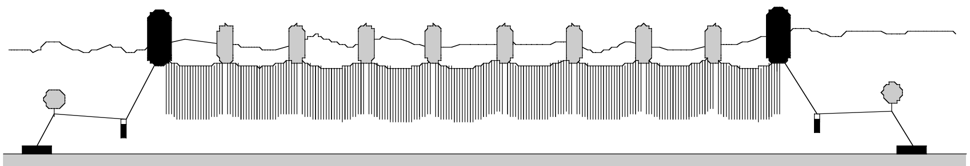


Fig. 13. Diagram of a subfloating line.

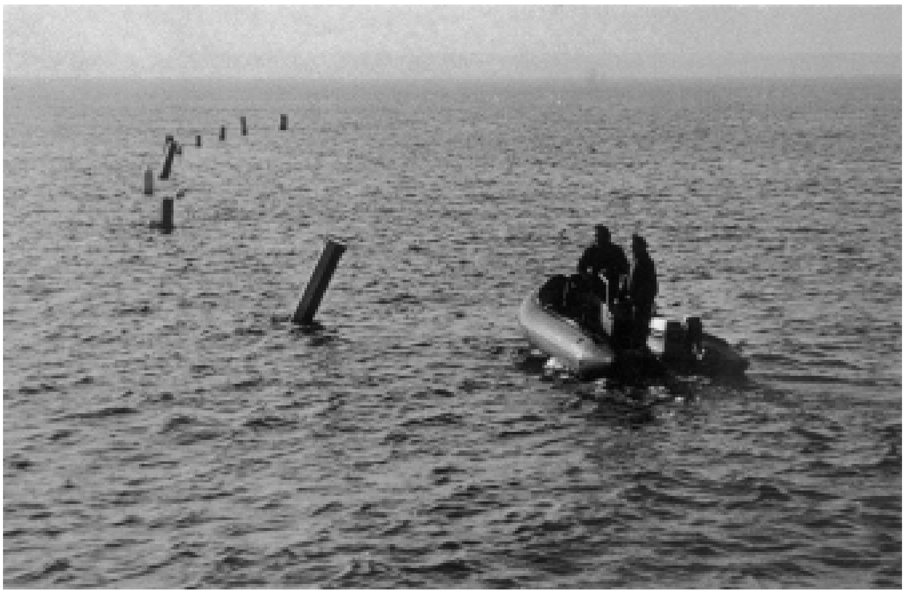


Fig. 14. View of the site of a subfloating line (IFREMER: A. Muller-Feuga).

The line should be kept perfectly taut. The experimental line is made of a mixed supporting line (steel/polypropylene) 200 m long, and includes "perched" (extending above the surface) plastic floats of 200 l at the head and a row of 150 l floats whose number will depend on production. The line is pulled tight between two concrete 5 ton dead weights by anchorage lines adapted to the area when tides may reach several metres.

This type of line was developed in France in the Atlantic, in Pertuis Breton. 240 lines of 100 m inspired by this experimental model were put in production with only one adaptation. If the principle of perched floats was maintained, in spite of their higher cost, their number decreased. The mussels are supported with "balloon" floats of 60 l placed between the "perched" floats (Fig. 15).

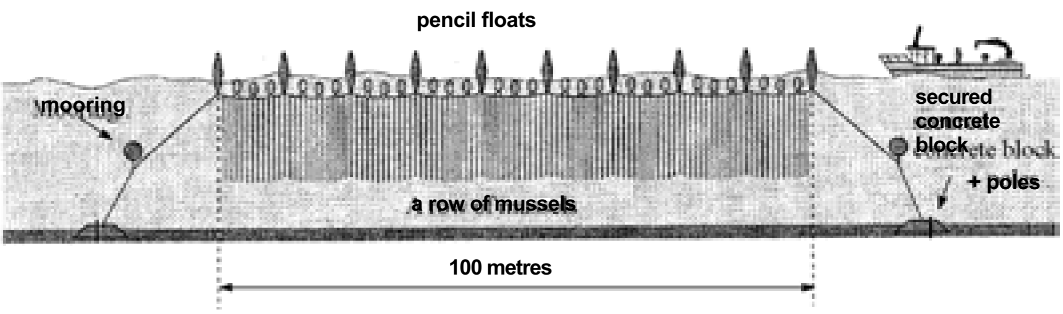


Fig. 15. Diagram of suspension lines in France in Pertuis Breton.

This type of suspension line as used in the Atlantic could be well adapted for use in exposed Mediterranean sites.

Mooring systems

A mooring line carries out two functions:

(i) It keeps the production structure in place to avoid it drifting with the current, wind or swell.

(ii) It keeps the supporting line taut since a slack line droops and can touch a neighbouring line, become tangled with it, or allow the suspension cultures to touch the bottom and scrape against the floor thus losing mussels (Fig. 16).

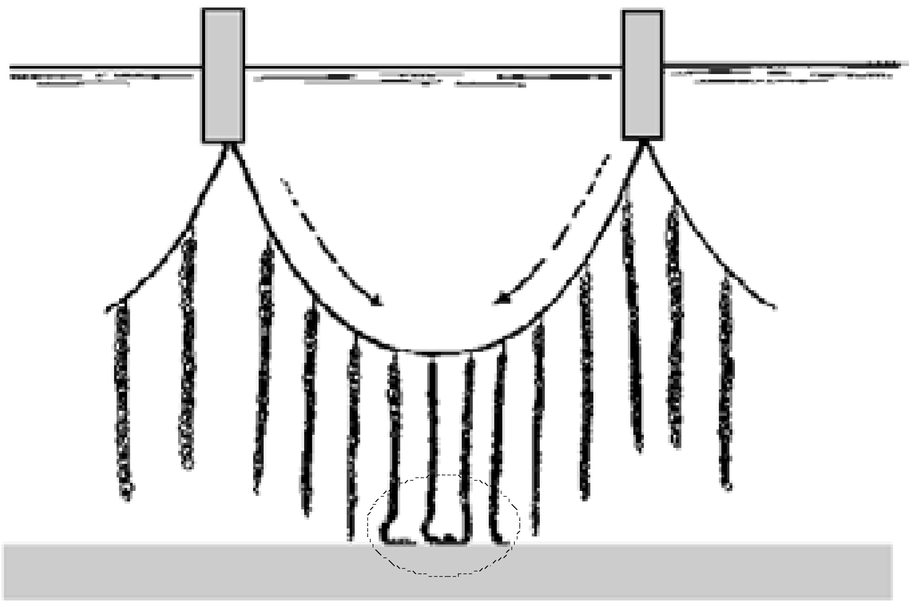


Fig. 16. Dangers of a slack support line.

Four types of moorings are currently in use (Fig. 17).

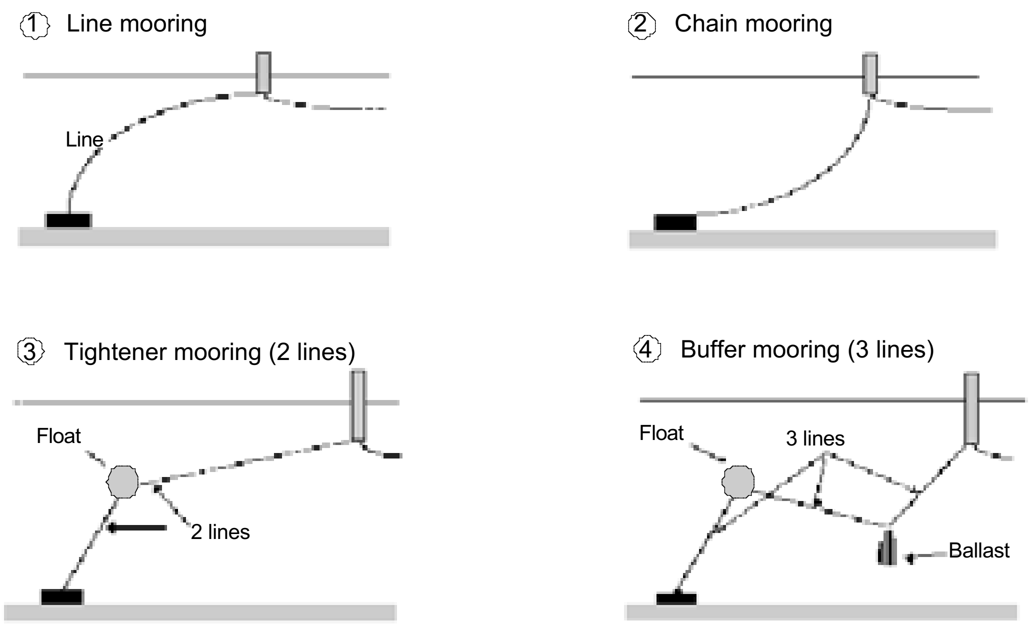


Fig. 17. Different types of mooring.

Line mooring

A rope joins the dead weight to the support line. This is the simplest and cheapest of mooring systems. However, it is difficult to keep the line taut and therefore not very efficient.

Chain mooring

Easy to design and frequently used by boats, the advantage of this system is that it efficiently absorbs the chafing of the swell. However, it is cumbersome and heavy and thus needs a bulky float at the head to bear the weight (between 1000 and 1500 l).

Buffer mooring

This type of mooring is made up of 3 strands at the joint, with a float on one side of the dead weight and ballast at the end of the line. This mooring is constantly deformed and follows the height variations of the water particularly well: it is therefore ideal for tidal seas. Whatever the height of the water, the line is always taut. However, the subsurface works (rings, shackles, joints, mooring eyes), necessary in this type of mooring, are bulky and hence onerous (Fig. 18).

The tightener mooring

This mooring is simple, and is halfway between a line mooring and buffer mooring. It is made up of two strands with a float, which keeps the anchorage line taut. This is used mostly on Mediterranean units.

Production structures

These structures are made up of four different parts: (i) shellfish plots; (ii) suspension culture; (iii) work boats and barges; and (iv) land bases.

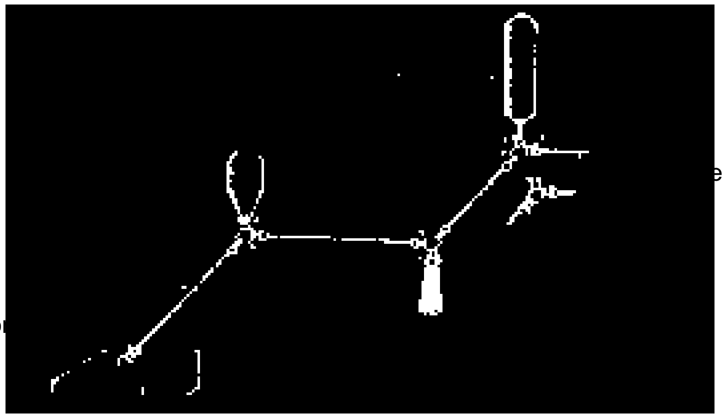


Fig. 18. Details of a 3-threaded buffer mooring used for subfloating lines.

Marine shellfish plots

The maritime surface area is leased by the State for shellfish culture, upon payment of a licence fee. These areas are therefore reserved for professionals of this activity and navigation and fishing are prohibited.

In Italy, there are 3 main areas (Fig. 19):

Fig. 19. Different mussel production sites in Italy.

(i) The Gulf of Trieste: a strip of 15 km to 600 m of the coast bordering on the navigation channel which links the ports of Monfalcone and Trieste.

(ii) The Gulf of Manfredonia: lease of 200 ha for 60 ha real occupation, distributed in 50 farms of four triple production units.

(iii) Taranto: industrial port where there the law prohibits shellfish production except authorized catches with a growth up to 3 cm and subsequent transfer offshore to a lease of 230 ha with sea floor at a depth of 10 m.

In France, in Languedoc-Roussillon, 4200 ha are occupied in the 3 mile zone, between – 20 and
– 30 m, divided into 4 plots (Gruissan: 261 ha with 35 suspension culture units; Vendres: 648 ha with 25 suspension culture units; Sète-Marseillan: 2754 ha with 240 suspension culture units; Les Aresquiers: 540 ha with 30 suspension culture units) (Fig. 20).

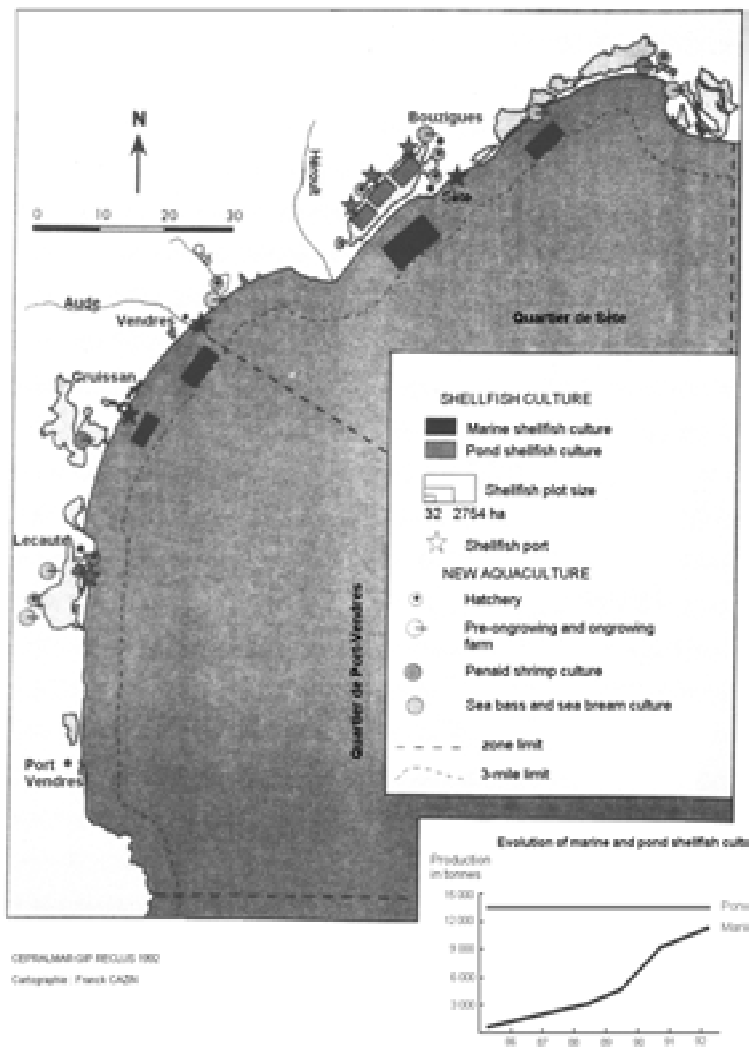


Fig. 20. Aquaculture production sites in Languedoc-Roussillon.

Between 1988 and 1992, 670 leases of three ha (300 m x 100 m) were granted. Each lease permitted the implantation of two production units. A grid pattern was set up in order to avoid overloading the area. Illuminated and radar-detectable buoys are placed around the perimeter of the unit and the walkways between the plots. These units are easily detected if they are marked out with buoys. This equipment is managed by the Authorized Unions of Producers of which all licence holders are members.

Farm structures

The production lines and their fittings have previously been described.

Seacraft and workboats

When offshore mariculture started, practically all the existing boats were made of wood. These boats were often former fishing boats which had been converted and fitted with cranes and jibs, or barges (Etang de Thau) of 6 to 10 m not equipped with hoisting devices and therefore requiring divers (Fig. 21).

Fig. 21. Fishing boats adapted for shellfish culture (cliché CEPRALMAR: C. Loste).

The profession soon had to make investment in specific craft; shellfish barges inspired by those used in the Atlantic with lengths of 12 m, 15 m and 20 m (Fig. 22).

These boats respond to the technical and economic demands of the activity: safety on board, mechanization of tasks, production with a sufficient number of lines. The lines can only be dropped from newly built workboat at least 12 m long. Figure 23 shows a 14-metre workboat with a rear cabin. A boat 5.60 metres long can serve a work area of 50 m^2.

All these barges have the following features in common:

(i) Large sizes – a minimum length of 12 m and breadth of 4 m, the maximum being 20 m x 6 m.

(ii) Shallow draft (0.4 to 0.7 m) guaranteeing stability when the lines are hoisted over the beam.

(iii) Adaptation of the vessels to work over the side of the boat.

(iv) Hydraulic or mechanical propulsion system allowing a speed of six to 12 knots and good manoeuvrability.

(v) Maintenance equipment: cranes equipped with winches to hoist lines, two jibs fitted with winches in order to position the line along the hull for preparation and harvest; a belt to recover the production lines and harvest; cogs fore and aft to enable the boat to move along the line (Fig. 24).

(vi) Large surface area thus facilitating work.

(vii) Large load capacity (up to 20 tonnes).

Fig. 22. 12 m Barge and workboat (CEPRALMAR: C. Loste).

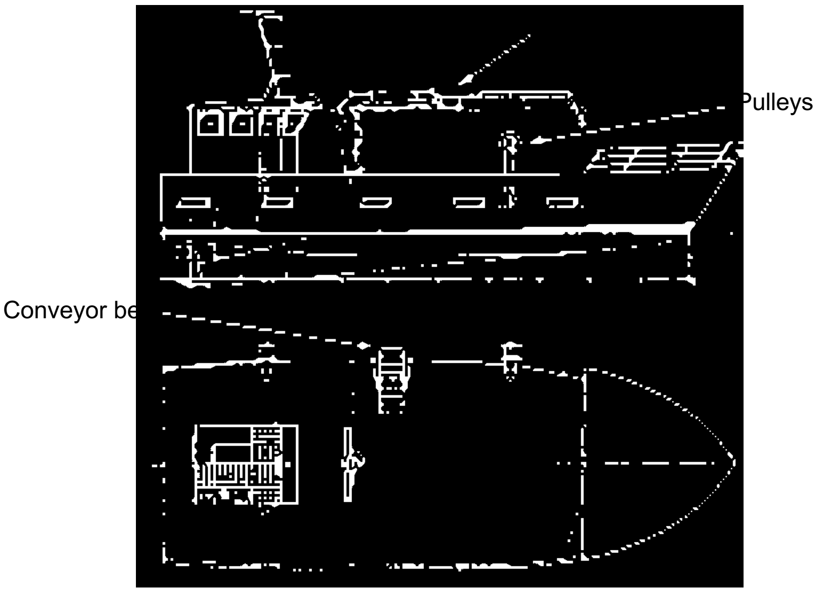


Fig. 23. Plan of the 14-m barge with equipment.

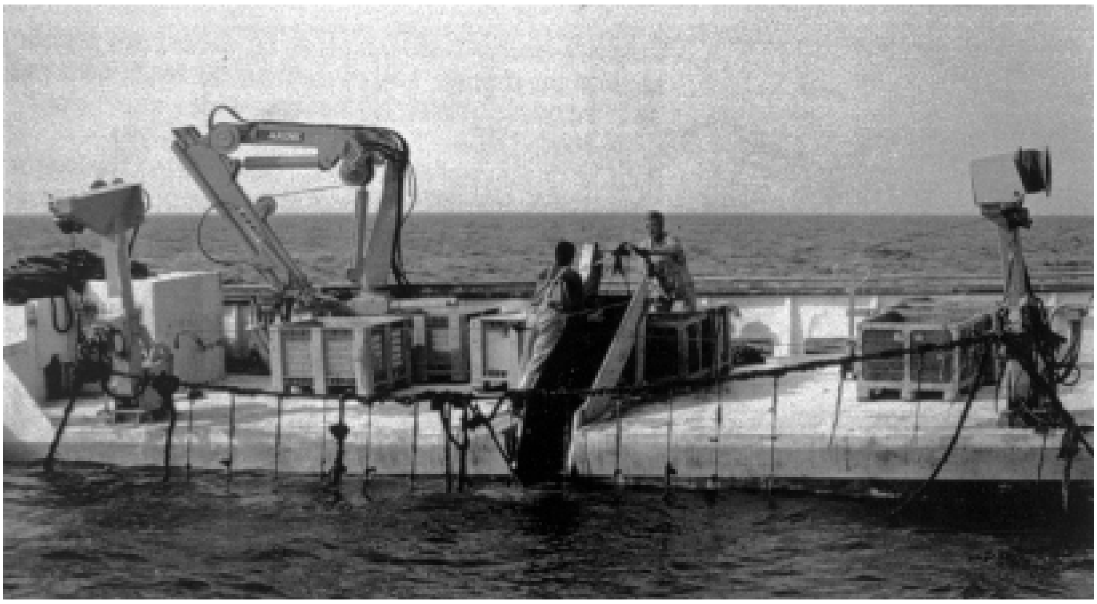


Fig. 24. Fully equipped barge (cliché CEPRALMAR: C. Loste).

Differences may be found between: (i) the shape of the vessel – single hull, catamaran; (ii) location of the cabin – fore or aft; (iii) construction material – steel, aluminium, polyester; and (iv) extra equipment – electronic, shellfish processing machines fitted on board (washing, classifying, weighing, bagging)

As a rough guide, in 1993: (i) a 20-m barge had an average cost of 1.2 million FF (excluding taxes) with a production capacity of 15 to 20 suspension lines with three workers; and (ii) a 12-m barge – 0.7 million FF for about ten suspension lines with two workers.

Land bases

In France, the premises were built next to the shellfish plots, housing the boats behind the sea wall. Preparation of production lines (fixing of the culture to the ropes, washing and maintenance, etc.) and post-harvest processing are carried out on the premises The facilities are:

(i) In Gruissan: eight individual premises approved for production and dispatch of products and collective pre-sale soaking.

(ii) In Vendres: eight individual premises for production tasks and an approved collective establishment for dispatch of products (Fig. 25).

(iii) In Frontignan: the land base was envisaged for the Sète-Marseillan Aresquiers production units. However, most firms also exploiting l'Etang de Thau situate their premises on the North bank (Fig. 26).

In Italy, for certain sites, part of the work is done at sea, as the base is a long way from the site. Production combines sea production, lagoon production and in certain regions, fishing, which makes offshore shellfish production difficult to develop. Processing stations are: one in Manfredonia (capacity: 20 tonnes/day), two in Taranto (capacity per unit of 7 to 8 tonnes/day) for processing before dispatch, and two in Triestre.

Fig. 25. Production premises at Vendres (CEPRALMAR: C. Loste).

Fig. 26. Aerial view of the Frontignan site (CEPRALMAR: C. Loste).

Production

The production cycle

Spat supply

Spat is most often caught naturally on lines (capture lines), placed on the suspension culture lines or otherwise from a generally abundant harvest on the supporting lines and line floats. Depending on the year, it is either produced on-site or bought from producers of other regions (Fig. 27).

Fig. 27. Surfacing of a spat capture line (Author unknown).

Spat is captured from March to June. Despite this benefit for production, it is also a drawback since it chokes the mussels on the suspension culture lines and slows down growth. It also adds considerable weight, which must be borne by the structures.

Small mussels (1 to 2 cm) are harvested in summer and are the main source of supply. The second source is based on mussels that have not yet reached commercial size at harvest, that is 3 to 4 cm. These half-sized mussels, of inferior quality, allow very short production cycles to be completed.

Attachment to the rope

The Spanish technique is the most widespread. The spat is spread around the strand in a tubular net with rhomboid mesh. Cleats are inserted through the rope at regular intervals in order to prevent mussels from sliding down the rope or becoming detached (Fig. 28).

Fig. 28. Preparation of a production line (CEPRALMAR: C. Loste).

The line length varies with the site depths. The initial load ranges from 1.5 kg/m for the small-sized mussels (1-2 cm) to 4 kg/m for the half-sized mussels (3-4 cm). This manual operation may be carried out using a device whose design is based on that of a sausage machine.

Work with the ropes

After 4 to 5 months of production, the ropes supporting the small mussels may be separated into strands. This procedure lightens the suspension-culture lines and favours maximum growth (Fig. 29).

The duration of the cycle

In France, the production cycle varies from 4 to 12 months depending on the size of the mussels when attached to the rope and when harvested (Fig. 30).

In Italy, the cycle lasts 18 months: 6 months for the half production of the spat caught from the wild and one year of production. Mussel production is carried out by small family units grouped together in co-operatives, which play an important role in this sector's activity.

Productivity of the farm structure

The average productivity of a unit made up of 500 lines of 5 m varies from 15 tonnes in a short production cycle to 25 tonnes in a long production cycle. The higher values may be obtained on a one-off basis on the above mentioned lines. Yields vary between 6 kg and 10 kg per linear metre of line.

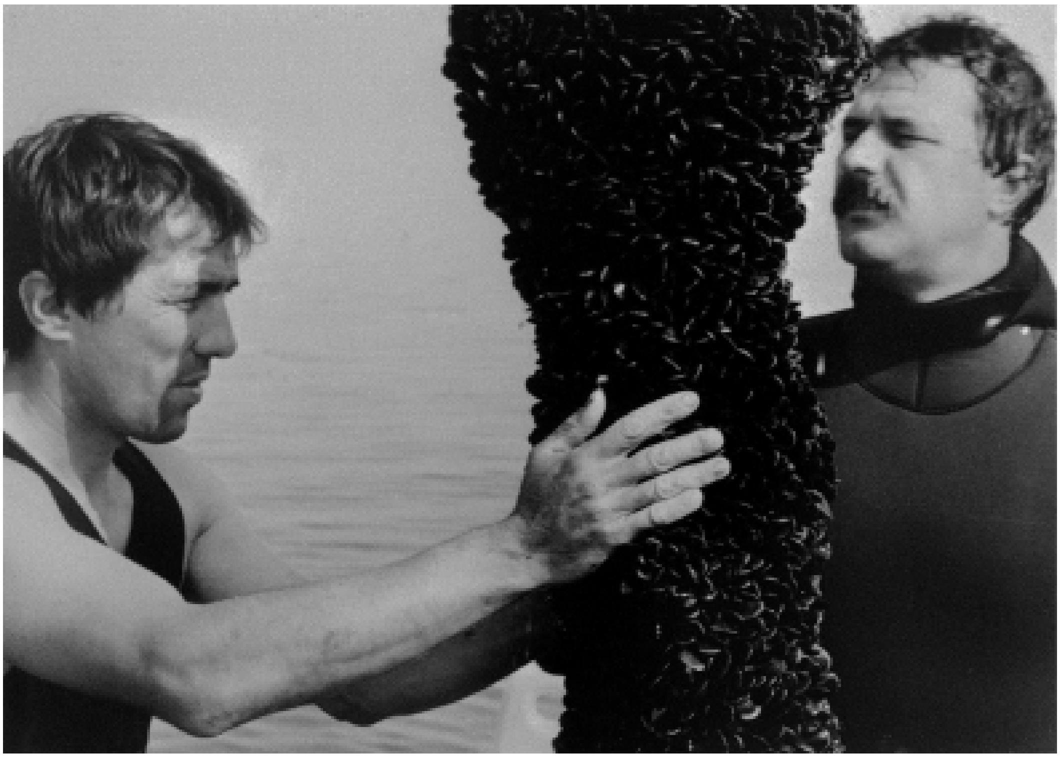


Fig. 29. Suspension culture lines pulled out of the water for division into two strands (IFREMER: X. Bompais).

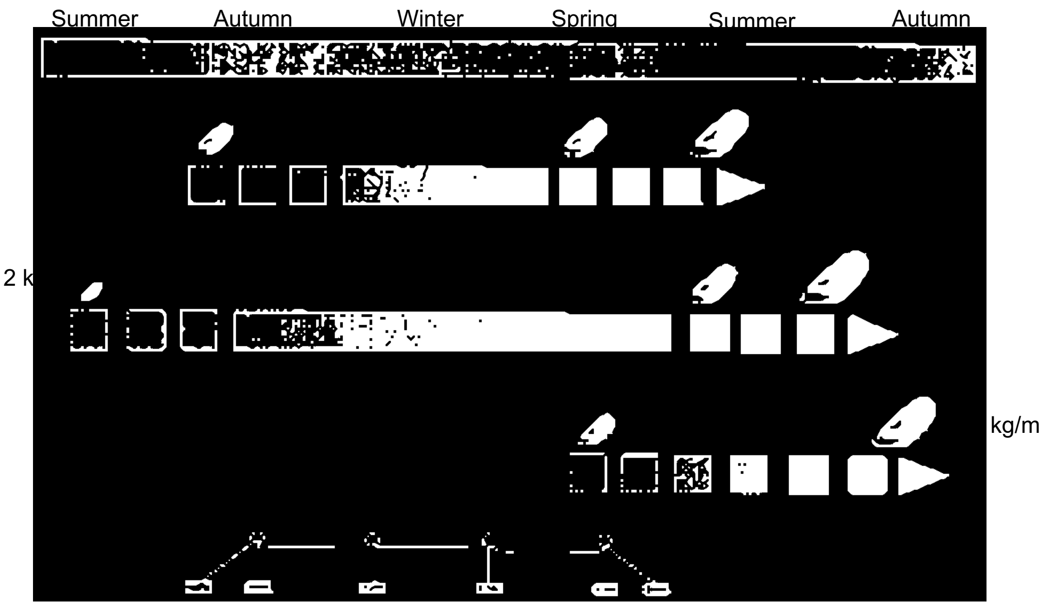


Fig. 30. Examples of production cycles.

Post-harvest mussel processing

Mussels produced offshore are not very resistant to exposure to open air. Direct marketing is almost impossible: the mussels must be soaked for protection when shipping. This soaking procedure may take from 24 to 48 h and normally takes place after washing, sorting and classifying: the mussels recover more easily from the stress induced by the machines and can be more easily detached from the lines (Fig. 31).

Fig. 31. Sorting and classifying before soaking (CEPRALMAR: C. Loste).

Soaking takes place mainly in a vat but can also be done in lagoons and ponds. The mussels are placed in pockets hanging from the tables. Most losses occur during the warm season when the water temperature rises above 25°C.

Mussel producers are building an increasing number of soaking vats. They are filled with chilled seawater and are fitted with hoisting equipment. This process favours the achievement of a better quality-controlled product complying with health standards.

The technical itinerary of offshore mussel culture (Fig. 32) follows the development of different operations inherent in offshore mussel culture.

Economic aspects

This section provides an approximation of production costs and margins of a farm of the Languedoc-Roussillon region (Loste and Cazin 1993; Loste, 1995). The data presented hereafter corresponds to averages estimated from the accounts of medium and large-sized farms whose main activity is mussel culture.

Only the production function is taken into account. The costs and margins affecting the shipping function are nearly always attributed to several products and it would be unwise to try to estimate the distribution of such parameters.

Investment in material and depreciation

The example presented in Fig. 33 is taken from a firm with a production potential of 300 tonnes per year.

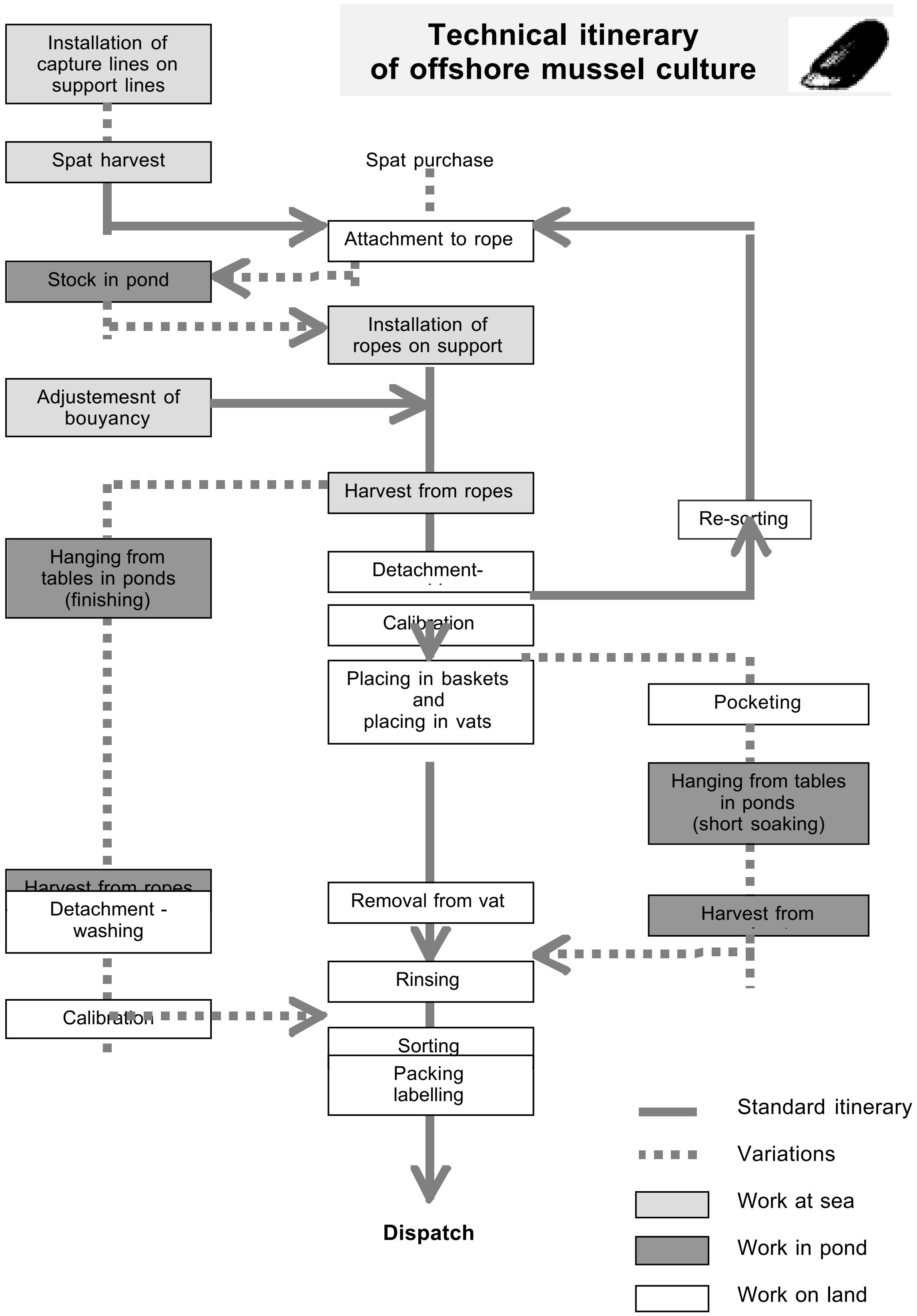


Fig. 32. Technical itinerary of offshore mussel culture.

12 rigs (300 t/year)	Total cost (FF)	Depreciation (FF/year)	Period (year)
	1,000,000	20,000	5

One barge (L = 20 m)		Total cost (FF)	Depreciation (FF/year)	Period (year)
	Hull:	800,000	80,000	10
	Engine:	400,000	80,000	5

Land-based premises		Total cost (FF)	Depreciation (FF/year)	Period (year)
	Building:	600,000	40,000	15
	Material:	200,000	40,000	5

TOTAL	Investments (FF)	Depreciation (FF/year)
	3,000,000	440,000

Fig. 33. Investment of a large business.

Investment amounts to 3 million French francs distributed among production units, work boat and the land base. Depreciation amounts to 440,000 FF for the same period of time.

Operating costs

These were calculated through average figures obtained from the accounts of the farms. They included personnel expenses (70%) including social charges, farm supplies (ropes), energy, and maintenance. Spat account for a very small part of the costs (less than 3%) (Fig. 34).

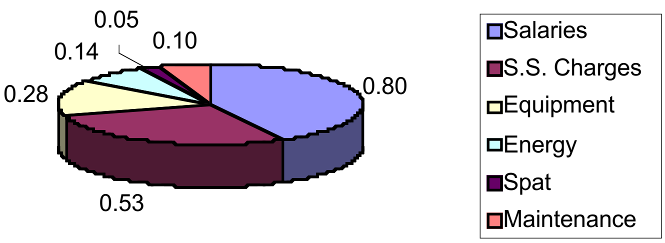


Fig. 34. Total operating costs (in FF/kg).

The total represents 1.90 FF per kg of mussels produced, or 51% of total production cost.

Overhead costs

These comprise depreciation (>80%), licences and taxes paid for occupying Public Maritime Domain, elimination of waste, running of professional organizations [Regional Section (SRC), National Shellfish Committee (CNC)] (Fig. 35). These costs amounted to 1.80 FF per kg of mussels produced, 49% of the total production cost.

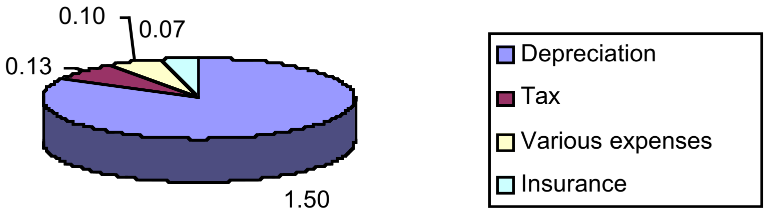


Fig. 35. Total specific costs (in FF/kg).

Production cost

Excluding financial expenses, this is therefore amounts to 3.70 FF per kg of mussel products. The assessment of financial expenses is difficult to make in general terms due to the variety of means of finance (importance of subsidized loans, partly self-financing). Subsidies (45% for workboats, 55% for buildings) within the Languedoc-Roussillon Region and from Europe have considerably lightened the burden of financial expenses and improved cash flow of firms embarking on offshore production. These subsidies average 35% of the investment costs.

Gross and direct margins

Average prices (mussels in bulk – 1995 price) were 4 FF/kg for average-sized mussels (30% of volume) and 5 FF/kg for large sizes (70% of the volume). These prices are presently 5 and 6 FF. An average reserve price of 4.7 FF/kg has been fixed in order to calculate margins. On this basis, the *gross margin* (market price-operating costs of production) amounts to 2.8 FF/kg and the *direct margin* (market price – production cost) is 1 FF/kg, or 20% of the turnover.

Conclusion

Offshore mollusc production developed in France and in Italy in the Mediterranean Basin makes up a large part of mussel culture in general. Trials are also being carried out in other countries which have not yet developed this activity at a commercial level.

Culture technologies, suspension culture, are described and compared with those set up in the Atlantic. The economics of these production units are also addressed thus offering an insight into the profitability of the activity.

In France, the production cost of offshore mussel suspension culture is high, around 3.7 FF/kg, 70% of which is devoted to personnel expenses, costs and depreciation of the production structures.

The estimated profit margin of 1 FF/kg is potentially very vulnerable, representing barely 20% of the market price. Production incidents (storms, *Dinophysis*) and hazards of the shellfish market are likely to have a strong influence. However, diversification of production as in terms of sites, species and functions allows the shellfish firms of Languedoc-Roussillon to cushion the consequences of these risks and show certain dynamism.

Action may be taken to increase this margin at several levels:

(i) As regards operating costs: if firms are engaged in various activities they can lower labour costs related to offshore production as they can carry out other tasks: thus the quiet period for mussel culture (November to March) coincides with a peak in activity in oyster culture (including the Christmas and New Year period). Diversification towards offshore production of the Pacific oyster is also in progress and may help spread costs.

(ii) Regarding overhead costs, levels of depreciation may vary in a firm due to several factors:

- Economy of scale between the number of culture lines exploited and the means employed (barge and land base), with, however, a maximum limit.
- Regular maintenance of the production lines in order to minimize the effects of fatigue and storms, thus avoiding unforeseen expenses.
- Contrarily, a bad choice of techniques, or a strong storm is likely to shorten the duration of the culture lines, thus increasing costs. The competence of the head of the production unit and the appropriateness of husbandry or technical skills in a harsh environment are the necessary conditions for the firm to be profitable.

(iii) Regarding the market price, in general, margin fluctuations are more closely related to the rise and fall of market prices than to production costs. This price varies with the development of other production sites, the opening up of European borders and the harmonization of health regulations, all of which facilitate trade. The concentration of the demand from large and medium-sized retailers and the lack of trade organization of the producers and shippers, are an important source of price fluctuation, generally downwards.

Overall, if this sector is to expand, it must make an effort to increase margins. Its products must also be promoted and its quality publicised. Producers should associate in organizations to influence it first hand sale price, and create new markets, for example in value added products. Other ideas are possible.

In Italy, production costs of suspension culture are evaluated at 750 liras/kg (Antona *et al.,* 1993), slightly higher than those estimated for lagoon units, and selling at 900 liras/kg. These prices are much lower than in France (1 FF ≈280 liras) but the direct margin makes up slightly less than 20% of the market price, very similar to that of the French producers. This margin allows enough profit for the offshore production units.

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