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SUMMARY – As in many parts of the world, aquaculture production in the Mediterranean is rapidly expanding. Although molluscan production still dominates in volume terms (~60%), marine finfish production (now ~39%) is increasing at a higher rate and in 1997 reached ~380,600 tonnes. The Mediterranean coast displays a wide range of geographical characteristics and supports many functions, such as tourism, residential development, and conservation, which may compete with aquaculture for resources. Many coastal areas are also physically exposed, unsuitable for traditional inshore-based farming. Within this context, intensive marine fish farming is increasingly moving towards exposed offshore environments, requiring technology development which has largely originated from Northern European systems. For small islands such as Cyprus or Malta and along highly urbanized shorelines (Catalonia, Spain) where space is scarce, such systems are particularly important in developing aquaculture. This paper reviews the process of development of marine fish farming in selected Mediterranean countries, i.e., Cyprus, France, Malta, Spain, etc., providing an introductory overview on production techniques, farm size, and the technology employed.

Key words: Marine aquaculture, systems, cages, Mediterranean, development.

RESUME – *"Mariculture en mer ouverte dans les pays méditerranéens". Comme dans de nombreuses parties du monde, la production aquacole en Méditerranée est en expansion rapide. Bien que la production de mollusques prédomine encore en termes de volume (environ 60%), la production de poissons marins (maintenant d'environ 39%) augmente à un rythme plus rapide et en 1997 a atteint environ 380 600 tonnes. La côte méditerranéenne présente une vaste gamme de caractéristiques géographiques et remplit plusieurs fonctions, comme le tourisme, le développement résidentiel, et la conservation, qui peuvent entrer en concurrence avec l'aquaculture pour les ressources. Beaucoup de zones côtières sont également physiquement exposées, inappropriées à l'élevage traditionnel sur le littoral. Dans ce contexte, l'aquaculture marine intensive se déplace de plus en plus vers des environnements exposés en mer ouverte, nécessitant le développement d'une technologie qui provient en grande partie de systèmes du Nord de l'Europe. Pour de petites îles telles que Chypre ou Malte et le long de littoraux hautement urbanisés (la Catalogne, Espagne) où l'espace est rare, de tels systèmes sont particulièrement importants pour une aquaculture en développement. Cet article passe en revue le processus de développement de l'aquaculture marine dans des pays méditerranéens choisis, comme Chypre, France, Malte, Espagne, etc., et offre une introduction aux techniques de production, à la taille des exploitations, et à la technologie employée.*

Mots-clés : *Aquaculture marine, systèmes, cages, Méditerranée, développement.*

Introduction

Aquaculture in the Mediterranean region is an activity which began many centuries ago and thus has a substantial history: it is possible to find signs of aquaculture from Egyptian civilization. Ancient Egyptian friezes on the tomb of Aktihep (2500 BC) shows what appears to be men removing tilapia from a pond (Bardach *et al.,* 1972). During ancient Roman times sea bass, sea bream, mullets and oysters were cultivated or simply kept alive off the Italian coast (Cataudella, 1996).

Mediterranean aquaculture initially developed in coastal lagoons. Management of finfish populations and oyster culture started in these confined environments thanks to their particular ecological conditions (Cataudella, 1996). This origin strongly conditioned the beginning of modern Mediterranean aquaculture, which is characterized by the coexistence of diverse production systems that use a wide range of production techniques; from coastal lagoon management to highly intensive raceways or cage fish farming.

Mediterranean aquaculture production has grown steadily over recent years, rising from ~743,516 mt in 1992 to 960,013 mt in 1997, an average rate of growth of 6% annually, and reaching some 4% of the world aquaculture production. Although production focuses mainly on molluscs (60%), the share of fish (39%) is steadily rising. Thus, over the 1992-97 period the fish subsector grew by 38%, while that for molluscs increased by 24%. Table 1 provides a breakdown of subsectoral production by country, and as well as showing the great diversity of output from individual countries, illustrates the increasing strength of the marine finfish sector in many countries, particularly Malta (+260% – 52%/yr), Cyprus (+511% – 102%/yr), Morocco (+255% – 51%/yr) Lebanon (+131% – 26%/yr), Greece (+217% – 43%/yr), Turkey (+375% – 75%/yr). Of these, Greece and Turkey are particularly significant, having both notable production levels and high growth rates. Trends in countries such as France, Spain, Italy, and Israel are also important, exhibiting steady growth from large production levels. Aquaculture in the region has in fact been dominated during recent years by the first three of these, which supplied 80% of total tonnage in 1991, mainly with mollusc production. This decreased to 77% in 1997 despite their increase in production. The entry of new countries, particularly Greece and Turkey, strongly focused on marine finfish, is changing the situation significantly.

Table 1. Comparative features of Mediterranean aquaculture production (source FAO: Fishstat)

Country	1997			% increase 1992-97		
	Fish	Mollusc	Total†	Total	Fish	Mollus
Albania	7	80	97	–76	–94	–72
Algeria	312	10	322	119	140	–41
Bulgaria	5,370	67	5,437	–33	–34	
Cyprus	947	–	969	525	511	
Egypt	73,454	–	73,454	15	15	
France	71,167	216,204	287,609	15	31	10
Greece	37,715	6,618	44,338	118	217	–21
Israel	17,370	–	17,370	40	40	
Italy	69,500	143,000	217,519	28	28	29
Lebanon	300	–	300	131	131	
Libya	100	–	100	25	25	
Malta	1,800	–	1,800	260	260	
Morocco	1,933	295	2,228	201	255	82
Portugal	2,742	4,440	7,185	12	25	5
Romania	11,168	–	11,168	–55	–55	
Spain	38,206	200,735	239,236	42	42	42
Syria	1,612	–	1,612	–68	–68	
Tunisia	1,947	65	2,012	134	144	8
Turkey	43,150	2,000	45,450	400	375	
Yugoslavia, F.R.	1,805	2	1,807	34	34	100
Total	380,605	573,516	960,013	29	38	24

†Total includes fish, mollusc, crustacea, seaweeds and other cultured species.

In 1997, molluscs (mussel, oyster, clam, etc.) were still the prevailing group, with over 570,000 t of production, whose steadly growth of 24% over the 1992-97 indicated possible market saturation, and/or site limitation. In the same period, fish production rose from 276,377 to 380,605 t. Freshwater fish are still important, with rainbow trout at ~140,000 t, and tilapias (37,600 t in 1997), both of which are steadily growing, an increase of 30% for trout (6%/yr) and 44% for tilapia (9%/yr). Carp production, traditional in some countries, decreased from the early 1990s (10%), mainly due to a fall in production in Bulgaria and Egypt.

Marine finfish demonstrated the highest rise, with increases in all of key Mediterranean species (sea bass, sea bream, turbot and mullet). Sea bass and bream, the main species produced, experienced the highest increase (Fig. 1), from 18,358 t to 73,914 t over the 1992-97 period (FAO statistics). Production for 1999 has been estimated at 88,060 t (FEAP: www.feap.org). Although only produced in Spain, France and Portugal turbot has risen a significant 58% over the same time (11.5%/yr) to ~3000 t in 1997. Over the same period, production of mullet increased by 43% (8.6%/yr), in 1997 reaching 21,665 t. Seawater grown eel production has however decreased, probably due to a lack of available seed and the conversion of some Italian units to onshore sea bass and sea bream production (Iandoli, 1997).

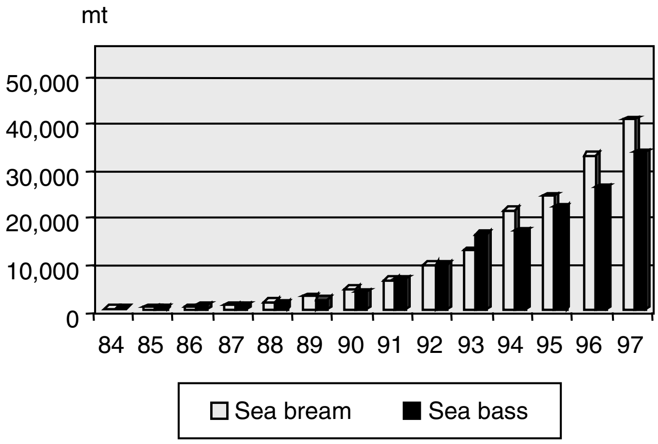

Fig. 1. Mediterranean sea bass and sea bream production.

As recent entries into the sector, output of crustaceans and seaweeds is still limited, 5000 of Graciaria seaweeds in 1997. For crustacean production, *Procambarus clarkii* is currently most important, but trials have been carried out for penaeid shrimp, particularly as a summer crop using extensive techniques in the northern Mediterranean, or using more intensive practices in southern countries. *Gracilaria* is the main species of seaweed cultured in the area (Pedini, 1996).

Marine fish farming production systems

The diversified character of Mediterranean coastal aquaculture is based on geographical differences (coastal lagoon, islands, etc.) together with a range of historical and socio-economic factors. The technology applied has evolved rapidly, both in modifying existing facilities (e.g., water recirculation for land based installations) and in developing new projects (e.g., off-shore cage technology). For sea bass and bream, production techniques are very diverse, ranging from extensive to highly intensive systems, involving valli systems, earth ponds, floating cages, or raceways or tanks. Cages are by far the most popular production technique, used in lagoons, sheltered bays or semi-exposed and offshore conditions. Some 82% of farms use cages, with about 900 units (Table 2), followed by land based intensive raceways or tanks (10%) and semi-intensive production in earth ponds (8%). However, as will explained later, these percentages are not proportional to farm production size.

Intensive systems

The rapid increase in growth for sea bass, bream and turbot has been due to the development of reliable seed production techniques, the formulation of specialized feeds and the application of intensive production systems, particularly cages. Good infrastructure support by the EU and strong markets from the late 80s to the early 90s have also played a significant role, and new candidates may increase the number of farmed species in the future, including various sparids such as *Puntazzo puntazzo, Pagrus pagrus* and *Dentex dentex*, groupers and *seriola.*

While overall growth offers good evidence of sectoral success, this masks failures of many enterprises at all scales of investment and production. Thus in Spain a crisis arose during the early 90s, when a significant number of sea bass and bream failed and disappeared; sea bream farms numbered 40 in 1996 compared with 46 in 1990. A key problem had arisen from the growth in supply and the consequent decrease in market prices. Periods of economic recession in Europe, as well as monetary fluctuations (e.g., devaluation of the Italian lira), worsened conditions for a sector which has been highly dependent on specialized markets and on the commercialization of a single product, mainly whole fresh fish (Stephanis, 1996). However, if development patterns for other species are to be followed, there is still likely to be room for additional production, although at lower prices. During recent years prices have become more stable and production costs are constantly decreasing due to better management, automatization, and better feed performance. This has allowed the few large businesses in the sector to improve and expand, while continuing to invest. Though intensive systems in land-based installations or cages generally demand high investment, the efficient production of high value fish products at cost-effective stocking density is a valid commercial aim.

Table 2. Sea bream and sea bass: units and production techniques in Mediterranean countries (developed through personal contacts with correspondents of the FAO/SIPAM Network)

Country	No. total units	No. cage units[†]	No. raceways and tank. units	No. Earth-pond units	1998 prod. (t)	Unit $\bar{x}$ product.
Croatia	35	35	–	–	1,800	51
Cyprus	8	8 (8)	–	–	1,034	129
France	35	25 (13)	10	–	2,483	67
Greece	269	264	5	–	36,000	134
Israel	6	3	3		1,826	304
Italy[††]	79	19	60		9,800[††]	114
Malta	8	7 (5)	–	1	1,950	244
Morocco	2	1[†††]	1	–	724	ND
Spain	45	23 (22)	4	14	7,738	172
Tunisia	3	0	2	1	368	123
Turkey	350	339 (5)	8	3	18,810	54
Portugal	51[††††]	2	1	≤48	712	39
Total	891	726	93	72	85,241	

[†]No. of cage units in semi-offshore and offshore conditions indicated in brackets.
[††]1500 t produce in *valliculture*.
[†††]Cages in lagoons.
[††††]Estimated.

Land based intensive systems

The origins of these date back some 20-30 years with the adoption of trout farming principles by extensive marine aquaculturists, using species such as sea bass and mullets, followed by trials with sea bream, initially using pellets for intensive fresh-water fish culture. Following positive results, research improved and accelerated this pilot phase, based initially on wild caught fry, or juvenile and sub-adults collected during migration in fixed traps at the entrance of lagoons or valli.

Current systems use concrete or earth tanks, raceways or ponds, based on the supply of high volumes of pumped water, specialized feeds and hatchery fry or fingerlings. However, for sea bass and sea bream, intensive land-based ongrowing is considered to be less competitive (De la Pomelie, 1995; Blakstad *et al.,* 1996) than cage farming; the main differences being energy cost, and space costs and availability. Environmental impacts and disease control are also problematic. The use of liquid oxygen in many farms has helped to reduce energy cost, increase production capacity per volume of pumped water, and improve effluent control. Although requiring further investment, windmills may also help reduce energy costs in some locations. Turbot is normally ongrown in land based tank facilities, though research is under way to apply cage ongrowing techniques.

A number of land-based intensive farms work indoors using treated and recirculated water, as is the case of glass eel weaning. As water quality control has become more critical, an increasing number of marine hatcheries can now be considered as indoor systems with a high degree of recirculation (Cataudella, 1996). Hatcheries have also been under increasing pressure to produce fry over the traditional 1-2 g size, to sell juveniles for cage culture (10-20 g to over 50 g), to meet increasing demand by offshore fish farms, as they reduce the need for initial grading. Thus, hatcheries may expand their systems to meet this growing demand, and research and development is currently under way to carry out intensive pre-ongrowing in raceways using recirculation systems. This may also provide a role for existing land-based ongrowing farms, which may become more viable if integrated with cage farming, producing part-grown fish for stocking offshore.

Cage farming

Although cage farming has been practised at artisanal levels for hundreds of years, modern systems did not develop until 20-30 years ago, primarily in line with the growth of salmon farming (Scott and Muir, this volume). Cage ongrowing has now become the primary basis for the rapid growth of the Mediterranean marine fish farming sector. Initial systems were designed for sheltered sites in inshore water, constructed from wood/polystyrene, poles/buoys, and later from steel and plastic, usually self constructed or supplied by local fabricators. These were originally placed in well protected coastal areas, where simple and inexpensive cage structures could be used, giving valuable geographical advantage to countries endowed with many sheltered bays, i.e., Greece, Croatia and Turkey. Here, aquaculture is characterized by numerous small farms using simple technology and requiring low levels of investment. In Croatia, 35 units produce 1800 t (51 t as average); in Turkey, where some 190 units produced less than 30 t, most units (334 out of 350) are located in in-shore conditions.

In many parts of the Mediterranean there is strong competition with tourism for coastal resource, a scarcity of protected sites or both, moving cage operations towards the open sea. Environmental concerns and policies may also play a role. In Malta offshore cage technology has lead to significant development (from 60 t in 1991 to 2200 t in 1998). In Spain, production in earth ponds, raceways and concrete tanks has been decreasing, while cage culture has clearly expanded, with most new projects using semi-offshore or offshore systems. Cage based production, in 1990 representing only ~17% of the total, rose to ~37.5% by 1996 and to 56% by 1998 (Basurco and Larrazabal, this volume). In France production techniques in marine fish farming (salmon, sea bass, sea bream, turbot) are extremely diverse, involving cages, earth ponds or raceways. Cages are used in lagoons, sheltered bays or semi-offshore conditions in Corsica and on the French Riviera. For the 1991-96 period, based on the number of farms, the only two techniques which developed were raceways and semi-offshore cages (De La Pomélie and Paquotte, this volume).

Many different types of cages are used in the Mediterranean; these are described elsewhere in greater detail. It is notable that most practical research and development for semi-offshore and offshore conditions has been carried out by farms; testing and using the most promising (and most expensive) structures for more exposed sites. As more experience had been gained on site characteristics and on technological issues, cheaper cages became more widely employed, e.g., in France and Cyprus (De la Pomelie and Paquotte, this volume; Stephanou, this volume). In Spain, most farms use simple plastic circle type cages and most recently platform structures are being used. Farms usually employ cages of different dimensions for different purposes: i.e., smaller cages for pre-fattening, cropping, auxiliary, experimental purposed and larger cages for ongrowing. Pre-fattening commonly takes place in small cages in sheltered bays or in land-based structures (raceways and tanks), with fish of 10-20 g or 50-100 g placed in open sea, reducing the ongrowing phase to less than one year, reducing risks and labour costs associated with initial treatment (i.e., vaccines), initial grading (e.g., at 25-50 g), net changing, etc. In some cases (e.g., Cyprus) more robust cage systems are used as offshore breakwaters, sheltering lighter and less expensive cages inshore. In Spain, circular plastic cages may be attached around platforms to increase production capacity at lower marginal cost.

Unit size of farms

This may vary significantly, and there are examples of small or big companies for almost all the production systems and techniques described. Though detailed information is scarce, the Mediterranean marine fish culture sector may be described as being in its growing phase (Stephanis, 1996) requiring many technological and management developments. For sea bream and sea bass the different types of company and/or farm units, based on their size, may be summarized as follows:

(i) *Large companies* with one or various farm units. In year 1995, for a total production of sea bass and sea bream of 46,564 t, only 8 companies (Nireus, Selonda, Cupimar, Salmona, Ortebello Cooperatives, Marost and Maricultura) accounted for almost 20% of the production (Bakela, 1997), i.e., an average of ~1200 t each. These companies also commonly have big marine hatcheries, and except for two – Cupimar and Marost – have several landbased or cage culture ongrowing units of several hundred tonnes capacity. They are often based on traditional sites and generally expand by increasing capacity of existing units rather than establishing new ones, preferring several units of 300,500 t within a reasonable distance, instead of one big farm. Their size, and their opportunities for raising capital, e.g., through share sales, also makes them increasingly able to acquire other, smaller or less viable farms. A significant number of these enterprises have already established packaging and processing plants and are now implementing quality systems (e.g., ISO norms).

(ii) *Middle size farms* (small-medium enterprises) typically operate intensive systems either inland (mainly raceways of ~200 t capacity) or in cage culture. These are the main types of farm going offshore, using offshore cages in production units of 200 to 500 t capacity, with progressive increase in automatization. Thus, though feeding is often still manual, automatic systems are increasingly appearing, and operations such as net changing and fish grading are usually mechanically assisted. Typical examples are the Maltese and Cypriot offshore farms. These units generally expand by developing large single sites, with increased operating efficiency. A greater number of enterprises are also developing their own hatchery capacity.

(iii) *Small farm units* are commonly family enterprises using semi-intensive systems (i.e., earth ponds in Portugal) or simple intensive cage culture in sheltered bays (Croatia, Greece and Turkey, and also in other Mediterranean countries, i.e., France and Spain). In Turkey, 189 out of 290 units produced less than 30 t. Though not uniformly, these farms may evolve through a gradual increase in average production. Thus in Spain in 1990 39 units produced less than 30 t, whilst in 1996 this decreased to 21, and previsions for 2000 are for only 10 units (Basurco and Larrazabal, this volume). The survival of this type of farm may lie in management improvements, specialization of production (i.e., pre-ongrowing) and their success in forming co-operatives and commercializing products in local markets. Although management experience may give these farms the opportunity to go for semi-offshore cage technology, it may be difficult for them to afford offshore technology as this requires greater investments in cages, workboats, feeding automation, etc. The exception to this may occur if such farms take up contract growing for larger companies, in which case they may be able to access the necessary capital, either by contract, or on the basis of their income potential.

Although there has been a steady tendency towards an increase in the size of units, this has not so far been as pronounced as in salmon farming. A slight increase in size of the average site has arisen, both due to development of very big farms and to expansion of middle sized and smaller farms. The tendency in intensive systems is to develop semi-offshore or offshore cages in units of 200 to 400 t capacity, whose size and cage composition will depend on the support systems available, i.e., harbour facilities, workboats, etc. Some consultants currently advise as an average size farm the establishment of 8 to 12 cages, 16 m diameter each and 2000 m^3 capacity, able to produce more than 250 tonnes and big enough to learn the "prototype" business of offshore production. New projects may expect a profitable operating scale with an annual production of ~300 t from about 12 cages. To reduce overheads, such units may grow over a period of 2-4 years to 500 or 600 t. Although bigger units, i.e., 1000 t, may have lower overheads, this advantage may be reduced by the risks of concentration in single sites (Basurco and Larrazabal, this volume). Overall, the type, volume and number of cages will mostly depend on the risks the company wishes to take and on its operational/management experience. Bigger cages, though cheaper per installed unit of capacity, are considered to be more difficult to handle, especially with small fish and therefore involve more risk.

It is interesting to compare this situation with turbot farming, which uses land-based tanks. In recent years, with technological improvement, farms have raised their break-even point for output and thus it is few viable farms have an installed capacity of less than 150 t. With perhaps less technical risk associated with onshore systems, producers may be less constrained in system size.

Constraints and development options

Successful development of sea bass and bream production in the Mediterranean has been achieved after overcoming various technical problems. However, growth in supply has led to a considerable decrease in market price, which caused instability during the early 90s. Production costs are very variable, given the variety of countries, sites, technologies and farm sizes, and this variation is accentuated as most enterprises are less than five years old and routine has not yet been achieved. The sector can be described as in a growing phase characterized by rapid growth, non generic market developments, stabilization of production techniques, development of sophisticated management. It is facing many of the same problems experienced by the salmon industry and may be expected to face others that are typical of mature and/or ageing industries, such as reduced growth in production, control on cost and rationalization, critical management, etc. (Stephanis, 1996).

Whilst the industry has been diverse in features and methods, incorporating both commercial and artisanal forms of production, there are increasing signs of aggregation and more clear-cut divisions between two main sectors: large scale corporate producers using intensive methods and smaller-scale family or co-operative producers. Competition is likely to increase, and prices and margins will tend to diminish, which will demand additional efficiency and productivity. This is likely to drive industry policy in further pursuit of size. In this context, the constraints for future development of the sector can be grouped in different categories, each requiring not only specific action but also co-ordination. Table 3 summarizes the main characteristics and constraints of the sea bass and sea bream industry. Although not the aim of this work, it can be noted that the categories of constraints (Pedini, 1996; Stephanis, 1996) which should be addressed are related to:

(i) Biological and technical aspects, mainly referring to disease problems, but also including diversity concerns due to the introduction of new species in the region and quality control problems.

(ii) Zootechnical constraints, such as seasonality of production facing different seasonal fluctuations of the demand.

(iii) Environmental concerns, linked to the location of farms and the impact of their effluents on the surrounding environment.

(iv) Limited availability of information for planning and for day to day operation of the farms.

(v) Scarcity of potential sites for new aquaculture projects.

Table 3. Sea bream and sea bass production characteristics and constraints

Market characteristics	Product availability	Production
• Although changing, specialized markets based on relatively high-priced products	• Seasonal availability, although gradually extending	• Reduction in production cost, though still high • Relatively short operation times of marine hatcheries (high cost)
• Mainly, a single product form (fresh whole fish)	• Limited sizes and product forms	• Diseases • Environmental concerns: effluent impact; biodiversity

The prices of these two rather similar high value commodities have been dependent on the relatively small size of total market supply, including capture fisheries and aquaculture, in which aquaculture production has taken the lead as supplier (Pedini, 1996). Sea bass and sea bream are thus steadily losing their luxury image and are becoming commodity items. Only a limited number of strategies may then be adopted to maximize profitability and ensure a continuing expansion in an ever more competitive market. Table 4 summarizes the market and production strategies potentially available. These include: (i) decreased production cost; (ii) increased selling prices; and (iii) greater product diversity. Note that these are not mutually exclusive. For example, reduced production cost, successfully achieved by the salmon industry (through improvements in feeds, disease control and prevention, genetics and breeding, management, automation, etc.) may be successfully accompanied by improved marketing methods, where product differentiation may play a significant role.

Table 4. Options potentially available for Mediterranean marine aquaculture development

Market strategies	Production strategies
• Introduction into new markets • Development of local markets • Improvement of product quality image: - application of identity and designation of origin - health - eco-labelling	• Reduction of production cost: - better management - nutrition - genetics - pathology - etc.
• Increased variety of output within the same species: - fish size diversification	• Diversification of production systems: - offshore cage culture - recycle systems
• Diversification in presentation, and supply of value-added products	• Species diversification: - within similar groups - within different groups

To decrease production cost, there is still room for improvement in farm management, automation, health management, better feed performance, genetics and breeding, etc, all of which may make it possible to maintain margins competitively. Although prices for sea bass and bream have become more stable during most recent periods, they will most probably decline further, as with salmon. Although possible, an increase in selling prices seems unlikely, as sophisticated and expensive methods of marketing and commercialization would be required, beyond the scope of many food products. Mediterranean producers clearly need to become more organized and co-operative (Bakela and Paquotte, 1996). It is also important not only to enlarge existing markets, but to penetrate and develop new markets. The industry may need to emphasize more sophisticated methods of marketing and base them on market research studies.

To expand markets, diversification will be a significant issue. This may refer to (i) product diversification – different market products for a given species, i.e., different size, manufacturing process, presentation, quality, etc.; and (ii) species diversification – production of new cultured species. The ability of producers to offer other species than those traditionally marketed would attract new consumption and may at least for some period support better prices, especially for innovatory species. The diversification of production systems (off-shore cage culture, recycle systems, etc.) may increasingly offer alternatives, as scarcity of potential sites is a key constraint.

Constraints and requirements for development of offshore mariculture

With only a few exceptions, is well accepted that a major constraints of Mediterranean aquaculture is access to coastal space. Although there are still convenient sheltered or semi-offshore sites, these are found only in a few countries or are submitted to severe use conflicts: urbanization, tourism, navigation, wildlife park projects, harbours, maritime traffic, etc. Following technological developments, offshore aquaculture may offer solutions for many of these conflicts. After several years of experience, we have witnessed how farms are steadily moving from semi-offshore conditions towards more exposed sites. The acquired experience for the management-maintenance of stocks and structures under the prevailing conditions have filled the gap in knowledge, since offshore mariculture is still a relatively new activity in the region. Thus, we can start to identify the technical as well as socio and legal requirements of offshore aquaculture systems; some of them unusual, others common to other production systems. For example, although it is being recognized that offshore fish farming has a lower environmental impact, we should not forget that these production systems, just as other aquaculture systems, are or will be watched by environmental agencies and government departments, so suitable environmental monitoring techniques need to be developed.

Social and legal requirements

From a broader perspective, the social and environmental cost of offshore aquaculture may have to be taken into account. In this respect the removal of aquaculture from highly competitive coastal zones may represent a positive economic gain. However, the social cost of reducing the competition from less intensive traditional forms of aquaculture may represent a notable disadvantage in some circumstances (Muir, this volume). For most Mediterranean countries, even though there are differences, there is a global legal framework for aquaculture, which reasonably regulates inland and on-shore aquaculture. With the exceptions of countries where aquaculture has developed recently thanks to offshore systems (i.e., Malta and Cyprus), legislations are not sufficiently updated to off-shore mariculture and still need to contemplate these practices. This means a possible barrier for investments and entrepreneurs who may face a legal vacuum when requesting permission for an offshore farm project.

Regarding leases or rights for offshore aquaculture sites, these permits may vary between and within countries. When projects are submitted, entrepreneurs will request permission for a reasonable number of years, as most of these projects range from middle to large intensive farm units, normally requiring high investments. In some cases, some administrations (always seeking to protect the coast) may be somewhat reluctant to give permissions for a new project (offshore) whose environmental impact is unknown; and therefore give short, renewable permits. Possible solutions for this problem may be found in some countries, such as Malta (Agius, 1999), where some guidelines have been issued to this respect: including site requirements, environmental assessment studies, etc., or Cyprus (Stephanou, this volume) where the rather arbitrary distance of about 3 km is left between the farms in order to minimize their interaction and joint effect on the environment.

The rotation of farm sites, which was being offered as a solution for farms placed in protected or semi-protected sites of 25 m or less depth in order to minimize environmental impacts, could also be applied to certain offshore cases. For offshore mariculture, this possibility should not be forgotten as conflicts with tourism, navigation, etc., may arise once the farm has already been established. Thus, although this possibility may encounter some technical problems, there are bigger constraints when obtaining site "concessions", as the necessary administrative requirements are costly and time consuming. A possible solution could be for the administration to provide two nearby site permissions for the operation of one unit.

Finally, there is also a need to improve pre-installation survey methodologies adapted to specific offshore systems (cages and moorings) for particular potential sites in order to assist project evaluations and risk assessment studies. Post-installation survey methodologies, which will later help to monitor the performance of the system and to monitor the environmental impact, are also needed (Turner, this volume). The information concerning the causes of losses and loss investigations should be made public, as this information is of extreme importance in the evaluation of projects and is necessary to promote the development of an adequate insurance system for offshore mariculture.

Technical requirements

Besides the constraints and needs already mentioned above, such as the scarcity of protected sites for mariculture or the need for regulations adapted to offshore conditions, in order to develop, the sector has technological needs in the field of engineering. Therefore, whilst there is still a need for R&D in the field of biology, such as the development of improved diets, new vaccines or methods for the prevention and treatment of disease, there is a noticeable lack of knowledge about different aspects of offshore engineering and technology. Moreover, all these operations are to be developed in a sector that, due to market forces, is obliged to lower production costs and at the same time improve the quality of their products.

Thus, there is a need for the development of more efficient and less expensive floating or submergible structures that could permit reliable operation in exposed offshore conditions. It should be mentioned that it is not only that offshore structures should withstand higher or stronger waves and currents, but also that the management and operation (feeding, handling, harvesting, batch classification, etc.) of these structures should be carried out efficiently. To this respect, there is a need for equipment that could allow higher management automation in these units and thus increase labour productivity. All this, and the high investments to be made, will lead offshore farms to evolve towards units with a production capacity from 500 to 1000 tonnes upwards.

In this context, pilot projects aiming to develop or improve technologies for operation in real exposed conditions should address the following aspects:

(i) Development of less expensive offshore structures.

(ii) Development of economic and resistant workboats and platforms for offshore operations, these offering a base for management, feeding and stock surveillance.

(iii) Development of remote control systems for offshore units.

(iv) Development of more resistant nets (incorporation of new fatigue-resistant material).

(v) Development of more resistant chains and mooring systems.

(vi) Development of environmentally friendly net anti-fouling systems.

(vii) Development of monitoring techniques for the control of environmental impact.

(viii) Development of systems to protect stock against environmental disasters, such as oil spills, plankton blooms, etc.

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