# STOCK ENHANCEMENT AND SEA RANCHING

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## Chapter 29
## Scallop Sea Bed Culture in Europe

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## Abstract

In recent years, scallop production throughout the world has been expanding at a fast rate, due to developments in aquaculture. Hanging as well as sea bed cultures produced good results in some countries. This latter method has been successful for *Patinopecten yessoensis* and *Pecten novaezelandiae* in Japan and New Zealand respectively.

In Europe, only *Pecten maximus* as a local species seems appropriate for development by a sea ranching production: the market demand is strong, the fisheries are closed due to over exploitation and hanging cultures are not economically feasible. Experiments in sea bed cultures started in the 1980s in France and extended to Ireland, Scotland and Norway. The technique involves the production of juveniles by spat collection and in hatcheries, and on-growing on the sea bed, on the natural scallop ground or in equivalent sites. Animals are then released at the minimum size at which they are capable of surviving.

Only France has a full set of results suitable for analysis to determine the main factors affecting sea ranching. These results are not sufficient for the study of stock enhancement, which requires a longer term approach. This is because the species are very fragile and slow growing.

In the Bay of Brest (France), hatchery production and intermediate hanging cultures are controlled and more than 3 million spat are released into the fishing grounds. Recapture rates have reached 25%, but depend on the seeding season and the vitality of the animals. In 1997, the population was composed of three animals from aquaculture for every one from the natural population.

Production costs, recapture rates and market prices are encouraging. The management of the fishing grounds and the regulation of the resource access are key factors. However, results have proved the major role of the ecosystem.


## Introduction

Pectinids are a highly regarded sea product. Three countries have contributed to their production development: United States, Japan and France. After 1970, processing and freezing facilities boosted this resource, providing a stable product of high value. This positive trend reinforced both the fishing pressure and the initial aquaculture research. Aquaculture production entered the world market in 1975 (Japan), was equal to the fisheries landings in 1991 and now represents two-thirds of the world production.

*Pecten maximus*, the main European species, is considered to be one of the most desirable species of the family, with a large market based on live and large size animals. The species has been very heavily fished and the natural resources are generally depleted. In the case of Japan, research in aquaculture has been initiated in both stock enhancement and ranching on one hand, and hanging culture in the other. This last technique has not clearly proved to have an economical future.

## The natural resource and the fisheries

*Pecten maximus* is found in temperate waters, from Morocco to Norway. *Pecten jacobeus* is a Mediterranean species of much less importance. The populations are concentrated on soft sediments, at places where coastal currents carry the larvae during the pelagic phase. These grounds can be sustainable resources, relying on meteorological conditions and local hydrodynamic features.

The main stocks of *P. maximus* are located around the UK (including the French coast) and those of *P. jacobeus* are found in the Adriatic Sea. Scallops are very sensitive to sediment quality and stability and prefer sheltered bays or waters shallower than 30 to 40 m. *Pecten jacobeus* has not been studied in detail, so the following is based on results obtained from *P. maximus* populations.

Due to coastal current cells, the stock is composed of independent populations, whose inter-relationship is poorly known. Genetic differences between populations are minor (Beaumont 1991), although phenotypic characteristics are maintained when juveniles are exchanged between two stocks: scallops from the Bay of Brest maintain a different reproductive cycle when placed in the Bay of Saint-Brieuc (Devauchelle & Mingant 1991).

*Pecten maximus* has a long life compared to the other pectinids. Gruyffyd (1974) estimated its life span to be more than 20 years, with a low mortality rate during the first half. Growth is fast initially and commercial size (10 cm length) can be reached in 2 to 3 years in the southern grounds (Antoine *et al.* 1976). Growth is slower but occurs over a longer period in the northern grounds.

*Pecten maximus* populations are composed of several year-classes up to a maximum accumulated biomass of about 5 animals per $m^2$. This represents the coverage of the ground by the depressions in the sediment where each adult lives, recessed under a fine pellicle on fine matter above the top valve.

Scallops can swim actively in two opposite directions. With each stroke a scallop can reach 1 metre above the substrate and several metres in length depending on the currents. They can be repeated several times, but decrease rapidly in distance. Hence, a scallop can escape from a predator, or react to a stress, but is considered a sedentary species.

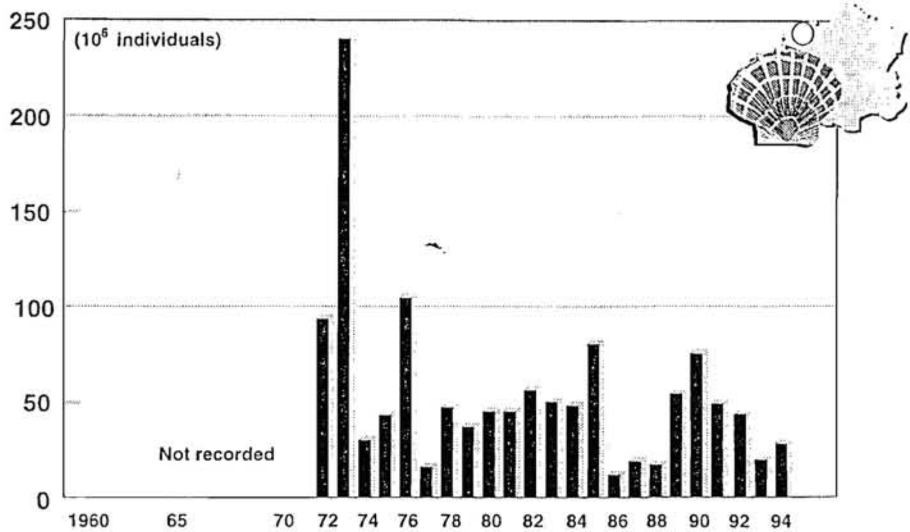


**Fig. 29.1** Annual recruitment in Bay of St-Brieuc (France).

Commercial vessels in Europe use dredges as fishing gear. The scallops are removed from their depressions and harvested in a bag. This technique is so efficient that economical catches can be made even on depleted fishing grounds (with a density of only a few animals per $100\,m^2$), in coastal fisheries where small vessels of low cost can operate. This represents 1/100 of the virgin density.

Active fisheries will maintain high fishing effort and rapidly reduce the accumulated biomass. The resource will be substituted by the following annual recruitment, which has been highly variable over the last 25 years (Fig. 29.1). As there is no relationship between stock and recruitment (Boucher & Dao 1990), these fluctuations will be a constraint for monitoring long-term regular landings.

In France, the market for live animals is dominant and there are few possibilities for storing the daily production. Short-term management efforts have been made in order to stabilize landings and markets through various regulations (fishing grounds, number and size of boats, closed season, time fishing, catch quota, fishing gears, commercial size and quality).

The present status of the management of the fisheries could be greatly improved. With a sedentary species that is easy to fish, it is possible to maximize the yield/recruitment ratio and reduce the incidence of recruitment fluctuation. Success depends on industry management and fisheries control. For fishing grounds deeper than 30 m, the only users are fishermen. In shallower waters, fishing by divers could compete with the traditional fishing methods.

Intensive exploitation of the recruitment does not allow the species to occupy its ecological niche fully. A good recruitment will reach 0.5 to 1 per $m^2$, compared to the 5 animals per $m^2$ for the accumulated biomass. This provides an opportunity

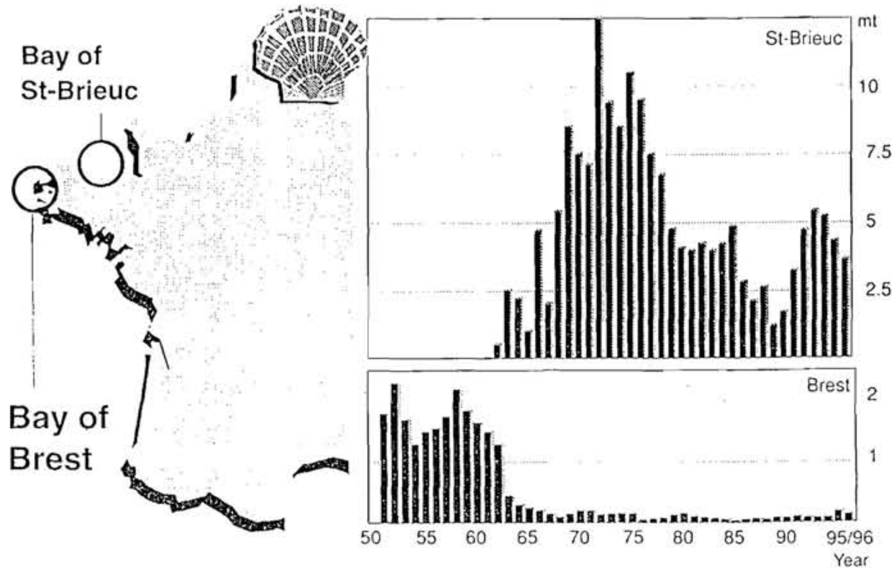


Fig. 29.2 Evolution of landings in two fishing areas: Bay of St-Brieuc and Bay of Brest (France).

theoretically to enhance the resource, particularly on scallop grounds where natural recruitment is at a much lower level.

On a different time scale, larger fluctuations are observed. In France the exceptionally cold winter of 1962/63 generated opposite effects on the Brittany stocks. The population has not recovered in the Bay of Brest, but has developed since that time in the Bay of Saint-Brieuc (Fig. 29.2). Over the last 15 years, scallop biomass has fluctuated in spite of fishery regulations.

## Stock enhancement and ranching of European scallop

### *The Japanese model*

Natural spat collection in Japan for *Patinopecten yessoensis* started to succeed in 1965 and began to be a large-scale operation after 1970 in the three main sheltered bays in the north of the archipelago. Juveniles have been used for both hanging and bottom culture. In each bay, production rapidly increased and exceeded the carrying capacity, generating mass mortalities. Management of the bays was undertaken to find a good equilibrium. This management included changes in the technical processes, as seen in Mutsu Bay (Fig. 29.3).

Progress was made by rigorous seeding strategies and rotation of fishing areas. Mass mortalities occurred when adult densities on the bottom were higher than 10 individuals per m$^2$. On one site (Sarufutsu) natural settlement was so abundant that additional seeding was not useful. However, fluctuations in the settlement occurred

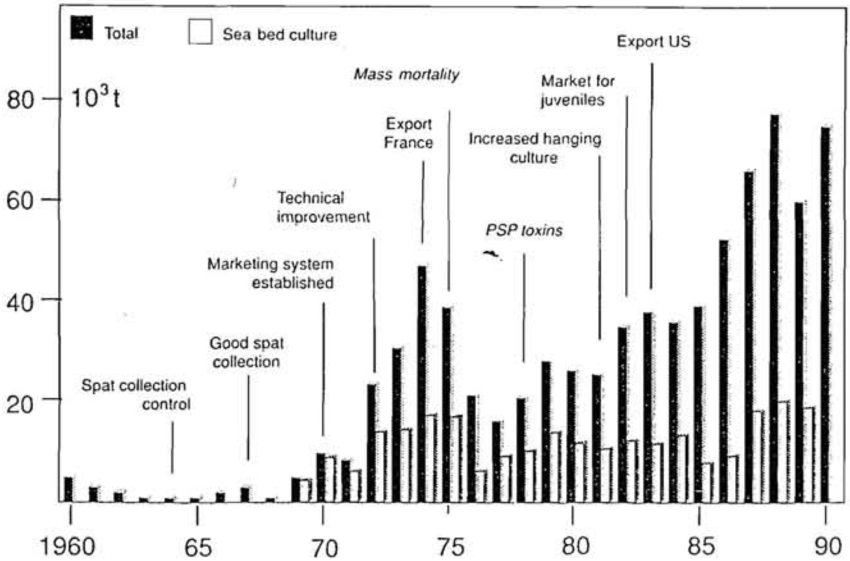


**Fig. 29.3** Evolution of scallop production in Mutsu Bay (Japan).

and disturbed the adapted market management. Seeding and control of the density of scallops on the fishing grounds are now combined.

Japanese production expanded from several thousand tonnes to more than 400 000 tonnes, with part of the production competing on the world market. The model has been successfully applied in New Zealand with *P. novaezelandiae*.

## *Juvenile production in Europe*

Juvenile production started in Europe in the 1970s, following the Japanese model. Data from spat collection were compared at the first International Pectinid Workshop held in 1976. Several countries attempted to develop the technique (Fig. 29.4), but only two sites are still commercially maintained: Mulroy Bay (Ireland) and the Isle of Skye (Scotland). Mulroy Bay suffered from tributyltin (TBT) pollution between 1982 and 1986 (Minchin *et al.* 1987).

Hatchery experiments in France have been successful and were developed in the beginning of the 1980s as a substitute for spat collection. Artificial rearing was based on the natural cycle (Cochard & Gérard, 1987, Cochard & Devauchelle 1993) and then extended to a longer period of the year by conditioning the spawners, a technique which is still improving (Devauchelle & Mingant 1991). The commercial hatchery where the results were applied (Fig. 29.5) produced 10 million spat between 1988 and 1995 and has increased in more recent years to 25 million spat per year. French results are the reference for the other European hatcheries (UK, Norway, Ireland).

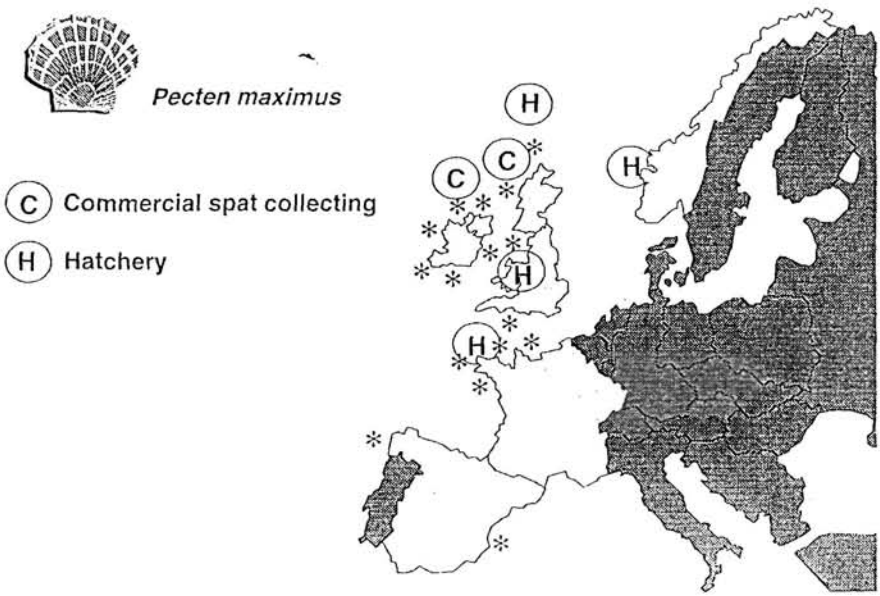


Fig. 29.4 Spat collection sites in Europe.

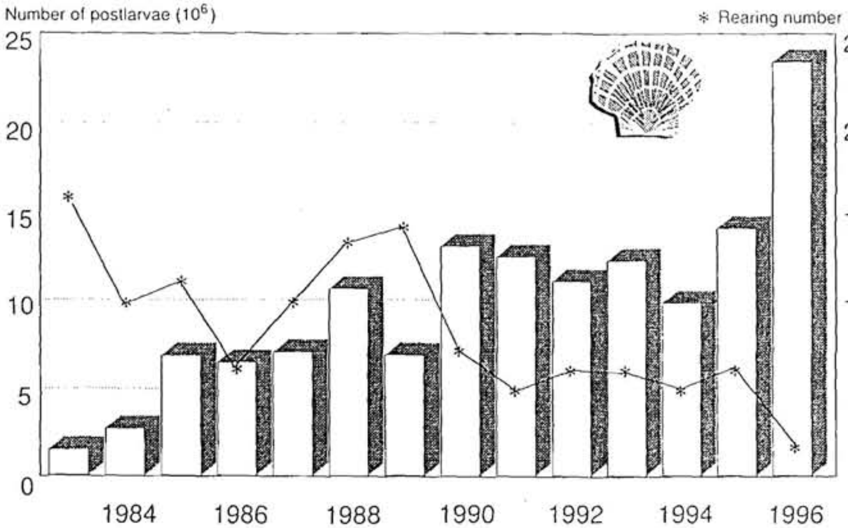


Fig. 29.5 Evolution of the postlarvae production in the hatchery of Tinduff (France).

Postlarvae and small spat are expensive (hatchery) or irregular (spat collection, hatchery). Techniques for long distance transportation of young spat have not yet been developed.

Natural spat collected in bags are mixed with predators and competitors. A selection must be made before over wintering the animal in pearlnets. In a hatchery the

1.5 mm postlarvae develop rapidly and the facilities, for microalgae culture for example, become rapidly limited and expensive.

Intermediate culture, including protection of small size animals, is undertaken in the open sea. Mortality occurs during the first period after the transfer. For postlarvae from a hatchery, the mortality can reach 65% in 6 or 8 weeks in baskets placed in frames laid on the sea bottom. At this stage the density of the animals can reach 20000 to 30000 per $m^2$. At 15 mm size, survivors are transferred to baskets with a larger mesh at a density of 2000 per $m^2$. The survival rate to 30 mm during the second intermediate culture is normally 95% (Fleury *et al.* 1995).

Intermediate culture has shown that scallops are very sensitive to environmental factors like minimum temperature at transfer, aerial exposure, transportation and handling, which make the species very different from other farmed bivalves. This has to be integrated in the production strategies of the hatchery.

*Sea bed culture in Europe*

Results of sea bed culture are incomplete for a number of sites where experiments have taken place (Fig. 29.6). Scallops are naturally tagged for most of the operations because animals show a stress ring at the seeding size, as well as evidence of fouling on both valves, indicating an intermediate culture. Most of the trials are recent or have been disturbed by uncontrolled factors. French experience represents the background and can be analysed through three periods (Table 29.1).

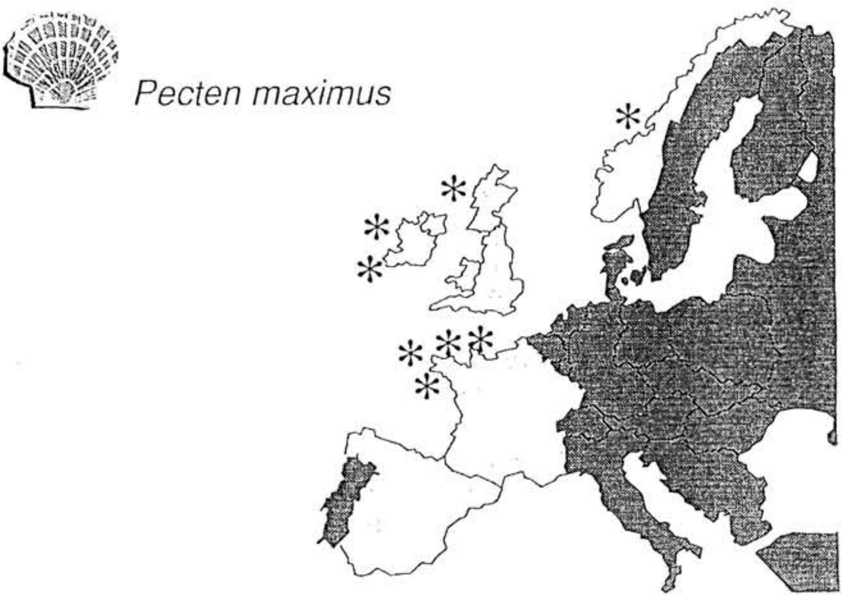


Fig. 29.6 Seeding sites in Europe.

**Table 29.1** Scallop recapture rate (%) from sea bed culture in the Bay of Brest (France).

| | Fishing technique | | |
|---|---|---|---|
| | Diving | Rental boat | Commercial fishing fleet |
| Initial experiments: 1976–83 | | | |
| • Natural spat from St-Brieuc | 45 | | |
| • Natural spat from Scotland | 46 | | |
| • Hatchery spat from Brest | 46 | | |
| Experimental seedings: 1983–90 | | | |
| • 1983 | | 22 | |
| • 1984 | | 26 | |
| • 1985 | | 11 | |
| • 1986 | | 13 | |
| • 1987 | | 37 | |
| • 1988 | | 33 | |
| Development seedings: 1989–•• | | | |
| • 1989 (Caro) | | | 19 (18–36)* |
| • 1989–90 (Roscanvel) | | | 22 (5–31)* |
| • 1990 (L'Auberlach) | | | 17 (8–22)* |
| • 1991 (L'Auberlach) | | | 16 (5–28)* |

* Observed range of survival rates on different annual seedings.

Initial experiments were conducted between 1976 and 1983, giving the basic results of a good survival rate of 45%, and confirming the sedentary behaviour and the lack of difference when using spats of various origins (Dao 1985). During the second period (Dao 1995) seedings (200 000 to 500 000 spats per seeding) and recaptures (harvested by a rented dredging boat) revealed a number of additional factors, such as size at seeding, habitat and quality of the water.

The last seeding group was harvested by the commercial fishing fleet from the Bay of Brest between 1991 and 1996. Again, the change of scale brought new factors affecting the recapture rate. The multiplication of seedings makes it impossible to conduct a detailed sampling programme during the growth of the animals, and results are issued from isolated diving observations and complete commercial landings (Dao *et al.* 1996). The recapture rate (economical index) can be calculated, but it does not always represent an index of the survival rate (biological index).

A general analysis of seeding and recapture is presented in Table 29.2. The economic feasibility has been studied for a hatchery producing 10 million postlarvae per year with a 30% survival in intermediate culture and a 25% recapture rate (Paquotte & Fleury 1994). At this scale, landings exceed total operating costs, but investments have a low return only in the long term. The analysis has to be reviewed to include more recent data (for example improved production in the hatchery, more rigorous husbandry, ban on winter seeding, recapture rates).

In addition, stock enhancement and ranching have to be considered in the context of the natural ecosystem including predators like starfish and crabs (Lake *et al.* 1987,

**Table 29.2** Seeding and recapture status, related to French experiments.

| Seeding status | | Recapture status |
|---|---|---|
| Survival rates | | Economical feasability |
| first year | 50% | recapture > 25% of seeded animals |
| at commercial size | 30% | price > 25 F/kg (live animals) |
| Mortality origin | | Loss origin |
| overdensity during intermediate culture | | dredging effects |
| handling at seeding | | site quality (long-term effect) |
| spat vitality at seeding | | non-efficient regulations |
| winter seeding | | |
| site quality | | |
| predators, competitors, parasites | | |

Minchin 1991), competitors such as the slipper-limpet and brittle-stars and also the quality of the environment. Other sources of mortality which have been observed include browning of the shell, indicative of a disturbance in metabolism, and red tide, due to *Gymnodinium* sp., and they can also affect the management programme.

Size at seeding, quality of juveniles and predation control have been the objectives of the recent Concerted Action, a European programme. It has been recognized that the majority of mortality occurs during the first year and especially the first days after seeding. Sizes, seasons, injured animals attracting predators, and vitality for recessing or escaping depending on energetic reserves are factors which should be examined in detail. Observations in the open sea are difficult research operations for the few small groups operating in Europe.

### *The Bay of Brest example*

Scallop resources in the Bay of Brest are in a depleted situation (Fig. 29.7). Resources are located in a limited area compared to early years. After the initial phase, the stocking and exploitation programme maintains the fishing grounds and reserved areas to keep a balance between operating costs and fishermen's interests (Fig. 29.8).

Juveniles from intermediate culture are seeded on natural fishing grounds using the regulation of a closed summer season during which they can undergo initial growth and get stronger shells, and on reserved areas the rest of the year. Densities at seeding are one to three individuals per $m^2$ on the fishing grounds, and four per $m^2$ on reserved areas, in accordance with the fishermen's regulations (fishing techniques, volumes to market). The size of the reserved areas cannot support the entire commercial fleet, but limits the risk of exceeding the daily market capacity.

The programme maintains two exploitation systems as a transitional phase. Financial contributions from fishermen are still lower than the operating costs, but are expected to rise rapidly and become equivalent.

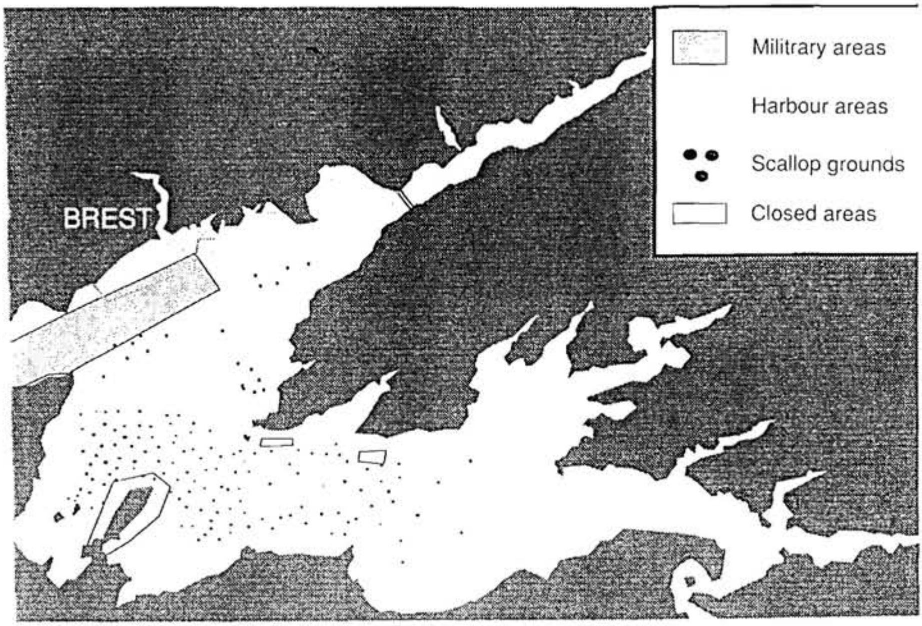


Fig. 29.7 The different areas in the Bay of Brest (France).

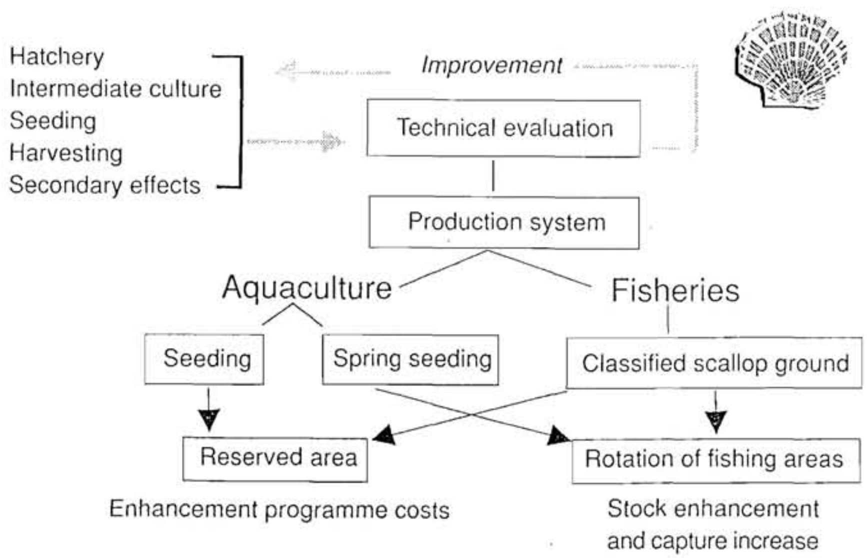


Fig. 29.8 The scallop enhancement programme in the Bay of Brest (France).

## Application of scallop ranching

Previous experiments and theoretical calculations have demonstrated the potential of scallop ranching. To be developed, new constraints must be solved that can be summarized as follows.

### *Sites and users*

Scallop ranching concerns open ocean areas in sites of natural resources or the equivalent. The species is fragile compared to cultivated molluscs such as oysters and mussels, and there is little background on the equilibrium between the species and the ecosystem, especially in the case of artificial additive recruitment.

It is obvious that ranching can be a more effective production system than the fisheries production of wild scallops, but the biomass per unit area will remain low (5 to 10 animals per $m^2$) even if it represents several times the best natural recruitments. Under European conditions, however, the effect of the additional biomass is unknown.

Two representative groups of users can be involved:

(1) Oyster farmers in the open sea: in France in the Bay of Quiberon, trials have been conducted on private beds used for the flat oyster (*Ostrea edulis*). Unless the yield per animal is higher for scallops (growth rate × price), the density of oysters (100 per $m^2$) does not allow the scallop to be competitive for monoculture. In mixed culture, both species maintain their productivity and the industry has expressed its interest. Other sites of this type exist in various places in Europe.
(2) Coastal fishermen: the example of the fisher community in the Bay of Brest is positive but not completed. There are a number of equivalent large sites in Europe where ranching could be applied to coastal fisheries.

### *Ownership rights*

Development of scallop ranching will occur only if investors can make a profit from the ranching productivity. In the case of the scallops, because they are a sedentary and benthic species, the exclusive rights can be limited to the use of the bottom. Other activities can be maintained (trap or net fisheries, sailing and various recreational uses).

In application to fishery systems, access must be uniform for all allowed fishermen and must follow national or local regulations (Table 29.3). More restrictive items can be added. In France, a licence system has been developed which defines the areas concerned, the recapture techniques, the fishing variables under control and the control of access and penalties. These regulations appear to be inadequate for the existing fisheries at the present level of catch per unit effort (overcapacity, illegal

**Table 29.3** Fishery and aquaculture control for scallops in France.

| | Fishery<br>Fishing licence | | Aquaculture<br>Grant | |
|---|---|---|---|---|
| Area | Fishing grounds<br>EU regulations<br>Non-classified | <br><br>Classified<br>National regulations<br>Local regulations | Private rights<br>(on sea bed)<br>Intensive use<br>Annual rental | <br><br>Extensive use |
| Recapture techniques | Dredging<br>Trawling<br>Diving | | Dredging<br>Diving | |
| Control variables | Time fishing | Quota per boat | Industry strategy | |
| Rights control | Administration control | | Private property | |

fishing, ban on individual quota). Scallop ranching will involve wide public territories on which exclusive rights will have to be defined.

In application to aquaculture, areas are granted for a long term (Table 29.3). The system gives good results for oyster culture but the annual rental is calculated for intensive use, which will not be the case for scallops with low productivity.

As scallops are a new species, ownership rights have not been established on a long-term basis. Classification of the waters (EU waters, 12 mile territorial waters, 3 mile limit) will also have to be taken in account for ranched scallops, giving local, regional or national variations. This is a priority to be solved (Curtil 1996).

*Production of juveniles*

Stock enhancement and ranching should minimize natural fluctuations of the recruitment. At the level of European development, only small-scale management can be undertaken. For example, 100 tonnes of production will require 5 million postlarvae from the hatchery. Most of the trials are still below this level, or based on an irregular production of juveniles.

Few studies have been undertaken to distribute the available juveniles to various sites, accounting for price and survival at transportation, biological risks, and slow progress in the ranching field. R & D projects are very dependent on regular spat production and low cost juveniles.

*Integration in coastal fisheries management*

Although scallop ranching can improve the fishery, there is no opportunity to stop the fishing and allow juveniles to grow for several years before a rotation of fishing areas is set up.

**Table 29.4** Present status of scallop management in France.

| | Administration | R & D | Private units |
|---|---|---|---|
| Long-term preservation of resources | ++ | + | |
| Control of the existing rights and fishing regulations | ++ | | |
| Penalties | ++ | | |
| Improvement in management regulations | + | ++ | |
| Environment quality, pollution, toxins | ++ | ++ | |
| Improvement in biology, ecology and husbandry | | +++ | + |
| Evaluation of the enhanced stock | | ++ | + |
| Reproduction and larval distribution | | ++ | + |
| Pathology | | ++ | + |
| Juvenile production | | + | +++ |
| Management of sea bed areas, mixed species | | + | ++ |
| Management and exploitation system | | + | + |

- First, there is no confidence about the real income available in the middle term: secure survival rate, illegal fishing, scallop fishery management will need to be argued. Also the efforts of the fishing community to catch other species will lead to antagonistic management (bottom trawling and other competitive activities). The scaling of the project can be differently accepted by decision-makers (time and production objectives). Scallop ranching has to be accepted at this level (fishermen project).
- Second, cost/benefit analysis has shown a positive return, but only in the long term (10 to 15 years). The initiation of the project will not depend on the fishermen themselves, even in the case of total resources failure, but on public funding to support the basic investments.
- Third, in the development of scallop ranching, operations will have to be financed by public subsidies, including technical assistance. The present status of the Bay of Brest shows the tasks which will have to be included in long-term management (Table 29.4), and progressively transferred when the development of the commercial operations is complete.

## Conclusions

Scallop ranching is a new concept for European waters. One of the major interests is an improved exploitation of the open sea. Scallops benefit from an excellent image as a sea food product. Their benthic nature and sedentary behaviour provide opportunities for a greater exploitation of coastal areas, leaving the sea surface for diversified activities. Examples from other countries with similar species show an impressive production development and these experiments and first applications demonstrate similar possibilities.

Scallop ranching is based on an integration of aquaculture techniques, fisheries management and the equilibrium between the species and the ecosystem to orient the natural productivity to the benefit of the species. Scallops are at a low level in the food chain, and like oysters and bivalves in general can develop a large biomass. However, access and ownership rights have not been examined in the context of large public territories or leases with extensive use. This is a priority for further improvement.

Scallop ranching is inducing stock enhancement. Biological effects can be expected on the resource in terms of increased natural recruitment or distribution. However, no change has yet been recorded.

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