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Management of oyster and mussel culture

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Advantages and constraints of oyster and mussel culture (M. Héral)

The world aquaculture production (fresh and marine waters) achieved 11.1 million tonnes in 1986 (FAO, 1989). The molluscs represented 21% of the total production. Marine aquaculture with 5.45 million tonnes reached 49% of the total production. The marine cultivated mollusc production was 2.25 million tonnes due mainly to oysters (36%), mussels (34%), clams (16%), and scallops (6%).

As the aquaculture production is clearly identified in the statistics only since 1984, the evolution of the production of oysters and mussels for the last 15 years has been analyzed with the FAO data for the total catch (fisheries and culture). By comparison of the two statistics for the same year (1986), the fisheries represented only 17% for oysters and 16% for mussels. Fig. 1 shows an increase of 37% of the oyster production and a tremendous boosting of 176% for the mussels in the last 15 years. Asian countries (Korea and Japan) increased their production from 40 to 58% of the total oyster production and Europe from 10 to 14% mainly due to French production. North American production had decreased from 38 to 25% in relation with the problems on the East coast particularly in Chesapeake Bay (Héral et al., 1990). For mussels, the expansion of the production was related to the

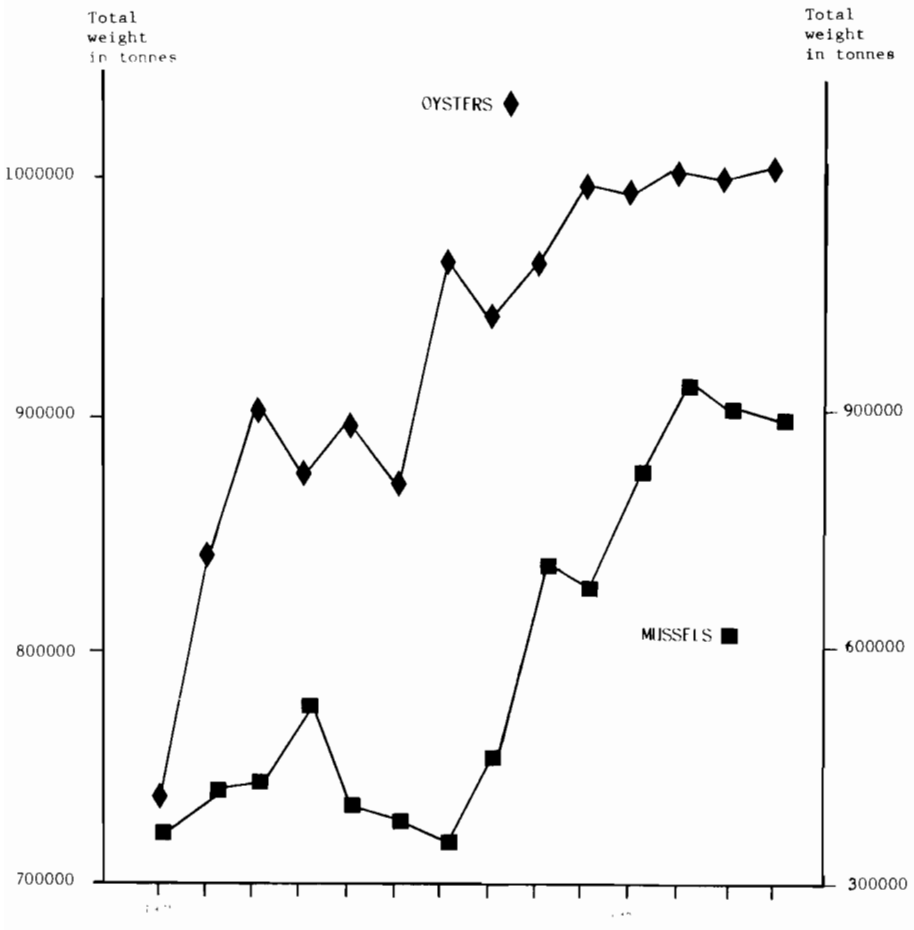

Fig. 1. Evolution of the oyster and mussel production expressed in total weight (tonnes) for the total landings (fisheries and aquaculture) (from FAO statistics).

large increase in Asian countries (5 to 24% of the total mussel production) mainly caused by Chinese production. The European production (Spain, Holland, and France) was stable. In 1974, it reached 80% of the world production and in 1987 it represented 68%.

These large production increases of molluscs have been permitted by several strong master trumps:

1) The juveniles for the culture are issued from the natural reproduction with settlement of the spat on collectors. The production in hatcheries is not significant compared to the world production. The hatchery production does not exist for mussels nor for oysters in Japan and Korea. It can represent 10% of the oyster production for the US with a development on the west coast and 2% in France with new techniques like "eyed larvae" and remote setting.
2) The filter feeding molluscs are consuming natural phytoplankton food which is

gratuitous. Furthermore they are secondary productors based at a low level of the trophic chain which is very efficient in energetic terms.

3) Molluscs are sedentary organisms allowing the development of simple breeding techniques and avoiding difficulties for space allocation by renting the parks with different systems.

The mollusc culture can on the contrary be limited by severe constraints. They have contributed in recent past to the decline or stability of the production in several bays.

A short list of the main constraints could be proposed:

ENVIRONMENTAL CONSTRAINTS

Climatic conditions

- storm and ice during winter causing mortalities;
- spring and summer dryness preventing mussel reproduction;
- cold summer preventing Japanese oyster settlement.

Quality of the water in relation to human activities

- bacteriological contamination by fecal coliforms and salmonella;
- pollutants contamination with direct consequences for the consumers particularly for metals (copper, zinc, cadmium, mercury, ...) but also with direct action on the life cycle of the molluscs [TBT salt (Héral et al., 1989 for a review)];
- anoxic conditions with hydrogen sulfite production in relation with eutrophication of lagoons and estuaries causing high mortalities in summer.

Toxic phytoplankton blooms

- Diarrhetic Shellfish Poisoning species (DSP) with e.g. *Dynophysis acuminata*;
- Paralytic Shellfish Poisoning species (PSP) with e.g. *Alexandrium minutum* or *Nitzschia purgens*;

Carrying capacity of the ecosystem

An overload of the carrying capacity appears to the aquaculturist by:

- a decrease of the growth rate;
- an increase of the chronic mortalities;
- a weakness of molluscs against disease.

DISEASE CONSTRAINTS

Recent history, particularly for oyster culture, has demonstrated with examples taken only in European countries, a succession of three epizooties for the flat oyster *Ostrea edulis*. The two last, *Marteilia refringens* and *Bonamia ostreae* had practically destroyed the production of this species. For the cupped oyster, two viruses had caused the disappearance of the

Portuguese oyster. The Japanese species *Crassostrea gigas* is not safe for the risk of parasites with mortalities which recently occurred on the West coast of America and in Japan.

TECHNOLOGICAL CONSTRAINTS

When some technological steps are not mastered, they can strongly limit production. Some examples are given:

- the control of the settlement function, of the abundance of the larvae, and of the techniques available to collect the spat;
- the control of the hatchery and nursery processes is a necessity for the countries without natural recruitment and for the world production when some new strains which are more resistant to disease or growing faster will be developed genetically;
- the growing techniques can be limiting factors for development. For example long-lines for open-sea mussel cultivation can be built with new designs weathering waves and strong currents, this will allow to colonize new areas for culture;
- the mechanization of the different culture stages is necessary to be more competitive by decreasing the production cost and the manual activities which are very often very tiresome.

SOCIAL AND ECONOMIC CONSTRAINTS

There are difficulties to maintain and extend mollusc culture as the coastal zone is very desired by several competitive activities as tourism, fishery, industry... The pressure to maintain wild environment can also become a strong limit.

The different uses of the space is a daily fight for oystermen (as for mussel and clam growers) particularly for the granting of concessions or licences for new sites. It is not only a problem of space but very often a fight for good water quality. Upper water activities on the river must be analyzed to provide against deterioration of the quality of a bay with a particular attention to industrial discharges and to intensive agricultural activities.

Obviously economic factors control the development of the mollusc culture. A general tendency is that the primary producers (the mollusc growers) are not enough organized to sell their products on the market. Generally, due to the familial structure of the enterprises, growers go to the price battle in a disorganized way. In front of them they find the agents of the purchase pool more and more concentrated as the retail trade is declining. The power of the buyers is strong enough to achieve a stability or more often a decrease of the prices. So, in France for example, the first scale for marketsize oyster is actually largely under the cost price of the culture (Bailly, pers. commun.).

Critical remarks on the so-called carrying capacity and site selection for the cropping of mussels (A.C. Drinkwaard)

There are plenty of sources of scientific information on the subject of mussels and mussel

culture. The biology of the mussels and their habitat, inclusive the life style of the mussels in relation to their environmental circumstances, are described all over the world. It whirls in your head when you think about that all, especially when you have to explain something in everyday language for the still increasing number of people, which becomes interested in this fascinating bluish-black creature, its farming and consumption. Exploiting a natural resource by more or less intensive or extensive musselfarming, nature and the natural processes have to be used in a way of cooperation. The natural environment is our friend. However, the production has to be boosted in a way - in terms of quantity and quality - that nature alone can not reach.

Do we know our friend well, in looking for the best ecological niches for our mussels and our benefit? I do not say yes and I do not say no!

For my part, I have to explain why my answer is not yes and not no in the question, do we know our friend nature enough for doing our work well?

Of course there is a mussel production in the world of more than 600000-900000t, semi-culture and wild fishery inclusive, but a lot of failures in the production can also be reported. Analyzing the misfortunes should be very instructive. I think that for this typical work, not yet highlighted earlier, EC grants have to become available, more likely than for not well prepared investments! Otherwise, what is from a scientific point of view the difference between a failure and a success, if we can not explain why it is what it is?

Should it be possible to help our oyster and musselfarming managers by studying the carrying capacity of the environment, where we are already in operation or where we have the intention to start?

Recent FAO publications speak still about reaching or surpassing the carrying capacity concerning growing areas in France and Spain. When we hear that in Maine (USA) a research and development project has been subsidized with a grant of US$ 500000 to study the carrying capacity for off-bottom mussel farming, than it becomes time that we get an idea what the concept carrying capacity means!

I consulted Webster's Dictionary and I was a little bit astonished to read that the carrying capacity was described as follows: "the population that an area will support without undergoing deterioration"! So, that is understandable for elephants and goats, but not for animals like mussels with their sedentary and social life style! And, when does an area undergo deterioration? There are two possibilities! This definition is not correct, or speaking about carrying capacities of estuaries and bays is speaking about an ecological concept, which is not well understood! In my opinion it is a slogan, which we have to leave entirely in hands of nature conservationists and colleagues, advocating conservation of natural resources. We can do nothing with this slogan, since under this heading no accurate information can be supplied to solve the simple question: How far can we go? How far can we go with the production of mussels and oysters in cooperation with the natural processes, governing the natural eco- and foodweb systems? For studies in that direction, in every case we have to look to three dynamic aspects of ecosystems which are important for checking the possibilities for musselfarming. They are: hydrodynamic capacity, trophic capacity, and

species structure. Under these headings, already in use, we also can come to exchange of information in mariculture circles ánd with nature conservation circles. From now on we speak about "carrying capacity" only anecdotically and in the sphere of nature protection.

That we have to come on speaking terms with nature conservation became quite clear during the last years. More notion to and fró is necessary!

During the Symposium on the Ecology and Management Aspects of Extensive Mariculture, organized by the International Council for the Exploration of the Sea, in Nantes, June 1989, several important papers have been presented, which can form a basis for a better understanding of the interaction of oyster and mussel farming with the environment, or say marine ecosystems. More than ever it will be important, that the study of marine ecosystems is not only the task of nature protectionists. It will be the task of cooperating nature and mariculture managers together. They have to consider the different possible sources of disagreement in a scientific way!

The discussions are now already coming in full swing to resolve the perceived realistic and non-realistic problems, as far as we did not yet arrive in artificial conflict situations. Moderate exploitation, by altering the age structure of a population - like mussels in an extensive bottom culture - can enhance efficiency and rate of production. By proper manipulation, whole communities can be changed into a younger and more successive stage. However, this is not going at the expense of diversity and stability, one of the structural aspects of marine ecosystems. A very good example is the Dutch high production of cockles year by year in two wetland areas. Negative climatological interferences play only a small part in the production level. The protected birds are enjoying the young cockle stocks too, like the plenty large enough stock of young mussels in our bottom culture sites.

In the ongoing research, energy-flow-units are used for the different processes as ingestion, excretion, growth and combustion. These units are more appropriate than either number or biomass units. However, the end of the story is, that the collected figures have to be converted again to simple comprehensibilities for politicians and mariculture managers ánd all environmentalists among them. That means to speak in tonnes. Generally we see that mussel populations are relatively efficient, when a high proportion of its members is young. In that case more food is transferred into net production, growth and reproduction, and less food is transferred into loss of energy. Harvesting means keeping your stocks young and parasitism low. So we have to explain, that quantitative estimates of rates of energy-transfer along food chains, has to be considered as the essence of mariculture capacity studies. However, this has to be done in relation to the aspect of the species structure, in which our colleagues of nature conservation are interested.

In principle there is no discrepancy between bivalve mariculture and nature conservation. Both are occupied with a careful preservation and protection of the natural processes. That means that they both must have the tools for a planned management of the natural resource in exploitation, to prevent destruction or neglect.

My opinion is, that oyster and musselfarmers are doing a lot for saving our natural resources. In exploiting the natural processes they are stimulating the primary production along our

coasts. Working with mussels means working with animals low in the food chain. In this way a lot of organic substance is not settled down, but very quickly mineralized or stored for cropping. This is of substantial importance in areas where our natural resources are waylaid by eutrophication.

However, fundamentalism in the protection of nature can become a new constraint in mussel farming, if the diehards in the nature lobby promote the attitude, that nature conservation also means that exploitation can not be accepted. You can be sure that once they will explain, that for reasons of conservancy, your area for mussel farming has to be designated to conserve pure nature, to recuperate nature and to keep it further in a safe or sound state..., what that may be! In every case, this means aging of the ecosystem structures and more parasitism. We are not only losing potential areas along our European coasts, but we were already thrown back in the Dutch, German, and Danish Wadden Sea. To the question: "what is safe and sound?", you can get different answers, from different worlds, dependent on the (production) targets!

The most simple nature lobby answer is out,... out with your dense stocks of mussels and the seed collection on the intertidal flats with your enlarged ships. Denmark decided for the Wadden Sea on a nature reserve. The establishment of mussel culture plots in the Wadden Sea has been banned. The West German states along the Wadden Sea decided on national parks. They try to curb the mussel production by freezing the number and tonnage of mussel cutters. The Netherlands gave this region a special status by means of an environmental planning procedure, with closed-off areas for the mussel seed fishery. The Danish approach seems to offer most prospects for a strict nature conservation policy.

The Dutch mussel culture needs some flexibility in locating the bottom plots by changing hydro-dynamic factors. The curbing can be done by freezing the not used potential areas for mussel culture ánd advancing the price of the given rights. This is to show you the political weight of the nature lobby, pushing through their simple trend of thought, that mankind does not belong to the nature!

This is what we can expect, but not only in the Wadden Sea! An inventory has to be made of designated nature reserves, closed for shellfish production or a charged curbing of activities without compensation! This is what we can expect from diehardism on our path, completely conservative fixed, without any concession or deliberation. On the contrary, cooperative management of involved parties to stop the pollution along our coasts, as well in nature reserves as in shellfish growing waters, needs joining efforts and independent consultative research.

International exchange of information how problems of this kind are tackled in different countries can be of help. Incorrect remarks about effects of the traditionally raised mussel culture have to come in balance with the reality, based on impartial studies and empirical know how about our aquatic living resources.

That all has to be tested and shared with the up to date knowledge of ecophysiology, food conversion, behavior interrelationships and culture technology, to decide if it is really necessary to stop further progress or to be curbed in using solidly the still available potentials

for mussel culture. Social webs can become more competitive than food webs in the European mussel culture branch. For this reason mussel culture will not belong to the wave of the future in sea food, as some people do believe for aquaculture as a whole!

Speaking about management of mussel culture is thinking about a wide scope of more or less substantial affairs. During long periods the professional mussel farmers could take it for granted, how nature was working for them. They could pay all their attention to the way of practical operation. In this time it is not more so easy to be a producer of mussels. In most European countries production, processing, marketing, and legislation are settled along evolutionary lines, at times marked by the results of hard figuring in the overall exploitation. In every case in Europe, it is a brave fight to keep the production on the levels already attained. A brave fight, in which the European cooperation in research and unity in sanitary control, is a necessity for maintaining our positions in future.

Nature conservationists in different European countries are not fighting side by side with mariculturists to force back the pollution influences. That is very depressing! What is more, fundamentalists in nature protection try to trip up mussel culture in the designated wetland areas, setting this activity on the same line as other human activities. The words "biocoenosis" and "ecosystem" are borne in the circles of oyster and mussel culture (Moebius, 1883). Ecosystems are now explained as something that can be disturbed by boosting the production of mussels. With mussel culture as an enormous pillar in aquaculture, we are truly not in a unique position. However, this is also very prickling and stimulating to fresh exertions to make the best of it and not only in Europe!

In the Dutch Eastern Scheldt we try also to make the best of it after the changing of the hydrographical pattern by the building of the storm-surge-barrier in the mouth of this sea-arm. This gave us a clear example of separate changes in this "ecosystème conchylicole", both in hydrodynamic and trophic capacity. It was concluded that the distribution of the cultivation plots of long standing did not longer match the modified pattern and the reduced velocities of the tidal current. This had to be solved first, assisted by model studies, predicting the new situation. After that operation the results of the trophic capacity studies were put forward, to get ideas concerning acceptable densities of mussels in the different sections of this formerly well known culture area for oysters and mussels.

This was really a sophisticated form of site selection!

Mussel culture in Canada (R.E. Lavoie)

The culture of the blue mussel, *Mytilus edulis* in Canada has a short history. From a few experimental endeavours in the latter part of the 1970's, mussel culture has developed to a point where it is now practised in the provinces of Newfoundland, Nova Scotia, New Brunswick, Prince Edward Island and Quebec, on the Atlantic coast, and of British Columbia on the Pacific coast.

Most operations utilize a long-line system, first to collect natural seed, and later to grow

mussels in vertical suspension in the water column. Typically, horizontal lines of 75 to 120m in length are supported near the surface by floatation of styrofoam or other plastic-based material and kept in place by anchor blocks placed at each end. A midwater counterweight sinker is sometimes used to absorb slack in the main line and prevent neighbouring lines from becoming entangled under the influence of waves and currents. A 100-m line of this sort can produce over 2t of market mussels in 18 months. Lines are often arranged in fields with spaces of 7 to 15m between lines to allow for work boat circulation. Fields are separated to allow for circulation of fishing and pleasure boats.

The Canadian production of cultivated mussel is still very modest by European standards. The estimated 1988 production was in the order of 2200 to 2500t. The most important producing areas are the eastern (Kings County) and central northern (northern Queens county) parts of the province of Prince Edward Island where 1400t of mussels were produced in 1988. Nova Scotia is the second largest producer.

Problems experienced by growers vary with their location. On the Pacific coast, a persistent summer mortality greatly limits production and dampens the interest of potential new entrants. On the Atlantic coast, winter ice adds difficulties and costs to winter production everywhere. Starfish and wild duck predation are problems which vary in severity between culture sites. The 1987 toxic outbreak of the diatom *Nitzschia pungens* in eastern Prince Edward Island created a need for constant monitoring and stringent quality control mechanisms. Existing markets show signs of saturation.

There are obstacles to further expansion of mussel culture. In the wake of the toxicity problem, the industry will have to reassure consumers that cultivated mussels are a safe product, in order for the market to resume its growth and for prices to improve. Some lobster fishermen fear that mussel culture operations will interfere with their traditional fishing patterns and that lobster habitat will be damaged. That fear translates into opposition to the granting of licenses for new growing sites. There appears to be a rising resistance to new sites near urban agglomerations for financial and aesthetic reasons. Shore property owners dislike the visual appearance of mussel culture lines in natural landscapes, resent debris from aquaculture operations on beaches, and fear a decline in the value of their property from the proximity of mussel culture sites. Their concerns translate into political opposition to the granting of licenses for new sites.

The outlook for further development remains positive. The industry is learning from its early mistakes at the community level and from its experience in the market place. It shows a healthy resilience against adversity and a determination to succeed which should make it, over time, a most valuable and stable part of several local economies.

The oyster culture in the Bay of Arcachon (France) (D. Maurer)

The area of the Bay of Arcachon is 155km^2, corresponding to an equilateral triangle with 20km sides. At the southern end, a narrow channel leads to the ocean. Important water exchanges occur through this channel. Freshwater inputs are due to three rivers or channels.

The total yearly freshwater input in the bay corresponds to the tidal exchange of three average spring tides.

The Bay of Arcachon is a major center of reproduction and rearing of the Pacific oyster *Crassostrea gigas*; 1000ha, in the intertidal zone, are granted by the State, which correspond to 5000 oyster parks. The oyster farms amount to a total of 600 and 2000 people are employed in this culture. The entire annual production is about 15000t with a reared stock of about 40000t. Eighty percent of the stock is cultivated by using the flat method, and the remaining 20%, by using the raised method. Furthermore, the Bay of Arcachon is an important spat productive center for most of the French oyster growing areas. Now, the situation of the bay seems to be quite good, but a historical study (Deltreil, in prep.) shows that it has not always been the case in the past, and that serious problems have occurred.

Several decreases in the oyster production have been observed since 1920, with important socioeconomic impacts.

Some were caused by mortalities. Firstly, the mortality of the flat oyster *Ostrea edulis* in 1920, with no identification of the pathogen agent. Secondly, a disease affected the cupped oyster *Crassostrea angulata*, which had settled in the bay, replacing the indigenous species. This was the gill disease, which caused a 30% mortality of the population. Lastly, a viral disease in 1970 destroyed all the stock. After this, the Pacific oyster *Crassostrea gigas* was introduced for the first time in the bay.

Other sources of decrease in production were insufficient spatfalls, probably due to natural fluctuations. But for 5 years, between 1977 and 1981, there was no spatfall at all. A contamination of the environment by the tributyl tin (TBT) compounds has been suspected and this point will be developed later.

Another cause of the decrease in production is a low growth of the oysters. It occurred during the fifties and the sixties, and was accompanied by a bad quality of the molluscs. This phenomenon of reduced growth can be associated with several observations:

- The study of the relation between stocks and production shows that the production seems to be limited when the reared stock increases beyond 50000t; it was the case at the beginning of the low growth period, during the fifties; so, at this moment, an effect of oyster overload may be suspected, with trophic limitation;
- After 1966, the gill disease affected greatly the growth of the survival population;
- During all these years, a paper factory was pouring its waste water in the bay via the Leyre River. Furthermore, the production of the factory increased tenfold between 1950 and 1960. We can suppose that the impact of the sewage could have been serious. Since 1970, the sewage has been collected with urban waste water and poured into the ocean at 20km south of the bay.

The problem of the tributyl tin in the bay is an interesting example of the impact of a pollutant on a shellfish culture. The first manifestations of the phenomenon occurred in 1973. There were oyster shell anomalies. The abnormal shells thickened and their cut showed numerous chambers containing a jelly. After 1977, the anomalies increased, and,

furthermore, a failure in spatfall was observed. Because of the development of pleasure craft in the bay and the use of new antifouling paints based on tributyl tin compounds, the action of these paints was suspected. The experiments carried out by His and Robert in the station of Arcachon, have shown the high toxicity of TBT acetate on the *Crassostrea gigas* veligers and on microalgae. These researchers determined a scale of action of these compounds and suggested that TBT was involved in the spatfall failure, probably by a disorder in the alimentation of the veligers, directly or indirectly by action on the nanoplankton they use as food. Other experiments, carried out by IFREMER stations, showed that TBT is a main cause of the shell abnormalities phenomena, with a disorder of the calcification mechanisms (Alzieu et Héral, 1986).

All these researches have led, in 1982, to a decree of the Ministry of the Environment, regulating the use of all the organotin paints, for the whole coastal area. The effect of the regulation in the Bay of Arcachon was obvious. A spectacular decrease of the shell anomalies, together with a decrease of the total tin concentration both in the water and the oyster flesh, was observed. Furthermore, 7 months after this decree, spatfall was once again witnessed in the bay. The Bay of Arcachon is an important example of the effects of a regulation on the environment, with a rapid recovery of a growing oyster area.

So, at the moment, the oyster culture situation in the bay is quite good. Reared stock assessments, carried out since 1985, show that the culture biomass seems to be stable. Experimental batches of oysters, followed in three sites of the bay, show that the growth is satisfactory, and that in the best growing area, the performances obtained are very good for the species. The individual live weight increases in 1 year from 25g to nearly 100g; at this time, the oysters are 2.5 year old. However, important differences exist between the sites and are studied in relation with environmental parameters. The hypothesis is that more extreme and unstable conditions in the internal part of the bay, together with rapid maturation of the molluscs, lead to a high energetic requirement for the oysters. At the moment when the food is scarce, especially in summer, these requirements could be met at the detriment of the somatic growth.

The conclusion to this account of the oyster culture in the Bay of Arcachon is that the general situation for oyster growing and reproduction is quite good; this leads to think that, in a short or middle term, problems of oyster overload and trophic capacity limits should not occur. The difficulties met in the past incite to pay more attention to environmental conditions, firstly, with the important development of other activities around the bay like tourism, motorcraft and intensive agriculture, and secondly, with the development, during summer, of filamentous green algae, especially since 1982.

Geomorphology and possibilities of improvement in mussel culture (A. Figueras and A.J. Figueras)

Improvements in mussel culture could follow three directions:

- in the whole system (geomorphology);

- in the devices that are used;
- in the culture techniques employed.

SYSTEM

As it has been stated (Figueras, 1976) mussel culture systems can be classified as:

1) on the bottom (The Netherlands);
2) on poles (bouchots) (France, Atlantic coast);
3) on hanging ropes:
   - racks: France (Mediterranean coast) and Italy;
   - rafts: Spain;
   - long lines: Ireland, United States, France.

The way in which the culture system is selected, mainly based on geomorphological reasons, has been summarized (Table I) in areas with tides. This cannot be applied to the Mediterranean.

DEVICES

The possibilities of improvement that can be introduced in the devices used in the suspended culture can affect rafts (materials and design) and ropes.

Materials

The use of polyurethane and fiberglass avoid the risks of fouling and sinking during rough weather. The major disadvantage could be the economic costs, because the number of rafts built does not support a specialized industry. In Spain, the main objective is to build a sturdy and resistant structure while in other countries low cost units are used although with an expected shorter time of use.

Design

Some improvements can be introduced on the design. Sinkable rafts would permit to culture mussels in rougher waters increasing the culture surface. In Japan these rafts are used for fish culture.

Another improvement that has been introduced is the mechanical settlement of the seed with a dramatic increase in production of seeded ropes.

CULTURE TECHNIQUES

The advantages of the suspended culture over the other methods in tidal waters remains mainly in the possibility of having a fixed working schedule, it does not depend on the variation of the tide level.

There are also possibilities of improvement in the mechanization of: seeding, thinning, harvesting, handling and shipping.

Table I. Selection of culture systems based on geomorphological considerations

Orography	
Flat	Uneven
Advantages	
Availability of shallow waters, possibility of culture in the bottom or poles	Availability of deep waters (suspended culture)
Less fouling, cleaner mussels	No dependence on the tides
Less human population on the shore	Faster growth Better use of space
No depuration needed	Shallow waters can be used for culture of species with more economic value
	Seed can be obtained from the rocks and from collectors
	There is exchange with seed from different origins
Disadvantages	
Work depends on tides	More human population on the shore
Growth is slower	Depuration is needed
Spat is collected on ropes and then a transfer is needed	Fouling is more important
No exchange of seed	
The use of space is less productive (same production, more space needed)	

In Spain the cleaning of harvested mussels depends on whether the destination is for canning (mussels are not cleaned) or for the fresh market (mussels are cleaned).

Mechanization should not have a negative influence on employment, this should have a positive effect on increasing economic margins and improving the quality of the work.

Management of oyster and mussel culture in Norway (B. Bohle)

Oyster and mussel culture is limited to inshore and shallow waters where we find concurrent activities as other forms of mariculture, recreation, commercial fishing, shipping. In the same areas, the water as recipient for domestic sewage and industrial pollutants. Finally, there may be interests for pure environmental protection.

There is a need for coordination and laws for taking care of the different interests for and maximal utilization of the resources in the water and at the sea bottom. This should be done in cooperation between governmental bodies and local authorities.

For the most easiest way of planning the use of the coastal zone, national or local authorities should have all rights of the sea shore and the water and bottom outside.

The shellfish people should lease the rights from the State. For aquaculture activity at deeper water, it is more suitable that the shellfish farmers get a license and pay a fee for running aquaculture, defined to certain localities and with description of the size and production potentials.

In Norway, local communities and counties bounded by the sea are obliged to set up plans how to organize the sea areas, giving priority to different activities in different areas. The coastal plans must be sanctioned by governmental bodies. Coastal planning is the most important way. Mussel and oysterfarmers have to secure areas for their activities.

In inshore waters a large number of factors limit how much biota which can survive and be produced per area and volume of water. This should be considered and restrictions set up, for example how much (or density of) spat are allowed to be relayed on the bottom. The authorities could set up quotas for each license holder. The authorities should also have the power to decide that an area should be used for integrated aquaculture (fish culture, filter feeders, rope and bottom culture in the same area).

Before the authorities give license for aquaculture, it must be documented that water and bottom quality are satisfactory, i.e. for assuring low level of pathogenic bacteria, heavy metals, and other pollutants. The authorities should also forbid aquaculture to be established where the currents are weak, in areas where shallow sills and narrow entrances may cause accumulation of feces and other waste from the aquaculture activity. Therefore, in coastal planning it is important that all kinds of expertise should be involved from the very beginning. Coastal planning must be founded on scientific knowledge.

To perform an overall view on the environment the authorities should administer surveys of toxic algae and analyses of mussels and oysters for toxic substances. That should be done in two ways: analyses 1) of wild mussels from the sea, and 2) of processed mussels ready for the market. Shellfish should also be examined for content of heavy metals, Poly Aromatic Hydrocarbons (PAH), and so on. Principally, the companies should pay for the tests which must be performed in laboratories controlled by the authorities to ensure neutral and confident results.

The authorities should establish quality standards of the products before marketing on sizes, acceptable toxicity levels, and content of bacteria and heavy metals.

For advice to solve specific problems companies or groups of companies running oyster and mussel cultures, should engage private consultant firms at their own expense. This is also obvious in planning of processing plants on the shore.

The authorities have a very important task in controlling imports and transplantations of live animals for relaying. The authorities must set up minimum call for certificates giving all relevant information which should guarantee the organisms free from parasites, epibionts, and diseases. The authorities should not allow non-indigenous organisms to be transferred or introduced before all ecological aspects and implications have been seriously investigated.

Discussion with the floor

The discussion started with the problem of transplanting the species and the parasites associated, between countries or inside the same country. The recommendations of the International Council for the Exploration of the Sea (ICES) have been presented. It is forbidden to immerge directly the imported species in the water, they must stay in quarantine. Afger a production of F1 in hatcheries in quarantine and after control of absence of disease, F1 can be immerged in the fields. This recommendation is not perfect but allows to reduce the risks bound with introduction.

Then the discussion focussed on the problems of red tides, eutrophication and outbreaks of *Dynophysis*. A discussion started on the relation between nutrients and *Dynophysis*, particularly between the discharges of intensive agriculture and *Dynophysis*. It appeared that a direct relation between the abundance of that DSP species and the level of nutrients (nitrogen and phosphorus) has not been proved yet. On the contrary, it has been well documented that the *Dynophysis* harmful bloom first occurred in the open sea after the spring phytoplankton bloom when the nutrients are no more available.

At a question on the relation between mussel contamination and the abundance of *Dynophysis*, it has been answered that mussel watch is achieved with mouse tests, recognizing that the calibration of that test is not perfect for human contamination. More research must be done on the measurements of the toxine by HPLC methods, immunodiagnostic tests are a way of research which could be more sensitive and more fast in time for response.

The session then focussed on Arcachon Bay which is a very good example of the difficulties to manage oyster culture. In the past, this bay was respectively struck by problems of overstocking in relation to the stocking density (1950), by an industrial pollution by a paper factory (1960), and by problems of TBT (1977) used as antifouling paint for recreational activities. The last pollution stopped in 1982 when a ban on TBT was decided upon permitting again good recruitment and growth rate for oysters in the bay.

Conclusions and recommendations

The past evolution of the production in different areas can give an idea of the success or the failure of management of oyster and mussel culture. The general tendency of the world

production of molluscs allows to think that the constraints have been generally well controlled.

Nevertheless some recommendations could be done:

- management of the quality and quantity of fresh water needs to be controlled to save the quality of different activities on the littoral, particularly intensive agriculture needs to be followed more and more carefully;
- To avoid human contamination by DSP or PSP phytoplankton which is causing accumulation of toxic substances in molluscs, a network must be achieved in each country at the vicinity of each bay producing molluscs with a high intensity of sampling;
- As the mollusc production is limited by the available food, the extension of cultivation will not be infinite. Management of the densities in the parks and for the total cultivated biomass in the bay must permit to stay under the limit of the carrying capacity of the ecosystem;
- Management against disease is very difficult to propose, it is bound to the previous point in relation with the densities and the physiological weakness. Prevention is the better solution, particularly to avoid the spreading of the disease. Direct transfer and immersion of marine organisms must be prohibited including spat and "eyed larvae", the ICES code of practice must be applied by the different countries;
- To reduce the space conflicts and the problem of the quality of the water, it is recommended that a management plan at the initiative of the states or provinces or departments could be established. The determination of the priorities for the use of the sea could be a very useful tool with protected areas well identified for development of aquaculture.

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