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PRODUCTION AND MARKETING TRENDS OF THE CULTURED MEDITERRANEAN MUSSEL *MYTILUS GALLOPROVINCIALIS* LAMARCK 1819, IN GREECE.

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ABSTRACT Bivalve production in Greece pertains to a vast extent of mussel farming and a few other species of fishery products. Mussel farming in Greece covers 375.5 ha primarily located in the northern part of the country. About 523 farms have been licensed since 1976, of which 218 are using the single long-line floating technique for a nominal production capacity of about 100 t/ha and a farming area of 1–2 ha on average. The total annual production (gross pergolari weight) increased to 36,000 t in 2008. Currently, there is a trend for further expansion by licensing new farming sites. Eighty percent of the farmed mussels are exported fresh and intact, primarily to Italy. One major problem seems to be the increasing number of harmful algal bloom incidents during the past decade. The future of the industry depends on the industrialization of production methods and the development of scale to suppress the production cost. Support of product branding and development of a quality scheme would further strengthen the sector.

KEY WORDS: Mediterranean mussel, *Mytilus galloprovincialis*, Greece, production, market, economics, risks

INTRODUCTION

Farming of the Mediterranean mussel *Mytilus galloprovincialis* Lamarck 1819, is the premiere, almost exclusive shellfish aquaculture production sector in Greece. Molluscan shellfish farming in Greece dates back to the 5th century, with records dating until the end of the Roman period (Basurco & Lovatelli 2003). Recent historical background shows that the evolution of the industry escalates during the mid 1980s, following the pioneers of Mediterranean suspension shellfish farming in Italy during the 1950s and France during the mid 1970s (Danioux et al. 2000).

In general terms, the development of the Greek shellfish farming sector can be divided into 4 phases, similar to those described by Theodorou (2002) for the sea bass/sea bream mariculture industry:

1. R & D phase (1950 to 1977) during which suspension mussel farming was established in Italy and France, and quickly expanded to Spain, United Kingdom, and Ireland. By 1980, it had expanded over almost the entire Mediterranean (Danioux et al. 2000). Early efforts to cultivate mussels in Greece were carried out by using poles, and were restricted in a few sites with high primary productivity, such as the Saronicos and the Thermaikos Gulf, close to the country's biggest markets of Athens and Salonica.
2. Predevelopment phase (1985 to 1990) during which the first pilot longline floating farms were established, creating an opportunity for mass expansion of the activity in Greece. Although mussel cultivation has developed rapidly since then, the full range of methods available and practiced elsewhere in Europe have not been made known on a larger scale. Almost all existing farms today use the Italian method of pergolari hanging, either from fixed scaffolding frames or from floating longlines. "Rope culture," practiced widely in Spain, has no application in Greek waters, although it permits a high degree of mechanization (Askew 1987).
3. Development phase (1991 to 2000) during which research, public, and industrial priorities focused on production elevation that resulted in a rapid increase that soon reached current levels. Techniques were gradually set up to establish complete production systems (suspension culture), to perfect and to scale-up specialized craft (shifting from craft work to pontoons, from modified fishing boats to 10–15 m shellfish boats specialized for longline systems, applying mechanization with mechanical winches). This phase has been generally marked by financial support provided to the farmers, with subsidies and private loans granted by regional authorities and the European Union (Danioux et al. 2000).
4. Maturation phase (2001 to present) during which new aquaculture strategies have been applied to make offshore systems reliable, while lowering production costs (using bigger vessels, 15–20 m long, equipped with star wheels, loaders, mechanical French–type graders, and packing machines), and to achieve economies of scale. This includes the production concentration of large companies or producer organizations (organizations of definitive production structures configuring the profession, organizing the trade, and applying quality schemes and research programs).

The aim of the current work is to demonstrate the major technical and economic achievements of the Greek mussel farming sector to current development, and to highlight the industry's major constraints and most probable risks in an effort to contribute toward sustainability of the sector.

MATERIALS AND METHODS

Data on bivalve shellfish landings and production harvests at a national level are insufficient (Kalaitzi et al. 2007). Discrepancy between different data sets weakens national and

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international data monitoring. Inefficient collecting systems are not a Greek phenomenon concerning fishery statistics in the European Union (EU) (The Economist 2008). Discrepancies resulting from measuring systems (e.g., pergolari vs. packed volumes, license capacity vs. actual production volume, export vs. ex-farm price, number of licensed vs. actively working and producing farms) constitute a major difficulty in the effort to produce reliable statistics objectively. Furthermore, there are issues raised concerning nearshore farming within protected natural reserve areas, rendering uncertain the legitimacy of the hanging park activity. As a result, the official licensing of such farms has been withdrawn. Officials were reluctant to implement the current law and postponed it to be dealt with in the pending implementation of the new Areas Organized for Aquaculture Development (AOAD).

In the current study, an effort has been made to develop an objective data series on production volume and value from 1976 to the present for the main cultured species *Mytilus galloprovincialis*. Context data from national (Greek National Statistic Service; NSS) and international authorities (FAO) were taken into account together with data from structured questionnaires and guided interviews following visits to mussel farms, processing companies, and producers' cooperatives. Periods of production dropped as a result of disease, and other constraints (Galinou-Mitsoudi & Petridis 2000, Galinou-Mitsoudi et al. 2006a) were taken into account.

GREEK MUSSEL FARMING

Industry Distribution

In contrast to the rearing of euryhaline marine fin fish species in Greece (sea bass and sea bream), which were developed in areas within the mild climate of the Ionian Sea, and the central and south Aegean Sea (Protopappas & Theodorou 1995, Wray & Theodorou 1996), mussel farming has expanded mainly in the northern part of the Aegean Sea (Fig. 1). Ninety percent of farms lie in the wider area of the Thermaikos Gulf (Macedonia Region), representing about 80–90% of the annual national harvest (Zanou & Anagnostou 2001, Galinou-Mitsoudi et al. 2006a, Galinou-Mitsoudi et al. 2006b). This is the result of the unique convergence of several large rivers, with currents that

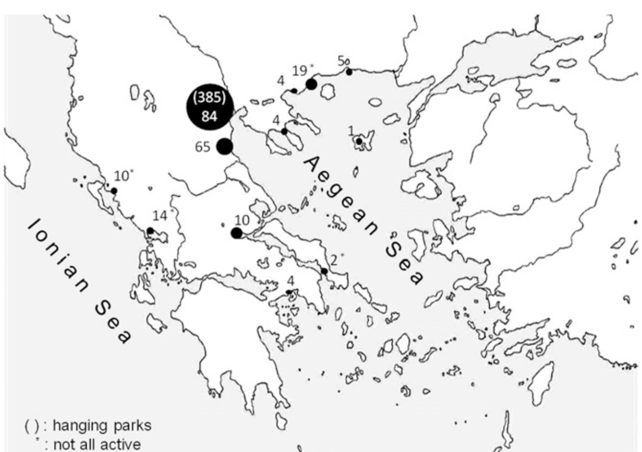

Figure 1. Location of mussel farms in Greece.

continuously move large volumes of freshwater, and thus provide excessive amounts of nutrients that ensure a desirable, high primary production (Karageorgis et al. 2005, Zanou et al. 2005, Karageorgis et al. 2006).

Relatively new mussel farming sites, of lower carrying capacities, are Maliakos Gulf in the central west Aegean (Kakali et al. 2006, Theodorou et al. 2006a, Theodorou et al. 2006c, Beza et al. 2007, Tzovenis et al. 2007) and the Amvarkikos semiclosed embayment in midwest Greece (Ionian Sea). Small farming sites and shellfish grounds are also found in the Saronikos Gulf, East Attica, and Sagiada (northwestern Ionian Sea), and isolated efforts to cultivate limited quantities (50–100 t) of bivalve shellfish were reported in the Fokida (Gulf of Corinth), Limnos, and Lesvos islands (Paspatis & Maragoudaki 2005).

Production Systems

In Greece, there are two production methods mainly in use for mussel farming: the traditional hanging parks, restricted in highly eutrophic shallow areas from 4–5.5 m in depth, and the single longline floating system, suitable for deeper waters (>5.5 m), which is the most popular and widely expanded cultivation method.

Hanging Parks

The method of hanging parks has been applied in shallow waters (up to 6 m deep) as it uses wooden or metallic scaffolding, wedged on a soft bottom, to hang from its nonsubmerged (1–2 m above sea level) mussel bunches. The latter are ropes, which provide space for mussels to attach and grow, that dangle just over the bottom. The overall device is made up of rectangular grids (15×100 m) installed at a certain distance to each other ($\sim$150 m) to allow for sufficient nutrition from the locally thriving phytoplankton (Alexandridis et al. 2008). Productivity per hectare of these systems is usually very high, ranging from 150–400 t live mussels. However, their application in Greece is restricted by the limited available space in suitable sites (shallow soft bottoms, desirable eutrophication levels, ease of access, protection from excessive seawater turbulence, location not in protected natural areas, and so on) (e.g., Karageorgis et al. 2005, Zanou et al. 2005, Alexandridis et al. 2006).

In Greece, a legislation change during 1994 incorporated bills on natural parks and coastal zone protection, and consequently removed the licenses of most of these facilities without involvement of the local authorities in the withdrawal of the facilities. Moreover, because these systems are very productive, and easy and cheap to construct, many farmers, and even unregistered newcomers, have extended these facilities. At times, this had led to serious losses as a result of suffocation or malnutrition of the settled spat (Kochras et al. 2000).

For some farms, the hanging park method is used complementary to their main longline system, supporting installation for the finishing of the product, for spat collection, and for biofoulant removal by lifting the mussel bunches out of the water and exposing them to the air for a certain time.

Single Floating Longline System

The single longline floating system is made up of a series of buoys that suspend a submerged rope ($\sim$1.5 m below surface) from which long mussel bunches are hung (down to 20 m), with the whole construction anchored from its two ends with heavy loads. The longline floating system overcomes the limited availability of space restricting the hanging parks, by expanding the farming activity to deeper waters. This can result in a somewhat lower productivity, ranging from 80–120 t/ha. Typically, a number of parallel single longlines of 100–120 m in length constructed by polypropylene ropes are UV resistant (diameter, 22–28 mm), and they are set 10 m apart and suspended from buoys of 180–200 L, or secondhand plastic barrels. A pair of moorings (3 t each) is used to anchor the floating installation laterally from each longline set to a direction parallel to the direction of the prevailing currents. The right anchor is site dependent (bottom substrate type, current direction), with an indicative ratio between sea depth and distance of anchor of 1:3.

In Greece, the installation of the longline system in the early phase of the sector, was done by placing the anchor off the borders of the licensed area, but recent regulation dictates that anchors should be deployed within the limits of the rented farming space. The current implementation of these rules poses a dilemma for the farmers forced to choose between either rearranging their farms (with the corresponding permanent decrease in capacity) or licensing the extra space needed to expand (with temporary loss of valuable production time by following the necessary administration paperwork, which takes more than a year).

MUSSEL FARMING BUSINESS

Today, in Greece, there are about 218 officially licensed farms for mussel cultivation occupying 375.5 ha. These farms follow the single floating longline technique, because the existing 305 hanging park farms, being placed within protected coastal areas, have had their licenses suspended until a legal formula can be found to legitimize their operation. The evolution of the licenses issued by the Greek authorities for each type of cultivation system is presented in Figure 2A. A significant increase in licenses coincides with election or government changes, which affect policies. Producing farms are plotted against the number of licenses, because it takes time for farms to implement their license. Several licenses remain inactive. Of note, several hanging park farms have expanded after their formal licensing or installed prior to licensing. The total farming area licensed to each farm type from 1976 to 2009 is presented in Figure 2B.

In Figure 3, actual production versus declared production to the authorities (NSS, FAO, Customs) is presented, as data for the latter were either overestimated (declaring merely the official production capacity) or underestimated by farmers. Production rates per hectare differ between the two cultivation systems, with hanging parks being more productive than longline systems. Hanging parks are more productive as a result of the excellent original placement of hanging parks in the most productive spot of the Thermaikos Gulf. After trial and error for the use of approximately 1 pergolari/m^2, the hanging parks achieved an annual productivity of up to 400 t/ha. Such installations represent very small licensed properties, originally 0.1–0.2 ha, because they cannot stretch outward toward the open sea (Kochras et al. 2000, Alexandridis et al. 2008). Cultivation system production varies from year to year and from site to site, because it depends mainly on local annual primary production. Local annual primary production varies according to annual environmental fluctuations and the biogeochemical characteristics of each location, influencing food availability, spawning, and growth patterns

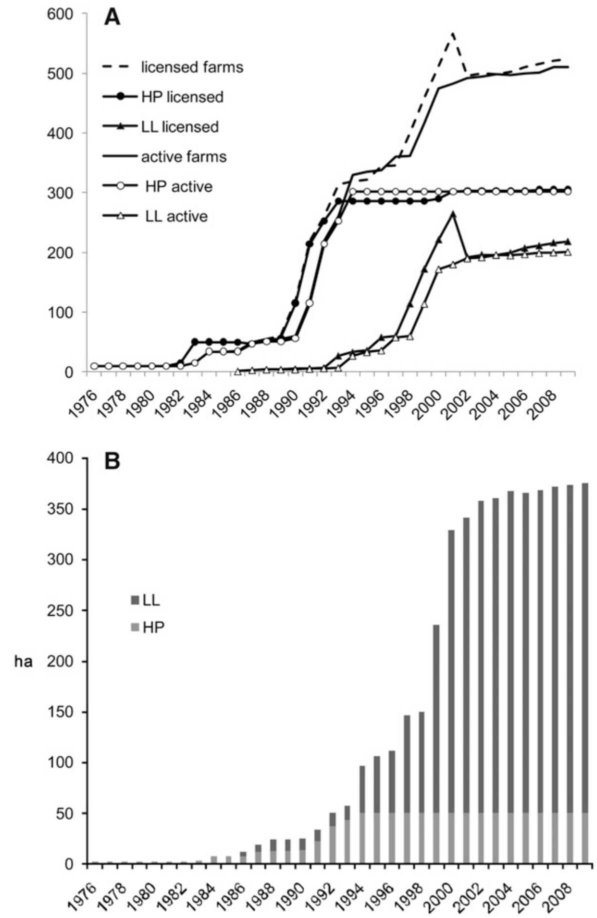

Figure 2. (A, B) Evolution of licenses (A) for mussel farming in Greece and farming area (B). HP, hanging park farm type; LL, single floating longline farm type.

(Rodhouse et al. 1984, Fuentes & Morales 1994, Martinez & Figueras 1998, Ocumus & Stirling 1998, Karayucel & Karayucel 2000, Edwards 2001, Kamermans et al. 2002).

Production Planning

Besides being the most popular cultivation technique in Greece today, the single longline floating system is currently the only one formally licensed, so its production plan is presented in detail here. Nevertheless, the production plan of the hanging parks does not differ significantly, because both techniques follow the life cycle of the local mussel *M. galloprovincialis*.

A fully deployed, floating, single longline mussel farm in Greece has an average production capacity of 100 t/ha/y (live product on a pergolari, biofoulants included) and covers 1 ha with 11 longlines of 100 m each, running in parallel, 10 m apart. The operation cycle each year commences by collecting spat (Fig. 4). Spat collectors of 2–2.5 m long, usually made of common polypropylene ropes (diameter, 12–18 mm), are dropped in the water from December to March at a ratio of 1 collector per 2–3 pergolari scheduled to be prepared at the end of the spat collection period (Theodorou et al. 2006b, Fasoulas & Fantidou 2008). Spat settles normally when it reaches about 20 mm long or 0.8 g, on 1,800 pergolari/ha (Koumiotis 1998), and is ready for harvesting from the end of May until mid July.

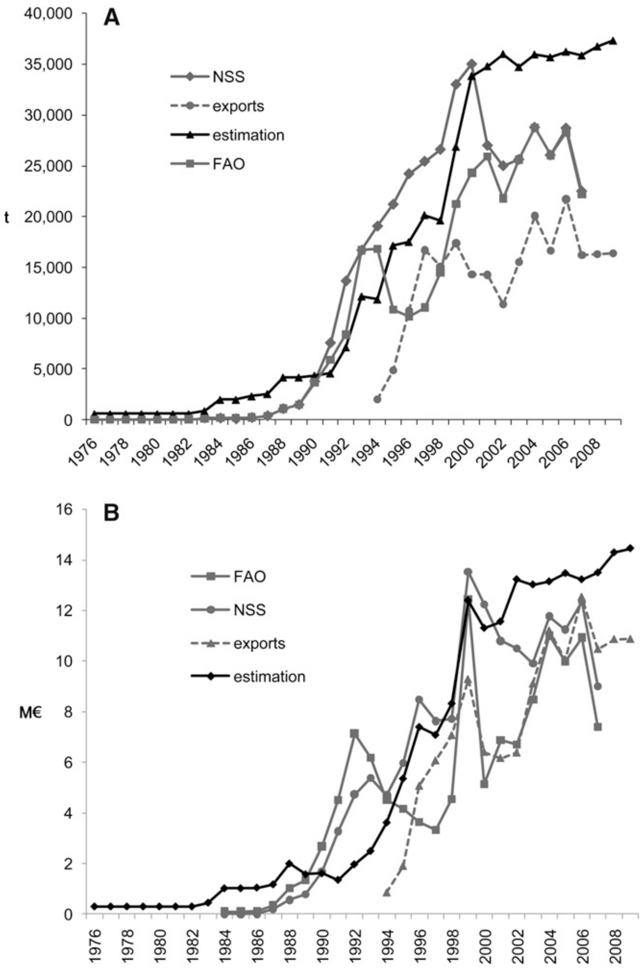

Figure 3. (A, B) Evolution of Greek mussel farming in actual volume (A) and value (B) plotted against declared data from national and international organizations. export, mussel commercial exports according to the Greek Ministry of Development; FAO, Food & Agriculture Organization (Rome); NSS, National Statistics Service (Greek).

The juveniles (>35 mm) are easily detached manually from the ropes, collected, and transferred to pergolari. These are plastic, cylindrical nets, 3–3.5 m long, with a net eye of 60–80 mm attached on a polyethylene rope hung from the single line every 0.5 m (201/100 m line or 5,400/ha). They are formed manually with the help of polyvinylchloride cylindrical tubes with a diameter ranging from 40–60 mm. From August to October, these first batches of seed are graded, again manually, and juveniles are placed into larger pergolari, with net eyes of 80–120 mm, formed using wider tubes 70–90 mm in diameter. A third grading is necessary, if these pergolari get too heavy and risk the loss of many mussels or even the whole bunch. From December to March, new pergolari could be formed using larger holding tubes of 90–150 mm in diameter with a plastic net eye of 105–150 mm, providing more space for the animals. Each tubing increases the survival of the attached mussels, leading to a final 33% of the original seed. In general, this strategy is used by all farmers and is modified at times to suit their local or temporary needs by using different tube sizes or net eyes. This depends on the quality and the condition of the seed stock.

Mussels are ready for the market after a year, when they get about 6 cm long, usually in early summer. At this time, the pergolari weigh about 10–15 kg/m, more than double the weight from their last tubing. The mussel quality at harvest, assessed by condition indices and chemical composition, varies seasonally, depending on the environmental conditions that prevailed during the grow-out period (Theodorou et al. 2007b).

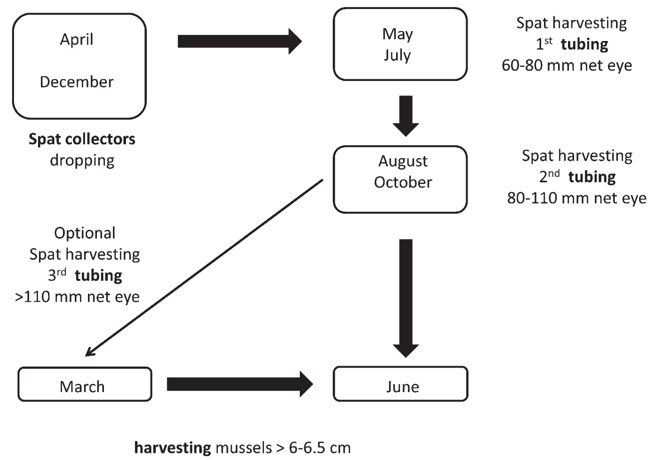

Figure 4. Typical production model of Greek mussel farming.

Production Economics

The profitability of mollusc shellfish farming is the convergence of certain factors such as natural productivity, technical practices, production costs, and product pricing (Mongruel & Agundez 2006). Several efforts to measure the economic performance of the mussel industry in Europe were indicative assessments based on generic estimations and assumptions (Macalister & Partners Ltd 1999) or pooled sampling data (FRAMIAN BV 2009), rather than detailed production economics studies. This was a result of a lack of information availability regarding the sector, especially for less developed countries (Commission of European Communities 2009).

Theodorou et al. (2010), in an effort to analyze the financial risks of mussel farming in Greece, performed a sensitivity analysis on the farm sizes commonly licensed, taking into account the current market situation and modern production practices. Results showed that farm sizes larger than 2 ha are viable, and the cost of new establishments or the modernization of existing ones could be afforded by large enterprise structures. Taking into account that the majority of the mussel farms are rather small (1–2 ha), it was concluded that the sector might need restructuring in larger schemes, such as with producers' organizations or cooperatives, to achieve financial sustainability and to benefit from scale economies. Furthermore, EU and/or national public support (up to 45% of the total fixed cost) is crucial for the viability of the investment. The Financial Instrument for Fisheries Guidance of the European Commission and other programs support new farm establishments, mechanization of existing farms, and improvement of depuration centers. In reality, working capital support is very limited, with no alternative existing to bank loans.

The Cost Structure

A representative investment cost for the establishment of a typical single longline floating mussel farm (1–4 ha) in Greece, ranges from €270,000–360,000 (average cost, €296,600). However, this amount varies depending on the farm size, location (distance from land-based facilities), equipment availability, and prevailing weather conditions in the area. The average cost structure of the industry was estimated using average fixed costs (Fig. 5A) and variable operating costs (Fig. 5B) of typical mussel farms of different sizes (1–4 ha).

The major investment costs (up to 61%) were related to the working vessel (48%) and the grading machines (13%). The floating installations (moorings, ropes, floats, and lighthouses) represented only 25% of the total investment cost, which was affordable for newcomers to the early phase of the sector's development. Other support materials were a car (7%), and a dinghy, (*ca.* 6 m long) with an outboard engine (up to 20 hp) (3%). The license cost was not of utmost significance, because it accounted for only 4% of the total investment. However, access to space and licenses are critical limiting factors, and a problem common to aquaculture development (Commission of European Communities 2009).

The major operating cost, other than fixed-asset depreciation (41%), is labor. Despite mechanization efforts applied recently, the work is still labor intensive, and salaries and wages represent 34% of the total operating cost. Relative labor cost has not differed much from those of other European mussel producers during the past decade (e.g., Italy (Loste 1995) and France (Danioux et al. 2000)). Consumables represent 7% of the total operating costs, including plastic cylindrical nets, packing bags, and polypropylene ropes.

The activity is low energy consuming (4%) and is, therefore, a true ''green'' business. Annual fees for sea rental (3%), maintenance and service (3%), car insurance (1%), and others (7%) sum up the rest of the operating costs.

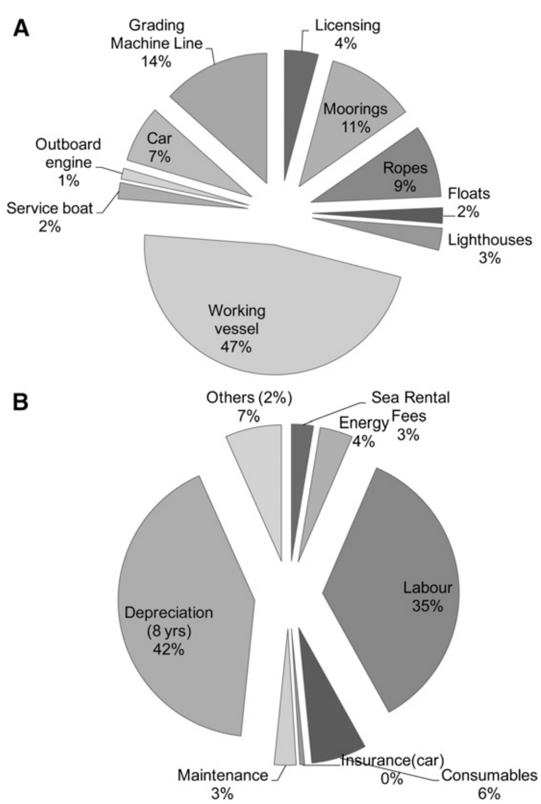

Figure 5. (A, B) Average fixed costs of Greek mussel farms per hectare (A) and average operational costs of 1–4-ha mussel farms (B).

Profitability

Looking at the sensitivity analysis by Theodorou et al. (2010), the break-even prices for profitable mussel farming in Greece are quite high (Fig. 6). Ex-farm bulk prices, however, have remained stagnant for a decade now and are quite low (range, €0.30–0.50/kg) in comparison with other European producers in the Mediterranean (e.g., Italy at €0.65/kg and France at €1.43/kg), according to a study by FRAMIAN BV (2009). Nonetheless, profitability could be improved if new marketing approaches were used to enhance the image of the Greek product.

Marketing

The distribution network from the farm to the fork is presented in Figure 7. Mussels, before they are sent to market, undergo a sanitary control according to Shellfish Hygiene Directives 91/492/EEC and 97/61/EC (Theodorou 2001a). Wholesalers and processors are required to have EU-certified packing stations and purification plans. Today, 22 units are in operation. Except for packing, branding, and selling their own products, these units provide such services to clients in the rest of the chain (producers, distributors, and so forth). Bivalve shellfish can be forwarded to European clients directly after official veterinary inspection, because the packing and processing plants are EU approved. The business of processing fresh mussels for the local market is very limited, because processors focus mainly on cheap bulk imports and repackage to distribute primarily frozen mussels and other value-added product forms.

A special niche market is mussel shucking (33 approved houses)—small, traditional primary-processing enterprises with small shucked/shelling plants. There, live mussel are shucked manually with knives by skilled workers. The mussel flesh is separated by hand and, after being rinsed, is vacuum packed in 0.5–1 kg plastic bags, which are preserved up to 4–5 days at 5°C according to product specifications.

It was estimated that during the 1990s, consumption of this product form reached 1,300 t annually, produced out of approximately 3,000 t of cultured, whole fresh mussels and processed by 20 EU-approved units, almost all family owned (Kriaris 1999). This type of product has a high acceptance rate, especially in the catering sector, because of the ease of handling and its ''natural freshness'' in contrast to the industrial flesh separation with the preheat/steaming process used in the rest of Europe (Kriaris 2001). Shucked mussels are more popular with consumers from urban areas, because these individuals are less accustomed to handling bivalves than those who live along the coast (Batzios et al. 2004). Thus, there is a constant need for the development of new technologies and efficient preservation methods that would extend the shelf life of such products (Manousaridis et al. 2005).

Export Markets

The total export product volume in 2007 (Fig. 8A) was 16,230 t, and value approached €10.48 million (Fig. 8B, data from National Statistic Service). The majority of Greek mussel production has been export oriented, with Italy as its major destination (Fig. 9), which received about 50% of the total

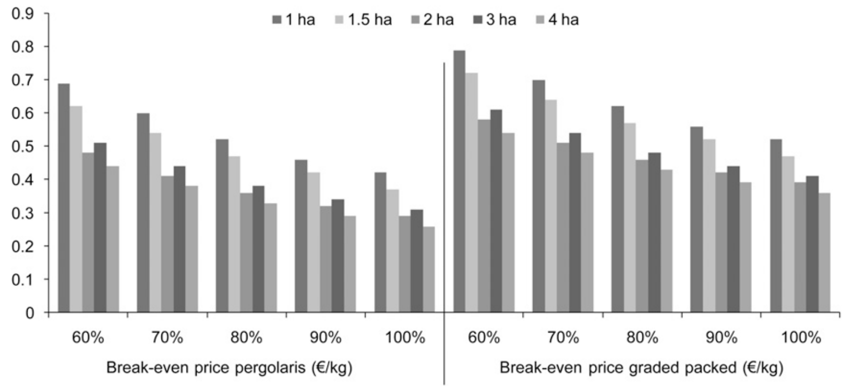

Figure 6. Break-even price for Greek mussel farm profitability depending on different farm size (1–4 ha) and different production effectiveness (percent of annual production capacity).

export volume of live product (~7.8 t), followed by France (33%) and Spain (14%). Countries such as the Netherlands, Romania, and Germany are niche spot markets absorbing limited quantities (Fig. 9).

European wholesalers, through local representatives or agents, mainly 6–7 big Greek producers and commercial enterprises, collect the amount of mussels required to load a truck (up to 20 t). The product form is fresh mussels either raw (2–3.5 m whole pergolari) or declumped mussels, graded and packed in 10-kg plastic net bags without any further processing. Modern grading equipment with brushes (French–type grading machines), capable of cleaning and grading 10 t of live mussels per day, gradually replaced the old-style cylindrical graders of limited capacity, because farmers can load a truck faster with live product for immediate transport.

A common practice is reimmersion in seawater of the 10-kg bag-packed product within the farm's offshore area for several days. This procedure provides a quick recovery from the grading stress and improves the animal's strength for transport; it also provides alternative handling during a harvest ban resulting from harmful algal blooms (HABs). The packed product form was introduced during the early 2000s as an effort to salvage live mussels, by withdrawing them from overweighted pergolari, during officially imposed long-term harvest bans resulting from HABs. In 1999, this caused extensive damage to the industry.

Mussels stored under normal air are transported within 3 days maximum to their final destination where, ideally, they get reimmersed in seawater for 3–4 days to recover prior to being retailed. Before going into the market, all shellfish are tested following Shellfish Hygiene Directives 91/492/EEC and 97/61/EC. When the retail centers are far from the coast, as is the case for the main shellfish markets of Brussels, Madrid, Paris, and Rome, the seawater reimmersion stage cannot be applied; therefore, shellfish should be transported at low temperature as fast as possible to reach the retailers within 2–3 days (Angelidis 2007).

Greek Market

Despite the presence of a wide range of shellfish species in the Greek seas, there is an obvious lack of tradition among Greeks for consuming shellfish species (Batzios et al. 2004). Apparent consumption based on data from 1999 to 2001 showed that shellfish molluscs (mussels, oysters, clams, and so forth) were

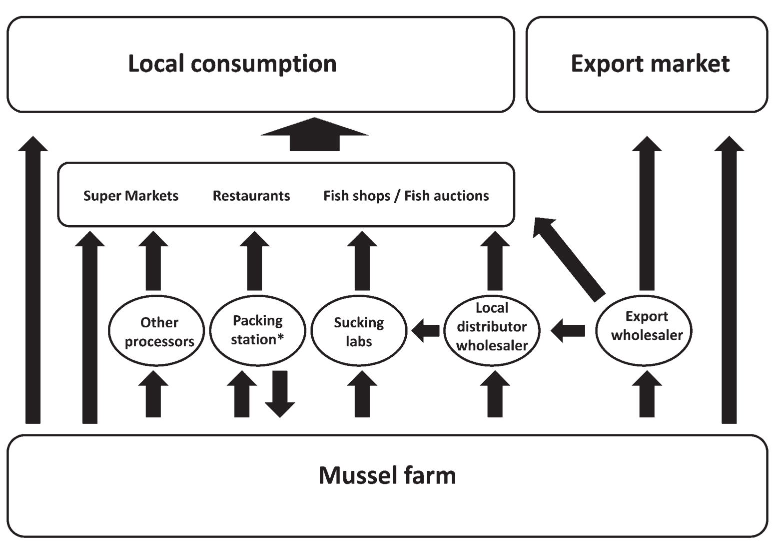

Figure 7. Market structure of Greek mussel farming.

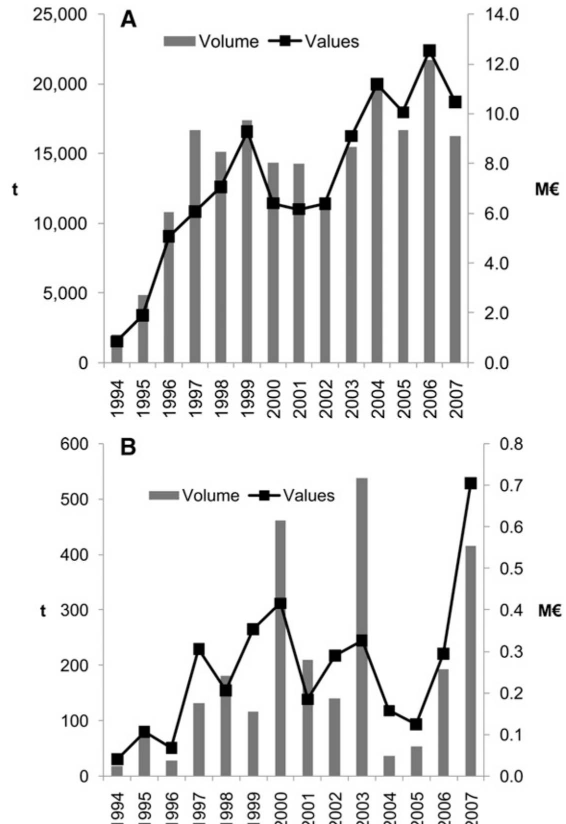

Figure 8. (A, B) Evolution of Greek mussel export (A) and import (B).

0.70 kg/capita annually at a total of 14.33 kg seafood/person (Papoutsoglou 2002). Most Greek consumers do not know how to cook bivalves and ignore their high nutritional value. Consumer reluctance was strengthened after poisoning incidents occurred during the 1950s, caused by shellfish harvested from polluted shipyard areas (Theodorou 1998).

People living close to the farming sites in northern Greece are more familiar with bivalve consumption. Galinou-Mitsoudi et al. (2007) reported on bivalve shellfish consumption in the city of Thessaloniki. Among native species consumed in local restaurants, mussels (93.75%) were the most popular, with the remaining shellfish types being consumed in small percentages (warty venus *Venus verrucosa* Linnaeus 1758, 2.68%; flat oyster *Ostrea edulis* Linnaeus 1758, 1.79%; and scallops *Chlamys glabra* Linnaeus 1758, 1.79%). Selection criteria seemed to be based on the lower price of the farmed mussels in contrast to wild-harvested species of limited availability.

Because farmed mussels are usually consumed live or fresh, their distribution to southern Greece or the Greek islands cannot be effected by usual fresh product transport logistics (such as those used for fish), because of the uncommon temperature (6–12°C) and handling requirements (plastic net bags) that disproportionally raise the distribution cost, especially for small quantities. Alternatively, fresh bivalve shellfish are distributed by the farmers or the fishermen by their own means of transportation. The competition for clients (restaurants, fishmongers, and so forth) among the different distributors depends on the availability and continuity of supply for wild-harvested species. Mussels in this context are sold in a complementary manner, because they are the basic product of the "special" niche market of bivalve shellfish.

Market interaction between wild and cultured bivalves, based on detailed statistics for the wild shellfisheries, needs further investigation, because recent reports on the latter show a considerable decline of catch (~700 t in 2005 vs. 7,000 t in 1994 (Koutsoubas et al. 2007)). This situation is clearly depicted in the local oyster sector state with negligible exports during the past decade (Fig. 10A) and an annually import volume ranging from 20–35 t during the same period (Fig. 10B). Fresh bivalves also have competition from imported frozen and processed products, with the advantage of easy-to-use packaging at a reasonable price. In 2005, 3,496 t of mussels in various product forms, mainly of added value, were imported, with a total value of €12.3 million The situation changed in 2007 as

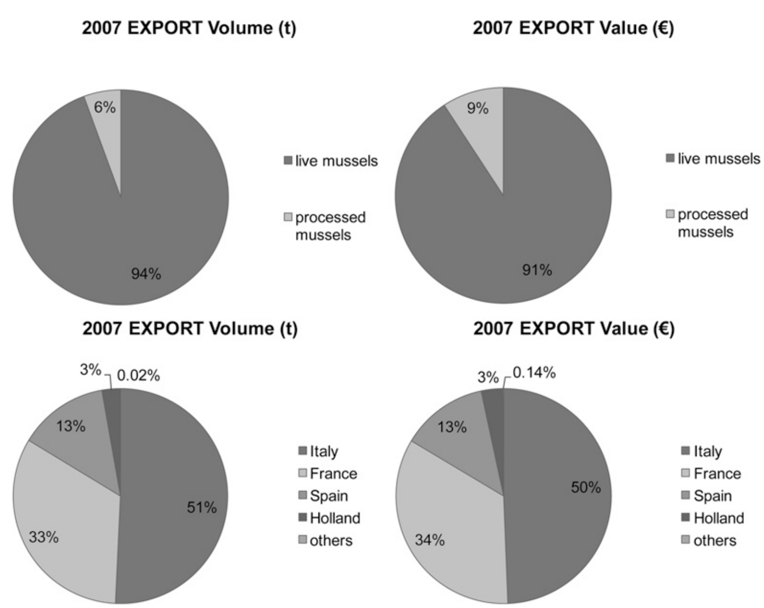

Figure 9. Analysis of the Greek export market for 2007.

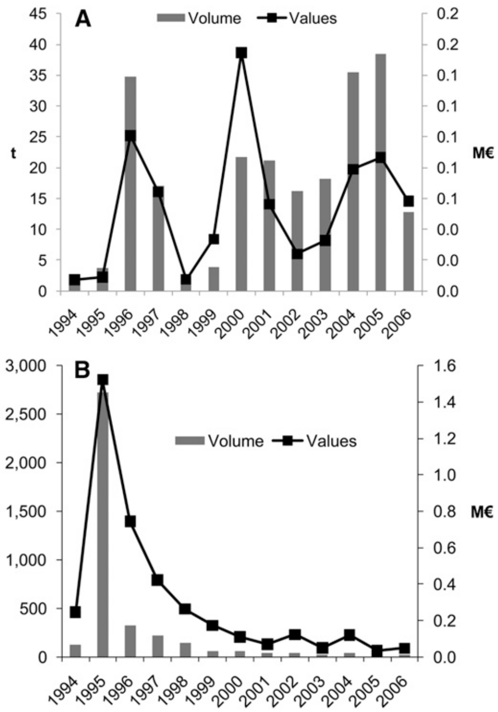

Figure 10. (A, B) Evolution of the export (A) and import (B) market of oysters in Greece.

imports of live product (almost all imported from Italy and Spain; Fig. 11) were 5 times higher and processed mussel products 5 times lower than in 2005. Overall figures were much lower, with live and processed mussels about half in terms of volume and less than one third in terms of value compared with 2005. Data were unavailable for mussels packed in air-tight packages, reaching 2.6 t in 2005.

In Greece, mussels are exported as raw material and imported as highly priced value-added products of a smaller total volume (Figs. 11 and 12). The negative balance between the exported and imported volumes of processed mussel products, despite the capacity of the local farming for it, implies that the Greek industry should move to more value-added products to compete with imports in the local market. Based on the trend of the farmed mussel market depicted in Figure 12, it is evident that the local market is currently at a standstill. Products not exported are forwarded locally to a small number of restaurants, fishmongers, retail chains, or seafood auctions, with public consumption restricted to specialty seafood restaurants and local ''tapas''-like bars (Fig. 7).

In brief, the domestic mussel-selling business is obviously in need of better marketing approaches. Sales could be improved by educating Greek consumers on shellfish matters (Batzios et al. 2003) and investing in product promotion in the local market. Because the per-capita consumption of seafood products increased during the past decade (Papoutsoglou 2002, Batzios et al. 2003, Arvanitoyannis et al. 2004), bivalves could potentially have a better share of this consumer trend.

Employment

Mussel farming in Greece during the past decade provided 1,500 full-time jobs in the production sector and another 500 in the shucking houses. During the peak production season, about 500 part-time positions were covered by the local communities (Giantsis 1999, Sougioultzis 1999). Because the number of farms has not changed significantly in recent years, no large changes are expected for these figures today. Labor is usually not a problem in the major production areas of northern Greece, because, despite the seasonality of production, jobs are offered year-round. In contrast, in areas with few or isolated farms, labor is a problem because of the seasonality of the job demand. As a result of the fact that the majority of the farms are rather small and the job positions are seasonal, the work is not attractive to employees. As a result, most of the workers in mussel production seek a supplementary and secure income from off-farm employment (agri-farming, commerce, services). The same approach is

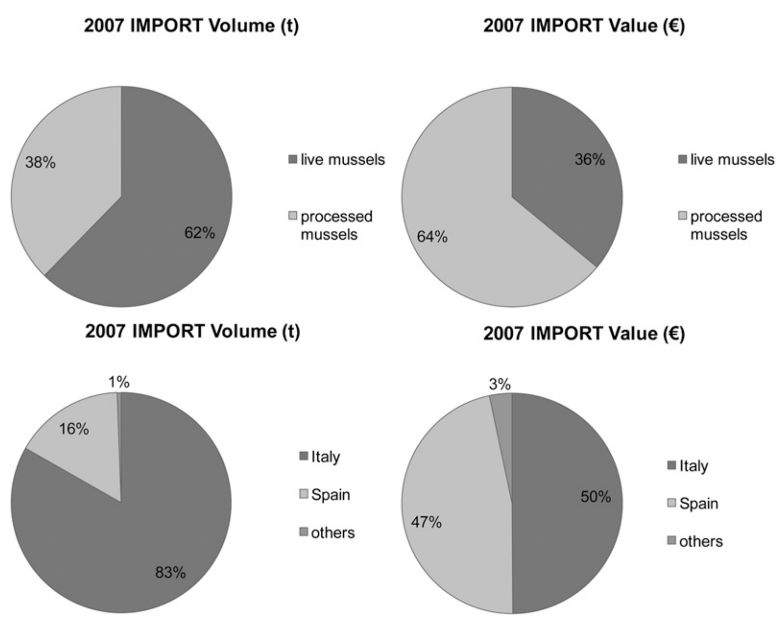

Figure 11. Analysis of the Greek mussel import market for 2007.

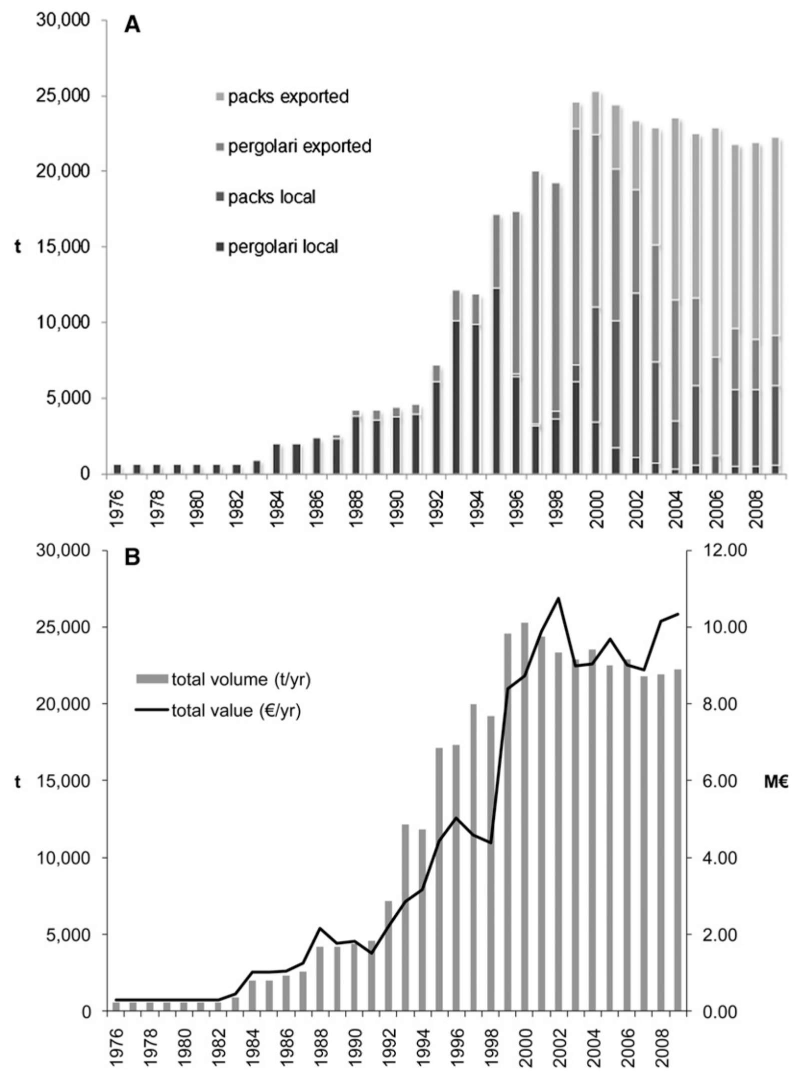

Figure 12. (A, B) Evolution of production volume (A) and market value (B) of Greek mussel farming based on different practices and ex-farm market prices. Packs, product packed in 10-kg sacks; pergolari, an entire mussel bunch, including biofouling; local, product consumed locally.

followed by mussel farmers to reduce their financial risk exposure or off-farm investments (e.g., agri-tourism, stock market). Available labor is not always suitable, because skilled and experienced laborers are found primarily in the main production area. No special legislation exists for mussel farm workers other than the usual certificates for driving a car or a boat (engines more than 25 hp); additional skills are required for safety use of a marine crane or a forklift. Food handling and even swimming work accidents do happen, especially when immigrants from countries that lack any tradition in marine life are employed.

Licensing and Legislation

The licensing system of mussel farming in Greece is described in Papoutsoglou (2000) and is similar to sea bass/seam bream cage farming (Papageorgiou 2009). Strong interest from other competitive activities, such as urbanization and tourism, for coastal space and natural resources progressively restrains mussel-farming activity. Lack of integrated coastal zone management (Kochras et al. 2000, Zanou et al. 2005) amplifies occasional water-quality problems generated from nutrient overloading by agriculture, sewage plants, freshwater discharges, and so forth (Karageorgis et al. 2005, Karageorgis et al. 2006). This also can be generated by confusion over usage priorities of certain sites. Another issue is the application delay by veterinary authorities of the existing legislation on zoo-sanitary health status identification and, consequently, continuous monitoring of each site. As a result, unauthorized shellfish movement still occurs, thus increasing the risk for disease transfer from site to site.

To manage mussel production appropriately and to maintain or improve the environment of farming sites, the Greek government has proposed to organize the activity within AOAD. Legislation for AOAD implementation would make provisions for water pollution control, rational space management, wildlife protection, and so forth, and would secure both the sustainability of the mussel farming environment and public health. Although the concept of such aquaculture parks was welcomed by farmers, its practical application has been delayed. The concept faces a lot of problems regarding the development of the correct structural management scheme for a certain area, the development of supporting infrastructures, and a lack of knowledge regarding the production and ecological capacity of each site. Furthermore, the concept also faces strong local opposition by rival groups (environmentalists and tourism or urbanization investors). Moreover, industry stakeholders raise concerns on costs that might be superimposed on the normal farm operation resulting from potential site shifts and extra facilities or equipment required for water monitoring, product purification, depuration, personnel welfare, and so on. In fact, strict rules for environmental monitoring and sophisticated zoo-sanitary handling may not be affordable by small farms.

This raises the question of how to protect consumer health without asking the farmer to pay for it, as normally the product gets contaminated by third parties (industrial, agricultural, or domestic effluents; ballast waters; and so forth). An idea to solve this would be the strict application of the concept that "those who pollute, pay" through integrated coastal zone management, thus raising the necessary funds for supporting depuration actions (CONSENSUS 2005).

CONSTRAINTS AND RESEARCH AND DEVELOPMENT

The Greek shellfish sector reached maturity in terms of volume growth during the past decade. Today, the priority is to deal with the constraints that threaten or hinder the sustainability and financial viability of the sector. Research and development priorities should, therefore, deal with enhancing growth within the available space; protecting production from environmental stress, disease, or biotoxins; and improving product quality and marketing.

Stock Selection

Because the aquaculture for most of the bivalve species is still capture based, it depends on wild stock availability. In general terms, each year (if there is no environmental crisis resulting from major weather or anthropogenic events), production ranges within grossly anticipated limits. To surpass these limits research must focus on either enhancing the collection of the available spat or on improving the genetic capacity of the seed. Seasonal trials with spat collectors at several depths (Theodorou et al. 2006b, Fasoulas & Fantidou 2008) showed that improvements are possible, but efforts must continue to achieve the maximum exploitation of each site without causing adverse shifts in the natural food web. A difficult subject is the normally unauthorized transfer of stock from one farm to the other, especially between very different locations or countries. This opportunistic behavior might garner occasional extra income for the farmer, but it puts the health of his own stock and of his territory in general at stake.

Thus, there is a need for installing experimental hatcheries that work with broodstock to enhance seed quality. Strong commercial interest for the continuous market supply of high-value shellfish species induces further research on fisheries and wild stock management (Galinou-Mitsoudi & Sinis 2000, Galinou-Mitsoudi 2004). Market diversification and restocking necessities may promote potential cultivation efforts (sea ranching) in the near future, despite the restrictions associated with space availability.

Product Shelf Life Extension

The majority of Greek mussels are sold live, kept on ice, with small quantities shucked, packed with tap water in polyethylene bags, and refrigerated. In either case, the shelf life lasts 6–7 days maximum. As mentioned earlier, the export of these products faces a critical time constraint because transportation to major markets takes at least 24 h and may be as long as 3 days (Angelidis 2007). Therefore, Greek exporters should extend the shelf life of their product to further their position in the foreign market. Modified-atmosphere packaging (MAP) technology may solve the problem. Although its application was limited in the past (Pastoriza et al. 2004), new development techniques indicate that shucked mussels packaged in plastic pouches under MAP and refrigerated could significantly extend shelf life by about 5–6 days (Goulas et al. 2005). Goulas (2000) tested a range of MAP under refrigeration and concluded that a mixture of CO_2:N_2:O_2 at 3:1:1 (v/v) preserves samples for ~10–11 days with an acceptable odor. A 35% extension in shelf life (11–12 days) of fresh mussels was reported by Manousaridis et al. (2005) for shucked mussels (*M. galloprovincialis*) that were vacuum packed and refrigerated in an ozone-saturated aqueous solution ("ozonated" for 90 min) under conditions that need additional optimization. Vasakou et al. (2003) added sodium lactate and potassium sorbate to the meat of Greek mussels. Chilled storage in pouches with water demonstrated no change in chemical decomposition indicators. Kyriazi-Papadopoulou et al. (2003) used salting technology to expand the life of Mediterranean mussel meat products that underwent vacuum packing and chilled storage. Turan et al. (2008) later reported up to 4 months of shelf life extension for similar trials. However promising all these efforts might sound, further research is required to provide applicable cost-effective processing of the live product tailor made to meet consumer expectations and producer/processor demands. A positive recent development is the strong interest expressed by the frozen and canning fish sector, which might speed up R&D.

Environmental Interactions

Most of the mussel farming sites are located in front of river deltas, which are characterized as natural reserves. Current research focuses on the environmental interactions of the biotic and abiotic factors within the activity (Galinou-Mitsoudi et al. 2006a, Kakali et al. 2006, Beza et al. 2007; Theodorou et al. 2007a, Theodorou et al. 2007b). The carrying capacity of the farming sites needs to be assessed and classified to manage the hosting ecosystems efficiently.

In this context, and in view of the potential variability induced by global climate change, special attention must be paid to bivalve shellfish spat recruitment and population dynamics. Besides the work on Mediterranean mussels, *M. galloprovincialis* (Theodorou et al. 2006a; b; Fasoulas & Fantidou 2008), reports on other high-value commercial species in Greek waters were published for the native flat oyster *O. edulis (*Virvilis & Angelidis 2006), warty venus *V. verrucosa* (Arneri et al. 1998), European native clam *Ruditapes* (*Tapes*) *decussatus* Linnaeus 1758 (Koutsoubas et al. 2000, Chryssanthakopoulou & Kaspiris 2005a, Chryssanthakopoulou & Kaspiris 2005b), smooth scallops *Chlamys varia* Linnaeus 1758 (Tsiotsios 2008) and *Flexopecten glaber* Linnaeus 1758 (Lykakis & Kalathakis 1991, Tsiotsios, 2008), and the lagoon cockle *Cerastoderma glaucum* Poiter 1789 (Leontarakis et al. 2005, 2008). Reports also exist for bivalves of minor commercial interest, including the bearded horse mussel Linnaeus 1758 (Virvilis et al. 2003), the smooth clam *Callista chione* Linnaeus 1758 (Leontarakis & Richardson 2005), the Noah's ark *Arca noae* Linnaeus 1758, and the razor shell (*Ensis minor* van Urk 1964, *Ensis ensis* Linnaeus 1758, and *Ensis siliqua* Linnaeus 1758) (Galinou-Mitsoudi & Sinis 2000, Katsanevakis et al. 2008). In addition, reports exist for bivalves characterized as endangered species, such as the fan mussel *Pinna nobilis* Linnaeus 1758 (Katsanevakis 2005, Galinou-Mitsoudi 2006b, Katsanevakis 2006, Katsanevakis 2007), and the European date mussel *Lithophaga lithophaga* Linnaeus 1758 (Galinou-Mitsoudi & Sinis 1994, Galinou-Mitsoudi & Sinis 1997a, Galinou-Mitsoudi & Sinis 1997b).

The spatial distribution patterns of bivalve species considered to be nonindigenous, such as the subtropical pearl oyster *Pinctada radiata* Leach 1814, have to be monitored, especially in the context of the eastern Mediterranean warming (Galil 2000, Galil & Zenetos 2002, Gofas & Zenetos 2003, Streftaris et al. 2005, Streftaris & Zenetos 2006, Yigitkurt & Lok 2007, Theodorou et al. 2008).

Diseases

Infections by the protozoan parasite *Marteilia* sp. have been diagnosed in several bivalve species of the Thermaikos Gulf during the previous decade (Karagiannis & Angelidis 2007). *V. verrucosa* and *Modiolus barbatus* were not affected by the parasite (Virvilis et al. 2003), but most probably decimated the local population of *O. edulis* and led its fishery to a halt in 1999 (Angelidis et al. 2001, Virvilis et al. 2003, Virvilis & Angelidis 2006). The population of *M. galloprovincialis* in the same area has been also infected (Photis et al. 1997, Virvilis et al. 2003), with the parasite affecting the "scope for growth" physiological index (Karagiannis et al. 2006). Although mussel production in local farms was negatively affected at times (Galinou-Mitsoudi & Petridis 2000), it has not inflicted a dramatic drop in the overall mussel production of the site.

The parasite has been detected only recently in Greek waters and is believed to have been introduced in the Thermaikos Gulf through oysters fouling ships, being transferred by their ballast waters, or through infected oysters illegally imported to the site (Karagiannis & Angelidis 2007). Therefore, the containment of the parasite in the site is of upmost importance and could be implemented by imposing strict quarantine rules to avoid the transfer of local stocks to other locations. The Greek Ministry of Agricultural Development and Food, following a recent presidential decree (article 5, PD28/2009), rules that all farms must be evaluated for animal diseases to control their potential spread to other sites. The full life cycle of the parasite in local waters has not been identified yet, because it uses an unknown intermediate host, most probably a copepod (Audemard et al. 2004). Nevertheless, the cultivation of mussels in deeper waters with the single longline floating method seems to have an advantage, in terms of marteiliosis, over the hanging parks established in shallow waters (Karagiannis & Angelidis 2007). This raises the issue of what is in store for the future of these farms.

Harmful Algal Blooms

Extensive or semiextensive aquaculture systems like mussel farming are more sensitive to production-independent risks (e.g., weather, pollution, predators, harmful algal blooms) (Theodorou & Tzovenis 2004), because they are vulnerable to regional or interregional mismanagement of natural resources (Theodorou et al. 2006c). Biotoxins generated as a potential defensive mechanism by noxious phytoplankton species affect nearshore aquaculture of primarily bivalve species on a global scale (Hallegraeff 2003). In Greece, *Dinophysis* spp. and, to a much lesser extent, *Prorocentrum* spp. have been identified as being as responsible for considerable diarrheic shellfish poisoning (DSP) incidents in certain occasions and certain locations during the past 20 y (Koukaras & Nikolaidis 2004). The first DSP outbreak, which occurred January 2000 in Salonica, resulted in the hospitalization of more than 120 people and was caused by contaminated mussel consumption from the nearby farms in the Thermaikos Gulf (Economou et al. 2007).

In 1999, a national program for biotoxin monitoring was initiated for regular monitoring of the waters of all coastal aquafarms in Greece in adherence to the then-EU directive 91/492/EEC and, later, the updated 853/2004/EC. The National Biotoxin Reference Laboratory (NBRL) was, at the same time, founded in Salonica to support the actions. Before harvest, all farms send water samples to the NBRL for detection of potentially toxic strains of phytoplankton. In addition, no mussels may be transferred from any farm without certification from the authorities after samples are analyzed by bioassays in NBRL for biotoxin contamination (DSP, ASP, PSP). If samples are contaminated or there is a good chance for developing an HAB incident based on analysis results, a harvest ban is imposed on the entire farming area until samples are clean again.

Karageorgis et al. (2005, 2006), in the context of developing an integrated coastal zone management scheme for the Axios River delta (in the Thermaikos Gulf), which has one of the most prominent mussel-farming sites, calculated the value of annual losses resulting from HABs to be about €3 million, assuming a per-year total production of 30,000 t (pergolari). The authors constructed 3 plausible scenarios for assessing the potential economic impact of the proposed actions to alleviate the negative effects: business as usual, policy targets, and deep green. The corresponding results highlighted the high probability of losses for the business-as-usual scenario, or €2.4 million average annual losses; compared with the deep-green scenario, with a 0.2 probability or €0.6 million in losses; and with the policy-target scenario, with a 0.65 probability and €1.95 million in losses). Although the sector has existed for more than 3 decades, it is neither insured by governmental funds nor by private insurance companies for potential losses. Because the option for such support would strengthen the long-term financial viability of the sector, a relative survey for risk assessment and management should be carried out as soon as possible to offer incentives and, potentially, to mobilize stakeholders in this direction.

DISCUSSION

Greek mussel farming has become an extensive aquaculture sector with an established status within the past decade. Nevertheless, Greek mussel farmers are still far more interested in production issues than in the commercialization of their product. Their attitude could be explained by the fact that the majority of them, unlike fish farmers, are of rural origin and are traditionally involved with agriculture and fisheries. These farmers have been trained more or less empirically for the job. As expected, their comprehension of the local and, especially, export market is limited. They focus on the technicalities of their production and how to improve their infrastructure. The situation is not unique; the same behavioral pattern has been described for Norwegian blue mussel farmers (Ottesen & Gronhaug 2004). Nevertheless, marketing improvement of the product is essential for farmers to sustain their profession in the future. During the late 1990s, more than 70% of the global mussel volume was produced in EU countries and showed a remarkable stability, with a small annual increase of 1% forecast for consumption and a small annual increase of 0.7% forecast for demand (Macalister and Partners Ltd 1999). Recently, however, although not yet a threat for the local farmers, New Zealand (*Perna* sp.), China (*M. edulis* Linnaeus 1758), and Chile (*Mytilus chilensis* Hupe 1854), which availed themselves of improved transportation and limitations in local supply resulting from declining local spat availability and HABs, found a market niche and have gained a significant market share in live and processed product each year (CONSENSUS 2005).

Greek mussel farming, despite recent modernization, is still labor intensive. Much of the labor cost is unpaid because of the active participation of the farmer and his family in the working routines. The FRAMIAN study (2009) estimated a contribution of labor of 40% of the total operational cost, excluding capital depreciation costs. Only 12.5% of the labor cost was paid to nonfamily personnel, with a total number of engaged persons of 2.5 per farm. These values were different from other developed industries in the Mediterranean that reveal a different cost pattern (resulting, probably, from a number of structural differences such as professional tradition, code of practice, and so forth). Spain, for instance, engages a similar number of persons per farm (1.15) and shows a of labor cost allocation of 52% of total operational costs, whereas Italy engages 8.3 persons per farm and shows a much higher labor cost of 65%. According to the study by Macalister and Partners Ltd. in 1999, production costs for the large, traditional European mussel producers were likely to remain stable. In contrast, in other countries like Greece, with a developing sector, restructuring toward scale economics was most likely (Anonymous 2000). Development of new structural functions such as producer organizations could suppress the production cost by targeting on scales. Nevertheless, major drawbacks might prove the organizational behavior of the sector (Theodorou 1993, Zanou et al. 2005) is governed by the individualistic mentality of the Greek mariculturist (Etchandy et al. 2000).

Besides cost structure differences, mussel farming in Greece achieves ex-farm prices constantly lower than in other European producer countries. Selling price is influenced by variations in the output of other European producers. In the future, this discrepancy may be corrected.

Expansion of Greek mussel farming in the foreseeable future is limited because of space availability restrictions. Hence, the sustainability of the sector requires restructuring toward economies of scale, an emphasis on value-added products, and technology development for extending the shelf life of the final product. Greek producers should also adopt more sophisticated methods for quality control (Theodorou 2001b) and marketing (Batzios 2004). This combination is not only a must for penetrating new markets, but is also necessary for enlarging existing ones.

Special emphasis should be put on the local market that, if widened, could offer larger overall profit to farmers. This would result from expanding the selling volume and from better prices in the local market. It would also provide a secure ground for the farmers (or farmer organizations) to take more risks in production expansion and, especially, diversification.

A first step could be participation of the sector in generic promotion campaigns for Greek trademarked food products, like aquacultured fish, olive oil, ouzo, wine, and so forth, to minimize the costs of such an attempt. A good strategy also could be to invest in advanced marketing channels, abandoning the traditional wholesale system by differentiating the product, either by processing or by branding it in a quality scheme (Theodorou 1998).

Mussel farming activity has to be communicated to the public as a true "green" one, as it promotes labor within the coastal populations without significant energy input or pollution drawbacks. At the same time, farmers themselves must become habitat keepers, thus preventing anthropogenic environmental pollution from local inhabitants. The establishment of an environmental code of conduct and support of ongoing research of environmental issues of the activity could strengthen the image of the industry. If successful, the campaign might convert the, thus far, negative opinion of the Greek public versus the product's safety by promoting the idea of a certified natural product from a closely monitored, clean marine environment. Additional arguments in this line could be favoring the carbon footprint, nearshore water denitrification, and extractive ecoengineering actions of the industry (Lindahl et al. 2005, Lindahl & Kollberg 2009).

Mussel farming, as a primary production sector, does not appear very promising for bankers. Because of this fact, financial viability of the venture depends heavily on EU funding schemes for assets to share the investment risk. In addition, farmers use personal deposits and use themselves in alternative activities to complement their cash flow when in need.

For the time being, no insurance policy exists for this sector. As a consequence, there is no support to compensate for losses, rendering the business vulnerable to operational risks. A thorough mussel farming risk assessment should be carried out to delineate all aspects needed by private companies, banks, or the government to formulate a valid plan for operational risk management of the sector. Meanwhile, special programs, providing training in labor and environmental safety procedures, may improve the risk management of the farms and thus decrease losses.

CONCLUSIONS

1. Greek mussel producers focus more on production technology rather than commercialization of production.
2. Mussel farming in Greece, despite recent modernization, is still labor intensive. Production costs follow the same pattern as in other European countries, although selling prices in Greece are always less.
3. The business expansion margin is low because of the limited availability of suitable space.
4. Sustainability of the sector may benefit from scale economics.

5. Profitability may increase if emphasis is given to diversification of value-added products and to product shelf life extension.
6. Profitability may increase by strengthening sales in the local market.
7. Sustainability may benefit by communicating to the Greek public the ecofriendly character of the activity.
8. EU investment risk sharing has proved crucial for the viability of the sector.
9. No policy yet exists to provide support of operational risks.
10. Further modernization initiatives should comprise incentives for training, work safety, and environmental management.

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