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RISK FACTORS AFFECTING THE PROFITABILITY OF THE MEDITERRANEAN MUSSEL (*MYTILUS GALLOPROVINCIALIS* LAMARCK 1819) FARMING IN GREECE

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ABSTRACT Public support of mussel farming in Greece is an important factor because of its financial viability. The profitability of the activity is seriously reduced in small farms (1–3 ha) as a result of their high production costs; however, small farms represent a major part of the industry. Mussel farming is an extensive activity, with space availability regulated by public administrators via licensing of marine cultivation area property rights. The available space, though, is limited and, consequently, impedes any future expansion, restricting the production capacity of small farms. Nevertheless, the cost of new establishments and the modernization of existing ones (suitable boats, grading equipment, and so on) is affordable only by the larger companies. For small farms, it seems harder to recruit the large labor teams needed to work on a seasonal basis because this is the optimum to effect least operational costs, as shown by sensitivity analyses. In conclusion, for financial sustainability this sector needs to be restructured and organized into larger schemes, such as with producer organizations or cooperatives, to achieve economies of scale.

KEY WORDS: Mediterranean mussel farming, *Mytilus galloprovincialis*, economics of scale, financial risks, Greece

INTRODUCTION

Mussel farming in Greece is a relatively new industry and is focused on rearing the Mediterranean mussel *Mytilus galloprovincialis*. Mussels are filter-feeding animals that depend on natural primary productivity for their growth and development, competing for the capture of phytoplankton, microbes, and detritus in the water column. Currently, mussel culture systems are extensive in their nature worldwide. Farmers use ropes to provide a controlled substrate on which the mussels can settle and grow in a select, highly eutrophic site nearshore. In Greece, the availability of such suitable places is limited, so the specific site and the occupied space play very important roles in the financial success of a mussel farm and its sustainability.

Development of the mussel culture sector in Greece occurred after the successful introduction of the ''innovative'' single-longline floating technology during the mid 1980s (Theodorou et al. 2011). In contrast to the sea bass/bream industry—the major marine farming activity in Greece, with large flexibility for site selection (Theodorou 2002)—there is a limit to the expected expansion of the mussel sector imposed by the small number of suitable estuaries or closed bays. Mussel farms currently occupy a sea surface of 3 ha on average (ranging mainly from 1–5 ha), producing up to 100 t/ha. The annual mussel production in Greece ranges from 25,000–40,000 t, with close to a maximum of 45,000–50,000 t projected for coming years.

The Mediterranean mussel farm industry in Greece is mainly an export-oriented activity based on the production of ''raw material'' for the processing and distribution networks of major consumer countries in Europe. However, structural problems in Greek mussel farming, such as poor marketing and lack of organized dispatch centers or purification plants, may put at risk the profitability of relatively small farms (Theodorou & Tzovenis 2007). In addition, the pending new legislation for site reshuffling in ''Areas for Organized Aquaculture Development'' might increase production costs by imposing additional expenses to it (increased fees, monitoring intensification, and so on). This new legislation may also impose additional investment costs—for example, relocation or new equipment purchase (monitoring, safety, and so on)—and may create conflicts with other coastal zone stakeholders (urbanization, tourism and so on) (Papoutsoglou 2000, Kochras et al. 2000, Theodorou 2001, Zanou et al. 2005, Karageorgis et al. 2005, Karageorgis et al. 2006, Konstantinou et al. 2012). On the other hand, environmental problems such as harmful algal blooms, insufficient environmental monitoring systems, predation by aquatic animals, or shortened rainfall periods may increase the risks of the farming operations (Theodorou & Tzovenis 2004, Theodorou et al. 2012, Vlamis et al. 2012). The current situation of Greek mussel farming, therefore, calls for more sophisticated managerial approaches and possibly an overall restructuring of the sector.

In European terms, available information on the mussel culture industry does not allow for the assessment of a sector's economic performance (Commission of European Communities, Brussels 2009). A relatively recent European survey (FRAMIAN BV 2009) used pooled data from several regions to describe the current status of the business, and made certain recommendations for improvement. Regrettably, the survey did not assess the effect that farm size might have on the financial

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sustainability of culture operations. In addition, the financial risks associated with certain recommended industry enhancement strategies were not very well defined with respect to Greek mussel farming.

Because risk is a relative measure, a financial analysis is usually conducted and focused primarily on profitability indicators as the reference point for subsequent risk analyses (Kam & Leung 2008). Therefore, an effort has been made in the current study to investigate the impact of major risks on the profitability of Greek mussel farms. In Greece, contrary to agriculture or finfish mariculture (Theodorou et al. 2010a), mussel farming has limited insurance services or a loss reporting system, making it impossible to identify and rank the risks through usual methods. Hence, a study of the mussel farmers' risk perceptions was conducted based on structured questionnaires and personal interviews of a large number of mussel farmers (Theodorou et al. 2010b). The major sources of risk that emerged were financial, farmers' personal welfare, and market, public health and safety, environmental, and institutional factors.

In the current study, only financial, market, and institutional risks were included. Personal welfare risks could be addressed by the national health system and/or private insurance policies. Environmental risks are commonly perceived as uncertainty by the underwriters, so—in agribusiness—they are usually covered (if at all) by extraordinary measures of the state. Public health and safety risks are normally considered best management practices or the industry's code of conduct failures, and therefore underwriters are reluctant to cover them (Secretan 2003, Beach & Viator 2008, Secretan 2008). In the study by Theodorou et al. (2010b), it was demonstrated that the ex-farm price was perceived to be the major source of financial risk, despite (or because of) the price stability exhibited during the past 2 decades (Theodorou et al. 2011). Price stagnation, combined with production cost increases and low expansion capacity, might negatively influence the profitability or even the financial viability of the farms. Furthermore, in contrast to intensive marine finfish farming, no technological advances enhancing production per occupied area were created during the past few decades. Therefore, farm size was included both as a financial and as an institutional source of risk affecting profitability, because the state licensing system lacks any reasonable flexibility. A sensitivity analysis, as described by Kam and Leung (2008), was conducted to determine how changes in key production and management variables (enterprise budgets according to Engle and Neira [2005]) of different farm size (including fuel and labor cost), harvest volume achieved per year (incorporating, to some extent, environmental risk), and product form (market risk) may affect profitability.

MATERIALS AND METHODS

Background

Recent efforts to study the risk perceptions of the aquaculturists in various countries determined institutional risks as a major source of risk and, in some cases, as the most important risk sources of the activity, such as in Norway with the salmon industry (Bergfjord 2009), France with oyster farming (Le Bihan et al. 2010, Le Bihan et al 2013), Vietnam with catfish (Le & Cheong 2010), Denmark with mussel farming (Ahsan & Roth 2010), and Bangladesh with shrimp (Ahsan 2011). In Greece, with Mediterranean mussel aquaculture, we investigated how farm size (directly dependent on the licensing system) works as a source of institutional risk and how to mitigate the adverse effects of this risk by providing risk management solutions.

Model Development

The following attributes were incorporated into the model:

1. Mussel growth depends on the natural productivity of a site, with limited options along the Greek coastline.
2. The only available culture technology today is of an extensive nature, thereby rendering the industry space demanding.
3. As in livestock production economic profitability analyses, the study is carried out at the farm production level to achieve maximum returns from production activities (Rushton 2009, Clark et al. 2010, Engle & Sapkota 2012).
4. The current local mussel farming industry functions as an industry in perfect competition (i.e., the number of mussel farms is fixed and each farm has a given size in a certain area locations).

The financial risk assessment of Greek mussel farming was conducted via a farm-level profitability analysis based on farm size, and it focused on the individual farm's/firm's short-term decisions based on perfect competition conditions (Parkin 2010).

To evaluate the impact of mussel farm size on profitability, we assessed a range of culturing operations (1–6 ha each) located in the same area (similar natural conditions and transportation costs) using similar technology and typical production methods.

Profit (π) was calculated as a single input-to-single output relationship (factor/product) for different farm sizes (levels of inputs used) and corresponding outputs (tons/ha). The expression is

$$\begin{aligned}\text{Profit}(\pi) &= \text{TVP} - \text{TC} = \text{TVP} - \text{TVC} - \text{TFC}\\ &= P_y \times Y - \text{TVC} - \text{TFC},\end{aligned} \quad (1)$$

where TVP is total value product, representing the total monetary value of the production of the mussel farm, and can be written as

$$\text{TVP} = P_y \times Y, \quad (2)$$

(where Y is the amount of output [harvested mussels in tons] at any level of farm size, P_y is price per unit of output [Euros per ton]); TC is the total cost, representing the total monetary value of all costs of production and can be written as

$$\text{TC} = \text{TVC} + \text{TFC}; \quad (3)$$

where TVC is the total variable costs, representing total monetary costs for the variable inputs used in mussel production; and TFC is the total monetary value of fixed inputs used for production.

Sensitivity analysis was carried out according to Kam and Leung (2008). Financial risk assessment was done by comparing the relative impact of hazards (production and price reductions, labor, energy and consumable cost increases) with a baseline for an ideal situation when no risks exists. Scenarios were used to describe multiple parameters that may change simultaneously. Hence, a scenario-based analysis was also used to investigate the role of European Union (EU)/public support (subsidy) in the profitability of mussel farm sizes under different production levels and market situations. The initial investment was a high-risk opportunity, because of the variability in production, resulting from the extensive nature of the business, increased the financial risk. As a result, there is limited interest from the banking sector to support this type of operation.

Last, a break-even analysis was used to determine the breakpoints and threshold values for the mussel harvest yield (measured as a percentage). In this type of analysis, only the value of a single factor is determined, which—in this case—was the mussel production cost for each farm size. The critical values (or switching values) of production and sales parameters predict losses, whereas the product cost and price offered provide indications for the market demand of each type of product (Adams et al. 2005) such as raw pergolari (mussels tubed in cylindrical plastic nets—Italian style) or mussels graded and packed in plastic net bags.

Information and data describing the production costs and the technical parameters of a mussel farm in Greece were obtained from a survey of 8 mussel farms of different sizes and locations. Fixed costs, such as equipment and boats, were obtained from industry suppliers. Personal interviews of mussel farmers ($n = 48$) were also conducted through farm visits within the main production regions in Greece and through a questionnaire distributed to all registered farms in Greece, which numbered 218 in 2008. The survey was implemented October to December 2008, and was developed to obtain empirical information on production and marketing risks. Production and management assumptions for a hypothetical operation were established according to Adams et al. (2005). A Microsoft Excel spreadsheet was developed so that, given production design and management assumptions, capital investment, operating expenses, and profitability could be estimated. Because mussel farming is a labor-intensive activity, an effort also was made to estimate the profit-maximizing level of labor use per hectare for the range of examined farm sizes. The spreadsheet also allowed the development of basic financial statements for the hypothetical systems, including a production cost budget and an income statement. In addition, the spreadsheet allowed for a sensitivity analysis to be performed on several key management variables to determine how sensitive profitability was to changes in these variables (yield, price, labor, energy, and consumables).

Baseline Assumptions of the Analysis

Production assumptions. Common mussel farm size in Greece ranges from 1–6 ha; therefore, sizes of 1 ha, 1.5 ha, 2 ha, 3 ha, 4 ha, 5 ha, and 6 ha were chosen for a series of realistic production scenarios. Farms in all cases were assumed to be in full-scale operation, located 2 mi from the nearest port, and constructed using the same material specifications. Because the current trend is to mechanize the production process, all scenarios assumed the farms to be equipped with the same modern grading equipment and to have a boat of reasonable size (15 m long) to install and monitor the site.

A production season is confined to a single calendar year. The assumed culture system is single, floating longlines, 100 m in length, placed 10 m from each other. All longlines are constructed of 26-mm-diameter, UV-resistant polypropylene ropes and are anchored laterally with concrete blocks (~3 t). All longlines are supported by 20 equally spaced (180–200-L) floats and can be loaded with 201 pergolari. The production process is described analytically in Theodorou et al. (2011).

Because labor is the major variable cost in mussel farming (Theodorou et al. 2011), the optimum size of the workforce in relation to productivity (costs and returns per individual per ton of mussels) is also examined across a common number of crew members (2–7 workers) for a 15-m working vessel.

Financial assumptions. The profitability of the baseline operation depends largely on assumptions regarding the financial aspects of the business (Adams & van Blokland 1998). The market prices used in the current financial analysis cover a range of the current bulk, ex-farm prices of graded, packed products. An effort to compare the production cost and the revenues of raw pergolaris and treated pergolaris (pergolaris that have undergone several seasonal washings to remove biofoulants) was also carried out to compare the profitability of the various product forms. European mussel farming, with Greece being no exception, is characterized by negligible credit support because production unpredictability, marginal profitability, and low turnover make it a high-risk activity for lenders (Commission of European Communities, Brussels 2009). Therefore, bank loans for either construction or operation of the farm were not included in the scenarios.

The depreciation of equipment and capital extends for 8 y. Because investment in aquaculture is strongly supported financially by the government and EU (EPAL-Operational Program of Fisheries 1994 to 2000, 2000 to 2006, 2007 to 2013), the scenarios assumes an EU subsidization up to 45% (which is an average contribution, depending on the area of application).

The total capital investment was estimated for each farm size. An overview of the various items in each cost category is not included here for the sake of brevity, but it is available from the authors on request.

The financial analysis included standard enterprise budgeting techniques, as used by Adams and van Blokland (1998) for hard clams and Adams et al. (2001) for southern bay scallop commercial culture in Florida.

RESULTS AND DISCUSSION

Investment Costs

The cost of licenses and permits does not generally represent a very large component of total fixed costs; however, access to space and licenses represents a crucial limiting factor to aquaculture development (Commission of European Communities, Brussels 2009).

The investment costs associated with different farm sizes are presented in Table 1. The largest investment component is the working vessel (150,000 €), which must be at least 15 m long to have enough space to support the adaptation of the modern French–type grading machines (42,500 €). Such a boat is assumed to be necessary for any size of farm, because the work tends to be mechanized to reduce labor. The car (27,500 €) and the 6-m working boat with a 25-hp engine (6,500 € + 4,500 € = 11,000 €) are also common for such farm sizes. The primary difference in the investment cost is a result of the licensing cost and the increasing cost of floating installations (moorings, ropes, floats, marker buoys), which is determined by farm size.

TABLE 1.

Investment cost for a range of sizes of Greek mussel farms (values in €).

	Farm size (ha)						
	1	1.5	2	3	4	5	6
Licenses and permits	10,000	12,000	15,000	20,000	25,000	30,000	30,000
Moorings	11,700	16,200	20,700	29,700	38,700	47,700	56,700
Ropes	8,711	12,807	20,051	25,093	36,433	40,324	49,667
Floats	5,775	8,663	17,325	17,325	28,875	28,875	34,650
Lighted buoys	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Working vessel, 15 m	150,000	150,000	150,000	150,000	150,000	150,000	150,000
Working boat, 6 m	6,500	6,500	6,500	6,500	6,500	6,500	6,500
Outboard engine, 25 hp	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Car	27,500	27,500	27,500	27,500	27,500	27,500	27,500
Land tools	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Grading machine line	42,500	42,500	42,500	42,500	42,500	42,500	42,500
Total	295,686	309,169	332,576	351,618	388,508	406,399	430,517
EU/public subsidized 45%	133,059	139,126	149,659	158,228	174,828	182,879	193,732
Owner Contribution 55%	162,627	170,043	182,917	193,390	213,679	223,519	236,784

The total cost of a new installation or the modernization of an existing installation is eligible for funding of up to 45% of the investment by government–EU funds, provided the equipment is new (Operational Program of Fisheries 1994 to 2000, 2000 to 2006, 2007 to 2011). Results in Figure 1 show that the total investment costs per hectare decrease when the farm is larger, mainly as a result of the economies of size associated with the investment cost of the boat and the grading equipment.

Operational Costs

Operational costs are typically estimated on an annual basis and are expressed in 2 distinct categories: variable costs and fixed (overhead) costs. Variable costs are those that vary directly with the level of the production, whereas fixed costs are often referred as "overhead" costs and typically do not change with the level of production addressed by this analysis (Adams et al. 2001).

Variable Costs

The largest variable cost, regardless of farm size, is the labor cost, because mussel farming is labor intensive (Loste 1995, Danioux et al. 2000) (Table 2). Energy costs refer to the fuel consumed during the production process, including transportation. Consumables refers to plastic nets for the pergolari, ropes for longlines, plastic net bags, and so on. Other expenses refer to any unexpected variable costs during the production period.

Fixed Costs

The annual fee for leasing the sea site of the farm is about 1,000 €/ha. Insurance is applied only to the car, because

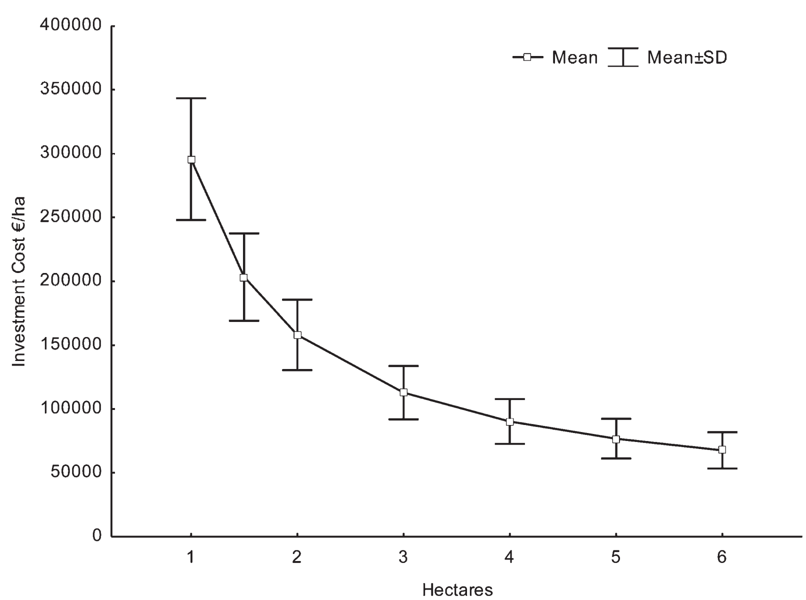

Figure 1. Total investment cost (capital expenses) per hectare for a size range of mussel farms.

TABLE 2.

Operational costs for a range of sizes of Greek mussel farms on an annual basis when not subsidized by EU/public (values in €).

	Farm size (ha)						
	1	1.5	2	3	4	5	6
Fixed cost (FC)							
Annual leasing fee	1,000	1,500	2,000	3,000	4,000	5,000	6,000
Permit amortization (10 y)	1,000	1,200	1,500	2,000	2,500	3,000	3,000
Insurance	925	925	925	925	925	925	925
Maintenance	6,550	6,650	6,750	6,950	7,150	7,350	7,550
Depreciation (8 y)	36,961	38,146	39,519	42,285	45,104	47,944	50,689
Accounting	2,100	2,100	2,100	2,100	2,100	2,100	2,100
Fixed overheads	900	900	900	900	900	900	900
Total fixed cost (TFC)	49,436	51,421	53,694	58,160	62,679	67,219	71,164
Variable cost (VC)							
Energy	3,054	4,396	5,670	8,448	10,867	13,826	16,457
Labor (4 persons)	14,870	19,650	24,820	35,560	46,020	56,550	67,100
Consumables	4,697	6,949	9,202	13,706	18,212	22,715	27,219
Others	7,380	7,380	7,380	7,380	10,230	10,230	10,230
Total variable cost (TVC)	30,001	38,375	47,072	65,094	85,328	103,320	121,006
Total cost (TC = TVC + TFC)	79,437	89,796	100,766	123,254	148,007	170,539	192,171

insurance for vessels used in mussel farming is not compulsory (Theodorou et al. 2011) (Table 2). The annual cost of installation maintenance and equipment repair is also included. Annual depreciation of the initial investment cost (spread over 8 y) is also taken into account and contributes a major share to overhead costs.

Table 2 shows the operational costs of a mussel farm when there is not any external financial support. Table 3 demonstrates how this fixed cost differentiates when external support is available (EU and public funding), mainly as a result of the elimination of the depreciation cost of the farmer's own contribution. In both cases, the total costs increase as farm size increases. When EU/public subsidization exists, the total cost is significantly lower, giving a competitive advantage to subsidized farms.

Annual Income and Returns (Profitability)

The annual income and returns for each farm size (1 ha, 1.5 ha, 2 ha, 3 ha, 4 ha, 5 ha, and 6 ha) were estimated by examining the profit (π) of each farm under full production capacity (100% Y) using a range of ex-farm commodity market prices scenarios (P_y), varying from 400–600 €/t for graded, packed products. Results of this effort, giving the profitability of each farm size without and with any EU/public subsidization, are presented in Tables 4 and 5, respectively.

In all cases, 4–6-ha farms were profitable, with net profit (π) margins ranging between 5% and 34%, and increasing up to 14%–39% if the assets were subsidized. Sale prices less than 400 €/t were not favorable for sizes smaller than 3 ha if the

TABLE 3.

Operational cost of a size range of the Greek mussel farms when subsidized by EU/public (values in €).

	Farm size (ha)						
	1	1.5	2	3	4	5	6
Fixed cost (FC)							
Annual leasing fee	1,000	1,500	2,000	3,000	4,000	5,000	6,000
Permit amortization (10 y)	1,000	1,200	1,500	2,000	2,500	3,000	3,000
Insurance	925	925	925	925	925	925	925
Maintenance	6,550	6,650	6,750	6,950	7,150	7,350	7,550
Depreciation (8 y)	20,328	20,980	21,735	23,257	24,807	26,369	27,879
Accounting	2,100	2,100	2,100	2,100	2,100	2,100	2,100
Fixed overheads	900	900	900	900	900	900	900
Total fixed cost (TFC)	32,803	34,255	35,910	39,132	42,382	45,644	48,354
Variable cost (VC)							
Energy	3,054	4,396	5,670	8,448	10,867	13,826	16,457
Labor (4 persons)	14,870	19,650	24,820	35,560	46,020	56,550	67,100
Consumables	4,697	6,949	9,202	13,706	18,212	22,715	27,219
Others	7,380	7,380	7,380	7,380	10,230	10,230	10,230
Total variable cost (TVC)	30,001	38,375	47,072	65,094	85,328	103,320	121,006
Total cost (TC = TVC + TFC)	62,805	72,630	82,983	104,226	127,711	148,964	169,361

TABLE 4.

Annual income and profitability for a range of size of Greek mussel farms when not subsidized by EU/public (values in €).

	Farm size (ha)						
Annual income and profitability	**1**	**1.5**	**2**	**3**	**4**	**5**	**6**
Production yield, *Y* (t)	106	154	202	299	395	492	588
Sales price (€/t)			Total value product (TVP = $Py \times Y$)				
400	42,409	61,686	80,963	119,516	158,070	196,623	235,177
450	47,710	69,396	91,083	134,456	177,828	221,201	264,574
500	53,011	77,107	101,203	149,395	197,587	245,779	293,971
550	58,312	84,818	111,324	164,335	217,346	270,357	323,368
600	63,613	92,529	121,444	179,274	237,105	294,935	352,765
			Total fixed costs (TFC)				
	49,436	51,421	53,694	58,160	62,679	67,219	71,164
			Total variable cost (TVC)				
	30,001	38,375	47,072	65,094	85,328	103,320	121,006
			Total cost (TC = TVC + TFC)				
	79,437	89,796	100,766	123,254	148,007	170,539	192,171
			Pretax profit (π) = TVP – TC				
400	**–37,028**	**–28,110**	**–19,804**	**–3,738**	10,062	26,084	43,006
450	**–31,727**	**–20,399**	**–9,683**	11,202	29,821	50,662	72,403
500	**–26,426**	**–12,689**	437	26,141	49,580	75,240	101,801
550	**–21,125**	**–4,978**	10,557	41,081	69,338	99,818	131,198
600	**–15,824**	2,733	20,678	56,020	89,097	124,396	160,595
			Net profit (π) = TVP – TC (income tax 25%)				
400	**–37,028**	**–28,110**	**–19,804**	**–2,803**	7,547	19,563	32,255
450	**–31,727**	**–20,399**	**–7,263**	8,401	22,366	37,997	54,303
500	**–26,426**	**–9,517**	328	19,606	37,185	56,430	76,350
550	**–21,125**	**–3,734**	7,918	30,811	52,004	74,864	98,398
600	**–11,868**	2,049	15,508	42,015	66,823	93,297	120,446
			Net profit (π) (%)				
400	**–87**	**–46**	**–24**	**–2**	5	10	14
450	**–66**	**–29**	**–8**	6	13	17	21
500	**–50**	**–12**	0	13	19	23	26
550	**–36**	**–4**	7	19	24	28	30
600	**–19**	2	13	23	28	32	34

Bold type in the table body indicates negative results.

investment was not subsidized, and 2 ha if funded. In all other cases, the net profits of mid-size farms of 3 ha ranged from 6%–23% if not subsidized, and between 7% and 24% for the subsidized option.

Profitability of 2-ha farms was between 7%–24% at sales prices greater than 450 €/t when subsidized, but was reduced to between 7% and 13% at a price range of 550–600 €/t and no subsidization. Profit did not exist for the 1-ha farm size. Even with EU/public subsidization, profit was limited at just 1% at a sale price of 600 €/t. Similarly, a 1.5-ha farm had losses when sales were less than 550 €/t, whereas losses for a financially subsidized farm existed at sales price less than 450 €/t. European Union/public subsidization enhances the viability of the smaller farms—hence, the profitability of the sector— by reducing the depreciation costs and thus the fixed costs of the operations.

Sensitivity Analysis

Effects of Changes in Yield

The single-variable method was applied to estimate the effect of changes in harvest yield on profitability. For each of the 2 scenarios (with and without subsidy), only 1 variable—namely, harvest yield—was allowed to change (from 60%–100% of the production capacity of each farm size) to simulate losses resulting from various reasons (mortality, weather, and so on). All other variable levels were maintained at the baseline value. The break-even price (total cost per ton of harvested mussel) is presented in the Table 6. The break-even price is the minimum income needed to cover the costs associated with facility investment and operation, including depreciation (Adams et al. 2005). In both scenarios, as harvest volume changes, the break-even price also changes. The break-even price decreases directly

TABLE 5.

Annual income and profitability for a range of size of Greek mussel farms when subsidized by EU (values in €).

Annual income and profitability	Farm size (ha)						
	1	1.5	2	3	4	5	6
Production yield, Y (t)	106	154	202	299	395	492	588
Sales price (€/t)	Total value product (TVP = $Py \times Y$)						
400	42,409	61,686	80,963	119,516	158,070	196,623	235,177
450	47,710	69,396	91,083	134,456	177,828	221,201	264,574
500	53,011	77,107	101,203	149,395	197,587	245,779	293,971
550	58,312	84,818	111,324	164,335	217,346	270,357	323,368
600	63,613	92,529	121,444	179,274	237,105	294,935	352,765
	Total fixed costs (TFC)						
	32,803	34,255	35,910	39,132	42,382	45,644	48,354
	Total variable cost (TVC)						
	30,001	38,375	47,072	65,094	85,328	103,320	121,006
	Total cost (TC = TVC + TFC)						
	62,805	72,630	82,983	104,226	127,711	148,964	169,361
	Pretax profit (π) = TVP – TC						
400	**–20,396**	**–10,944**	**–2,020**	15,291	30,359	47,659	65,816
450	**–15,095**	**–3,234**	8,100	30,230	50,118	72,237	95,213
500	**–9,794**	4,477	18,221	45,170	69,877	96,815	124,611
550	**–4,493**	12,188	28,341	60,109	89,635	121,393	154,008
600	809	19,898	38,461	75,049	109,394	145,971	183,405
	Net profit (π) = TVP – TC (income tax 25%)						
400	**–20,396**	**–10,944**	**–2,020**	11,468	22,769	35,744	49,362
450	**–15,095**	**–3,234**	6,075	22,673	37,588	54,178	71,410
500	**–9,794**	3,358	13,665	33,877	52,407	72,611	93,458
550	**–4,493**	9,141	21,256	45,082	67,227	91,045	115,506
600	606	14,924	28,846	56,287	82,046	109,478	137,554
	Net profit (π) (%)						
400	**–48**	**–18**	**–2**	10	14	18	21
450	**–32**	**—5**	7	17	21	24	27
500	**–18**	4	14	23	27	30	32
550	**–8**	11	19	27	31	34	36
600	1	16	24	31	35	37	39

Bold type in the table body indicates negative results.

with yield. Because break-even prices are affected by farm size (McCullough et al. 2001), the largest mussel farm (6 ha) in the current study (Table 6) had the lowest break-even price when supported by EU/public subsidization. Thus, to minimize potential losses, Greek mussel farms should estimate and target a minimum acceptable yield for their size, as is done, for example, with shrimp farms in Honduras (Valderrama & Engle 2001).

Break-even prices less than 500 €/t are reasonable for export markets, whereas a higher break-even price forces the producers to seek higher prices from buyers in the local market in an effort to achieve better profit margins. Local markets have a poor capacity to consume all the mussels produced, so several farms would be forced to export. About 70%–80% of Greek mussel production is exported (Theodorou et al. 2011).

Farms of 3–6 ha were profitable if export oriented at yields even down to 70% of capacity when subsidized. Farms of 2 ha with yields less than 90% could target local market regardless of whether they are subsidized. Similarly, farms of 1–1.5 ha were totally local-market oriented because break-even prices were greater than 500 €/t (except the ideal case of a 1.5-ha farm operating at full capacity plus EU/public subsidization). This finding suggests that farms smaller than 2 ha have greater production costs per hectare at all product forms (pergolari, cleaned pergolari, or graded packs) (Fig. 2), because capital investment per hectare is too large for the expected outcome. Even with EU subsidization, yields of at least 80% are required to have a marginal profit (Table 5) in the export market.

Alternative marketing methods, such as direct sales in local markets, might be a solution for financial survival. Farmers could sell small quantities directly to the consumer at a price of 2,500–3,000 €/t, instead of less than the 600-€/t wholesale price. Additional costs must be added, though, for direct marketing, such as packaging, distribution, labor, and so on (Adams & van Blokland 1998). However, the Greek per-capita

TABLE 6.

Sensitivity analysis of mussel harvesting yield (% capacity per farm size) for 2 scenarios (without and with EU subsidization).

Assumptions		Farm size (ha) 1	1.5	2	3	4	5	6
		Production capacity (t/y)						
		106	154	202	299	395	492	588
Scenario I: no subsidization	Total production cost (€)	79,437	89,796	100,766	123,254	148,007	170,539	192,171
	Yield (%)	Break-even price (€/t)						
	60	1,248	985	841	695	630	583	549
	70	1,045	819	698	571	515	474	446
	80	923	725	618	508	458	423	398
	90	826	650	555	458	414	381	359
	100	749	582	498	413	375	347	327
Scenario II: plus subsidization	Total production cost (€)	62,805	72,630	82,983	104,226	127,711	148,964	169,361
	Yield (%)	Break-even price (€/t)						
	60	987	785	683	581	539	505	480
	70	820	647	562	474	437	408	387
	80	726	575	499	423	389	364	346
	90	652	517	450	382	353	329	313
	100	592	471	410	349	323	303	288

Break-even price: total production cost per ton harvested.

consumption of mussels is still low with markets near the production areas (Batzios et al. 2003, Batzios et al. 2004), thereby rendering such an alternative very difficult to accommodate today.

Effects of Changes in Farm Size

Figure 3 shows that the net profit per hectare of the range of farms (1–6 ha) was marginal or even negative for small farms (1–2 ha) with graded packs (10-kg packages of same-size mussels). Larger farms, in contrast, had higher net profits as a result of a significant decrease in the per-hectare unit cost with increasing size (Fig. 4). Total investment cost per hectare was very high for the 1–2-ha farms (Fig. 1), resulting in greater depreciation for the main equipment purchased, such as the 15-m working vessel and the grading machine line. Alternative strategies should be investigated, such as contracting services from larger neighboring mussel farms to avoid the purchase of such equipment. Using a smaller vessel is a possible alternative solution that may enhance the viability of the farm.

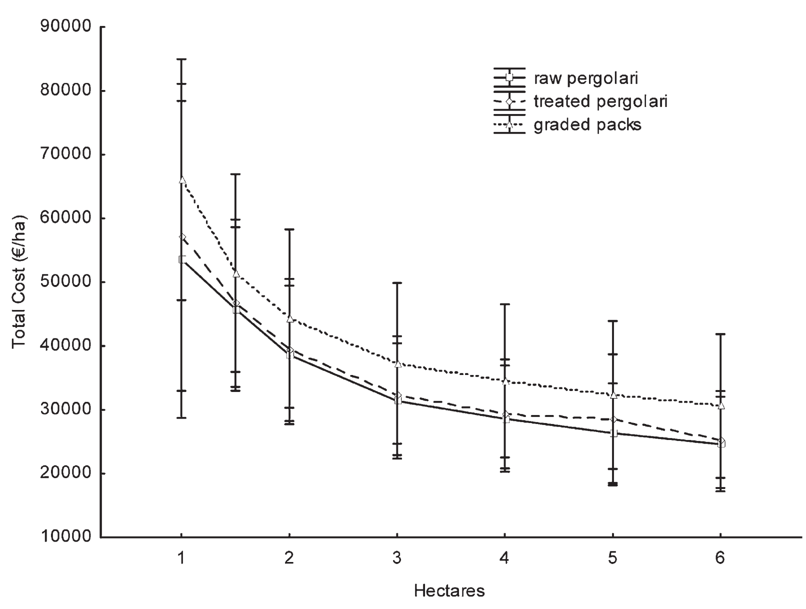

Figure 2. Effect of farm size on the total cost (TC) for different forms of the final product (raw or treated pergolari vs. graded packs).

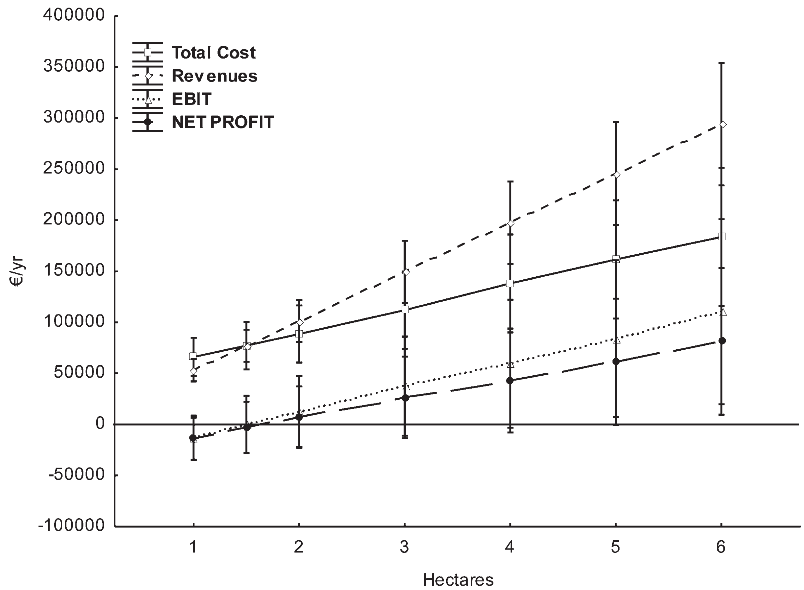

Figure 3. Annual revenues (total value product [TVP]) of the graded packed mussels in relation with the total cost (TC), the pre-tax profit (π) (earnings before income tax [EBIT]), and the net profit of a range of farms (1–6 ha).

These trends were independent of the product form, although were better for graded packs, whereas the difference between raw and treated (washed and cleaned) pergolari was minimal (Fig. 2). The earnings before income tax per hectare were positive again for the larger farms (3–6 ha) and negative for the smaller ones (1–3 ha) (Fig. 5) across product types.

Effects of Changes in Labor Units

Mussel farming is a seasonal and labor-intensive activity. Labor is a major component of the production cost (Theodorou et al. 2011). The variation of the level of wages might be an important risk factor, as in other industries; however, in the current study, it was not significant because of the very low range occurring in the Greek agricultural sector at the time of the study. Nevertheless, labor management had a significant impact on the total labor cost in relation to the farm size. MANOVA demonstrated that the total cost per ton of harvested product decreased with increasing working-labor units (from 2–7 individuals), with the size of the farms playing a smaller role (Fig. 6A). The pretax profits (π) showed an increase with larger crew size of the working vessel (15 m) at any farm size (Fig. 6B). Furthermore, because the labor-intensive period

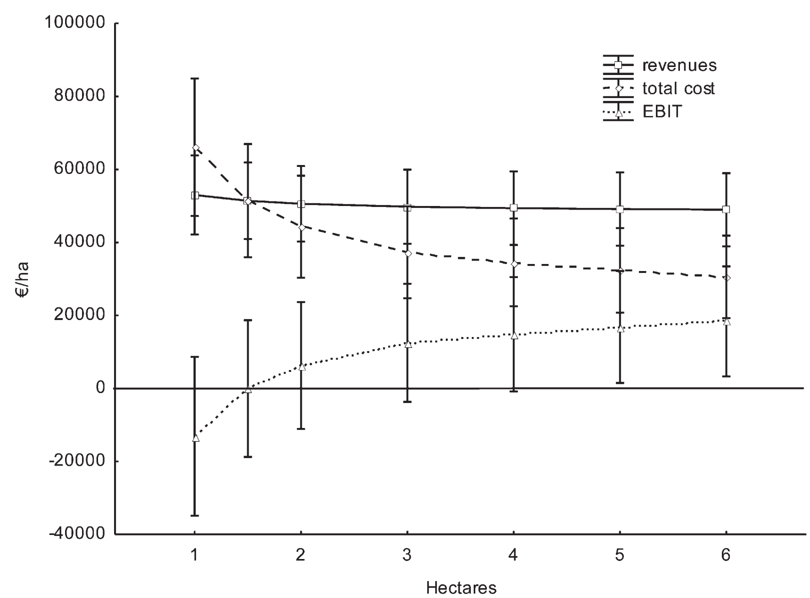

Figure 4. The revenues (total value product [TVP]) per hectare of a range of mussel farms (1–6 ha) in relation with the per hectare total cost (TC) and the pre-tax profit (π) (EBIT).

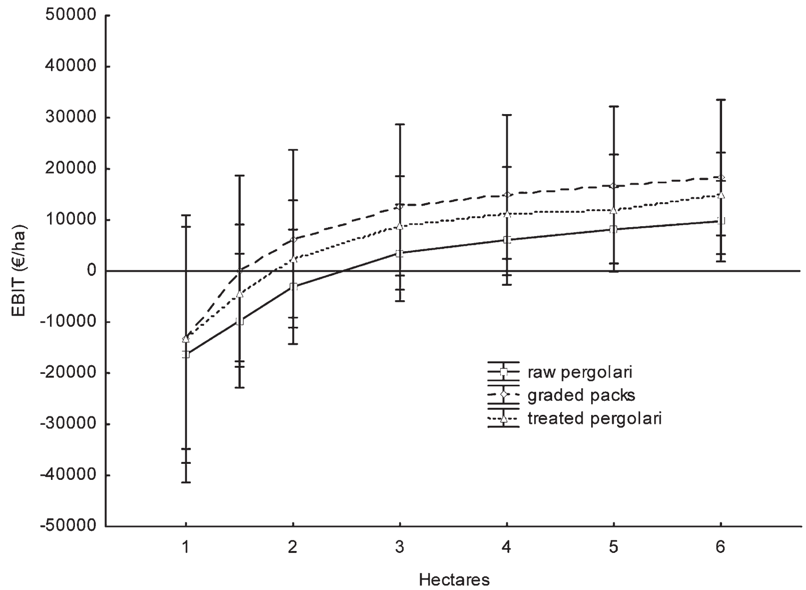

Figure 5. The effect of farm size on the unit pretax profit (π) (earnings before income tax [EBIT] per hectare) for different forms of the final product (raw or treated pergolari vs. graded packs).

is actually restricted seasonally to about 4 mo overall, full-time employment could be replaced by seasonal employment or by outsourcing this activity to a professional working crew that services multiple farms in the area. However, legal obstacles would need to be removed for seasonal employment to be used, as is done in terrestrial farming.

Current Industry Policies

Globalization is serving to increase competition in national markets, but also is improving opportunities for exports (Thong 2012). By the nature of food markets, much of the larger scale aquaculture output is increasingly at a commodity level, where the most important competition focuses on price. Achieving a lower cost of production is, therefore, a key factor in successful competition. Thus, any regional factors that add to production costs (either directly, such as higher labor costs or site licensing costs, or indirectly, such as increased administrative costs resulting from regulatory requirements) could affect business investment decisions. An alternative competition strategy is niche marketing, where producers are able to differentiate their product on the basis of quality, locality, service, or brand (Borisova et al. 2007, Commission of European Communities, Brussels 2009).

Gordon and Bjorndal (2009) examined the productivity and the profit composition in the shrimp farming sector in 3 Asian countries. A key conclusion was that small farms are disadvantaged not because they are underproductive or lack the skills to manage the farms, but because, in general, the farms in all 3 countries considered were too small. Larger scale production systems usually benefit from economies of scale as a result of production efficiencies (Adams & Pomeroy 1992, Kam et al. 2001, Kam et al. 2002, Kam et al. 2006, Borisova et al. 2007, Liu & Sumaila 2007, Kam & Leung 2008). This finding was also demonstrated in the current study for the Mediterranean mussel farming sector in Greece, where earnings are low as the result of downward pressure on the selling price of Greek mussels. The ex-farm price of the mussels in Greece is very low in comparison with the other European Mediterranean countries, such as France (1.43 €/kg) or Italy (0.65 €/kg), according to FRAMIAN BV (2009). However, the situation could be improved if new marketing approaches could be used by Greek producers to enhance the image of the Greek product through product discrimination (Theodorou et al. 2011), negotiation for better prices abroad through upgraded export services, and so on. All these strategies, of course, require investments that might not be affordable by the smaller farmers demanding formation of stronger producer organizations.

There is extensive documentation in agricultural economics that viability and profitability of an agricultural activity it is affected by farm size (Penson et al. 2010).

In contrast to the rather flexible land-based farming policies in Europe, the size of marine aquaculture farms is dictated by national licensing systems regardless of its activity, be it salmonids in Norway (Oglend & Tveteras 2009), seabream/sea bass (Papoutsoglou 2000, Theodorou 2002) or mussels in Greece (Theodorou et al. 2011) and Spain (Caballero et al. 2009, Caballero et al. 2012). Similar policies regarding marine property rights of aquaculture farms have also been reported outside Europe, such as in New Zealand (Rennie 2002) or Canada (Joyce 2008).

However, policies may need revising from time to time to adapt to financial, socioeconomic, and technological change (Goulletquer & Le Moine 2002, Mongruel & Thebaud 2006). In Norway, the salmon farming industry started in the early 1970s from pilot-scale farms that led to licensing of many farms of moderate size, reflecting the will of the government to develop the sector with a critical mass of small farms, minimizing risk and attracting many investors (Oglend & Tveteras 2009). Today, though, there are mainly large farms because the original sizes are not viable economically. An analogous experience led Greek authorities to revise the original licensed sizes for sea bass and seabream farming (Theodorou 2002). Furthermore, technological advances led to a greater production of salmon in the available space using improved cage

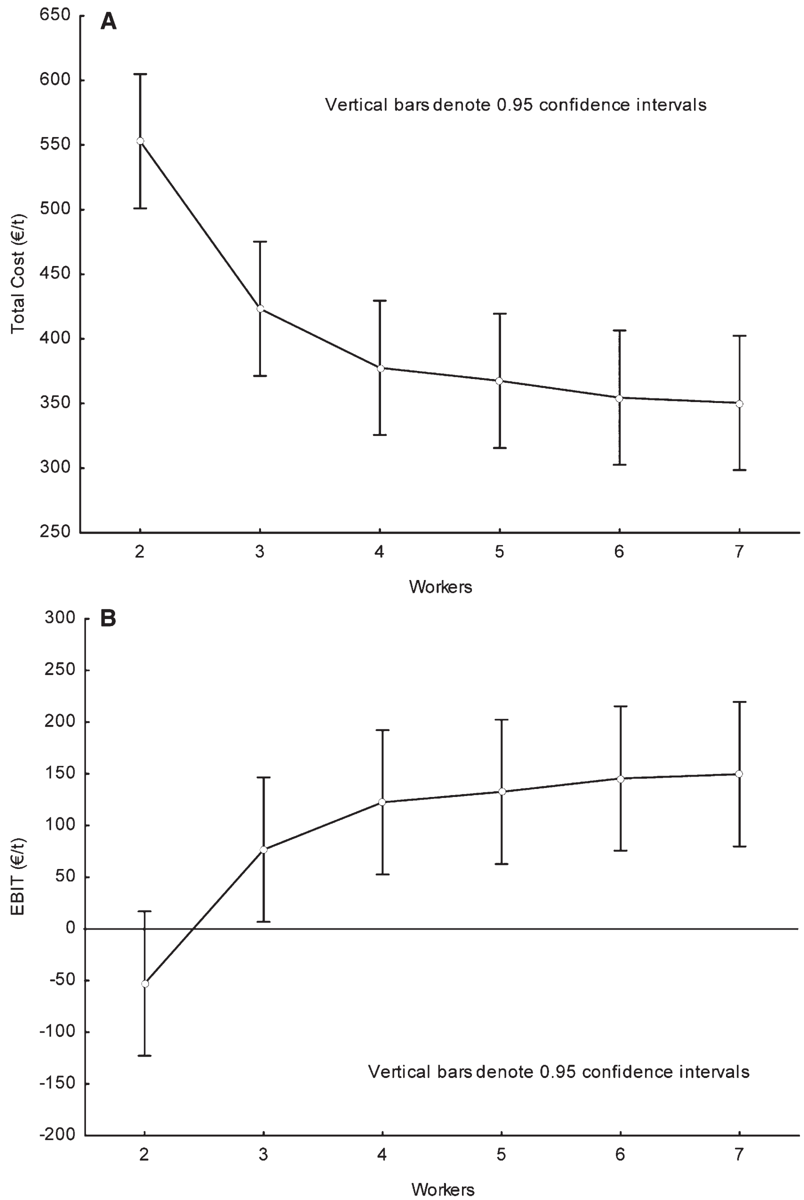

Figure 6. (A, B) Effect of the working crew size on the total cost (TC) (A) and on the pretax profit (earnings before income) (B) after MANOVA analysis. Confidence intervals reflect variation also caused by different farm size.

systems, well boats, feeding schemes, and feedstuff (Asche et al. 1999, Tveteras 1999, Tveteras 2002, Tveteras & Battese 2006).

In contrast, bivalve shellfish farming systems are still area dependent; the animals are fed by the natural plankton promoted by light and nutrient availability in carefully selected sites (Dowd 2005, McKindsey et al. 2006, Aure et al. 2007, Brigolin et al. 2008, Stevens et al. 2008, Brigolin et al. 2009, Rosland et al. 2009, Guyondet et al. 2010). In the early days of Mediterranean mussel farming, the carrying capacity of the water column was based on the assumption that 1 ha near the shore supports a production of 400 t/y on poles whereas, later, a floating longline was assumed to produce 100 t/ha/y. These figures are still used in the Greek licensing system, although modern methods can give much more accurate site-specific estimations using a bio-economic approach (Sara & Mazzola 2004, Ferreira et al. 2007, Duarte et al. 2008, Ferreira et al. 2008, Filgueira & Grant 2009, Caroppo et al. 2012, Konstantinou, et al. 2012).

In our case, it is clear that, for the majority of the Greek mussel farms (Theodorou et al. 2011) that are less than 3 ha each, there is a significant financial risk related directly to restrictions of space resulting from the licensing system. Horizontal integration could be used as a strategy to scale up production to benefit from economies of scale, and this is already a prominent strategy in the marine fish-farming (sea bass and seabream) sector in Greece (Theodorou 2002). This strategy is still effective for marine finfish in Greece because the barriers to newcomers are high. Such firms would need to start with high production-scale installations because there is great difficulty in acquiring a new license from authorities that might prevent them from expanding on time in the future (Commission of European Communities, Brussels 2009, Papageorgiou 2009).

Such horizontal consolidation is not evident in the Greek mussel-farming sector. Individual farmers seem to prefer less strong links among themselves (i.e., cooperatives), whereas more sophisticated, integrated entities (Ltd's, SA companies) choose to operate on their own. Perhaps this is a reflection of the fact that the sector has been less exposed to international competition. This might change soon, because significant levels of imports—in particular, from Chile—are now occurring in Greece. Nevertheless, it is probable also that economies of scale are not as significant as in marine fish farming, which could limit the potential for consolidation (Commission of European Communities, Brussels 2009). The challenge for public administration is to motivate small producers to be organized into larger groups (such as producer organizations, cooperatives, and so on) so that the advantages of economies of scale can be achieved (Gordon & Bjorndal 2009). The challenge also exists for small farms to self-organize into larger entities. Kassam et al. (2011) showed that small-scale producers in many developing countries adopt a "cluster management" strategy to allow implementation of certain production standards. Implementing appropriate best management practices can be an effective tool for improving aquaculture governance and management in the small-scale farming sector, thereby enabling farmers to work together, improve production, develop sufficient economies of scale, enhance knowledge to participate in modern value chains, increase their ability to join certification schemes, improve their reliability of production, and reduce risks such as disease.

CONCLUSIONS

Mussel culture in Greece is an extensive farming activity, with returns depending on a combination of factors such as natural productivity, technical practices, production cost, and pricing. In this study the critical role of space availability was demonstrated.

Mussel farm size in Greece is dictated through a licensing system, and we showed that this procedure could be a major risk factor for financial sustainability of the sector. We demonstrated that farm size is critical to the financial viability of the producers, because profitability is too limited for smaller farms (up to 3 ha) as a result of the high production costs per hectare. Labor by working crews of at least 4 workers could improve farming productivity even for smaller farms.

Our findings also highlighted the importance of EU and government support for the startup and consequent viability and sustainability of the farms through the relief of depreciation costs.

The future of the industry might lay in producers getting organized in larger schemes that promote production industrialization and farming scale-up that, in their turn, reduces average production costs and aids value-added processing.

LITERATURE CITED

Adams, C. M., C. V. Martinez, D. E. Sweat & M. Lopez. 2005. A preliminary assessment of the financial feasibility of marine shrimp culture in outdoor, freshwater ponds in Florida. Final project report, U.S. Department of Agriculture. Cooperative States Research Service, project UPN: 02020716. Gainesville, FL: University of Florida. 30 pp.

Adams, C. M. & R. Pomeroy. 1992. Economies of size and integration in commercial hard clam culture in the southeastern United States. *J. Shellfish Res*. 11:169–176.

Adams, C. M., L. Sturmer, D. Sweat, N. Blake & B. Degner. 2001. The economic feasibility of small-scale, commercial culture of the southern bay scallop (*Argopecten irradians concentricus*). *Aquacult. Econ. Manage*. 5:81–97.

Adams, C. M. & P. J. van Blokland. 1998. Economic and financial considerations regarding the small-scale commercial culture of hard clams in Florida. *J. Appl. Aquacult*. 8:19–37.

Ahsan, D. A. 2011. Farmers motivations, risk perceptions and risk management strategies in a developing economy: Bangladesh experience. *J. Risk Res*. 14:325–349.

Ahsan, D. A. & E. Roth. 2010. Farmers' perceived risks and risk management strategies in an emerging mussel aquaculture industry in Denmark. *Mar. Resour. Econ*. 25:309–323.

Aure, J., T. Strohmeier & O. Strand. 2007. Modelling current speed and carrying capacity in long-line blue mussel (*Mytilus edulis*) farms. *Aquacult. Res*. 38:304–312.

Asche, F., A. G. Guttormsen & R. Tveterås. 1999. Environmental problems, productivity and innovations in Norwegian salmon aquaculture. *Aquacult. Econ. Manage*. 3:19–29.

Batzios, C. H., P. Angelidis, D. K. Moutopoulos, C. H. Anastasiadou & V. Christopolitou. 2003. Consumer attitude towards shellfish in the Greek market: a pilot study. *Medit. Mar. Sci* 4:155–174.

Batzios, C. H., P. Angelidis, E. P. Papapanagiotou, D. K. Moutopoulos, C. H. Anastasiadou & V. Christopolitou. 2004. Greek consumer's image of the cultured mussel market. *Aquacult. Int*. 12:239–257.

Beach, R. H. & C. L. Viator. 2008. The economics of aquaculture insurance: an overview of the U.S. pilot insurance program for cultivated clams. *Aquacult. Econ. Manage*. 12:25–38.

Bergfjord, J. O. 2009. Risk perception and risk management in Norwegian aquaculture. *J. Risk Res*. 12:91–104.

Borisova, T. A., G. E. D'Souza, D. Miller & W. C. Labys. 2007. Remaining competitive at the regional level: developing a local aquaculture industry. *Aquacult. Econ. Manage*. 11:73–98.

Brigolin, D., G. Dal Maschio, F. Rampazzo, M. Giani & R. Pastres. 2009. An individual-based population dynamic model for estimating biomass yield and nutrient fluxes through an off-shore mussel (*Mytilus galloprovincialis*) farm. *Estuar. Coast. Shelf Sci*. 82:365–376.

Brigolin, D., A. Davydov, R. Pastres & I. Petrenko. 2008. Optimization of shellfish production carrying capacity at a farm scale. *Appl. Math. Comput*. 204:532–540.

Caballero, G., M. D. Garza & M. M. Varela. 2009. The institutional foundation of economic performance of mussel production: the Spanish case of the Galician floating raft culture. *Mar. Policy* 33:288–296.

Caballero, G., M. D. Garza & M. M. Varela. 2012. Legal change, property rights system and institutional stability: the case of the floating raft culture in the Galician mussel sector. *Ocean Coast. Manage*. 55:84–93.

Caroppo, C., L. Giordano, N. Palmieri, G. Bellio, A. Paride Bisci, G. Portacci, P. Sclafani & T. Sawyer Hopkins. 2012. Progress towards sustainable mussel aquaculture in Mar Piccolo, Italy. *Ecol. Soc*. 17:10.

Clark, J. L., R. N. Weldon, C. M. Adams & F. Wirth. 2010. Risk assessment of a shrimp aquaculture investment in Florida. *Aquacult. Econ. Manage*. 14:332–357.

Commission of the European Communities, Brussels. 2009. Building a sustainable future for aquaculture: a new impetus for the strategy for the sustainable development of European aquaculture: impact assessment. 183 pp.

Danioux, C., X. Bompais. C. Loste & P. Paquotte 2000. Offshore mollusc production in the Mediterranean basin In: J. Muir & B. Basurco, editors. Mediterranean offshore mariculture. Zaragoza: CIHEAM-IAMZ. 215 pp. (Options Méditerranéennes: Série B. Etudes et Recherches; n. 30). Advanced Course of the CIHEAM

Network on Technology of Aquaculture in the Mediterranean on "Mediterranean Offshore Mariculture", 1997/10/20-24, Zaragoza. *Cah. Opt. Medit.* 30: 115-140.

Dowd, M. 2005. A bio-physical coastal ecosystem model for assessing environmental effects of marine bivalve aquaculture. *Ecol. Modell.* 183:323–346.

Duarte, P., U. Labarta & M. J. Fernandez-Reiriz. 2008. Modelling local food depletion effects in mussel rafts of Galician rias. *Aquaculture* 274:300–312.

Engle, C. R. & I. Neira. 2005. Tilapia farm business management and economics. Aquaculture CRSP, Corvallis, OR: Oregon State University, 41 pp.

Engle, C. & P. Sapkota. 2012. A comparative analysis of the economic risk of hybrid striped bass fingerling production in ponds and indoor tanks. *North Am. J. Aquacult.* 74:477–484.

Ferreira, J. G., A. J. S. Hawkins & S. B. Bricker. 2007. Management of productivity, environmental effects and profitability of shellfish aquaculture: the farm aquaculture resource management (FARM) model. *Aquaculture* 264:160–174.

Ferreira, J. G., A. J. S. Hawkins, P. Monteiro, H. Moore, M. Service, P. L. Pascoe, L. Ramos & A. Sequeira. 2008. Integrated assessment of ecosystem-scale carrying capacity in shellfish growing areas. *Aquaculture* 275:138–151.

Filgueira, R. & J. Grant. 2009. A box model for ecosystem-level management of mussel culture carrying capacity in a coastal bay. *Ecosystems* 12:1222–1233.

FRAMIAN BV. 2009. Definition of data collection needs for aquaculture: Part 1, Review of the EU aquaculture sector and results of costs and earnings survey, Brussels, Belgium: European Commission, FISH/2006/15, lot 6, 170 pp.

Gordon, D. V. & T. Bjorndal. 2009. A comparative study of production factors and productivity for shrimp farms in three Asian countries: Bangladesh, India, and Indonesia. *Aquacult. Econ. Manage.* 13:176–190.

Goulletquer, P. & O. Le Moine. 2002. Shellfish farming and coastal zone management development in the Marennes-Oléron Bay and Charentais sounds (Charente Maritime, France): a review of recent developments. *Aquacult. Int.* 10:507–525.

Guyondet, T., S. Roy, V. G. Koutitonsky, J. Grant & G. Tita. 2010. Integrating multiple spatial scales in the carrying capacity assessment of a coastal ecosystem for bivalve aquaculture. *J. Sea Res.* 64:341–359.

Joyce, A. 2008. Risk and opportunity in British Columbia shellfisheries: the role of limited property rights in aquaculture. PhD diss., University of British Columbia, 197 pp.

Kam, L. E. & P. Leung. 2008. Financial risk analysis in aquaculture. In: M. G. Bondad-Reantaso, J. R. Arthur & R. P. Subasinghe, editors. Understanding and applying risk analysis in aquaculture. FAO fisheries and aquaculture technical paper no. 519. Rome: FAO. pp. 153–207.

Kam, L. E., P. S. Leung, A. C. Ostrowski & A. Molnar. 2001. Economics of a Pacific threadfin (*Polydactylus sexfilis*) hatchery in Hawaii. Waimanalo, HI Center for Tropical and Subtropical Aquaculture Publication No. 146. 47 pp.

Kam, L. E., P. S. Leung, A. C. Ostrowski & A. Molnar. 2002. Size economies of a Pacific threadfin *Polydactylus sexfilis* hatchery in Hawaii. *J. World Aquacult. Soc.* 33:410–424.

Kam, L. E., P. S. Leung & C. S. Tamaru. 2006. Feasibility of direct marketing Hawaii's cultured freshwater ornamentals. Aquafarmer information sheet no. 152. Honolulu, HI: Center for Tropical and Subtropical Aquaculture. 19 pp.

Karageorgis, A. P., V. Kapsimalis, A. Kontogianni, M. Skourtos, K. R. Turner & W. Salomons. 2006. Impact of 100-year human interventions on the deltaic coastal zone of the inner Thermaikos Gulf (Greece): a DPSIR framework. *Anal. Environ. Manage.* 38:304–315.

Karageorgis, A. P., M. S. Skourtos, V. Kapsimalis, A. D. Kontogianni, N. T. Skoulikidis, K. Pagou, N. P. Nikolaidis, P. Drakopoulou, B. Zanou, H. Karamanos, Z. Levkov & C. Anagnostou. 2005. An integrated approach to watershed management within the DPSIR framework. *Axios River Catchment Thermaikos Gulf. Reg. Environ. Change* 5:138–160.

Kassam, L., R. Subasinghe & M. Phillips. 2011. Aquaculture farmer organizations and cluster management: concepts and experiences. FAO fisheries and aquaculture technical paper no. 563. Rome: FAO. 90 pp.

Kochras, D., L. Kokokiris & S. Galinou-Mitsoudi. 2000. Lack of integrated coastal zone management in Thermaikos Gulf area. Thessaloniki, Greece. Coastman Project Working Paper No. 9.

Konstantinou, Z. I., Y. N. Krestenitis, D. Latinopoulos, K. Pagou, S. Galinou-Mitsoudi & Y. Savvidis. 2012. Aspects of mussel-farming activity in Chalastra, Thermaikos Gulf, Greece: an effort to untie a management Gordian Knot. *Ecol. Soc.* 17:1.

Le, T. C. & F. Cheong. 2010. Perceptions of risk and risk management in Vietnamese catfish farming: an empirical study. *Aquacult. Econ. Manage.* 14:282–314.

Le Bihan, V., S. Pardo & P. Guillotreau. 2010. Risk perceptions and risk management strategies in French oyster farming. Working document Lemna 210/35. Institut d'Economie et de Management de Nantes-IAE (IEMN-IAE), Nantes, France. 18 pp.

Le Bihan, V., S. Pardo & P. Guillotreau. 2013. Risk perception and risk management strategies of oyster farmers. *Mar. Resour. Econ.* 28:285–304.

Liu, Y. & U. R. Sumaila. 2007. Economic analysis of net cage versus sea-bag production systems for salmon aquaculture in British Columbia. *Aquacult. Econ. Manage.* 11:371–395.

Loste, C. 1995. Approche des couts de production et des marges des enterprises de miticulture sur filieres en Languedoc-Roussillon (France). *Cah. Opt. Medit.* 14:113–121.

McCullough, A., C. M. Gempesaw, W. H. Daniels & J. Bacon. 2001. Simulating the economic viability of crawfish production: A two-stage modelling approach. *Aquacult. Econ. Manag.* 5:69–79.

McKindsey, C. W., H. Thetmeyer, T. Landry & W. Silvert. 2006. Review of recent carrying capacity models for bivalve culture and recommendations for research and management. *Aquaculture* 261:451–462.

Mongruel, R. & O. Thebaud. 2006. Externalities, institutions and location choices of shellfish producers: the case of blue mussel farming in the Mont-Saint-Michel Bay (France). *Aquacult. Econ. Manage.* 10:163–181.

Oglend, A. & S. Tveteras. 2009. Spatial diversification in Norwegian aquaculture. *Aquacult. Econ. Manage.* 13:94–111.

Papageorgiou, P. 2009. Support to the GFCM Working Group on marketing on aquaculture products: development of a strategy for marketing and promotion of Mediterranean aquaculture. National aquaculture market report. Greece: GFCM-CAQ Working Group on Marketing. Rome, Italy: GFCM-FAO, 56 pp.

Papoutsoglou, S. E. 2000. Monitoring and regulation of marine aquaculture in Greece: licensing, regulatory control and monitoring guidelines and procedures. *J. Appl. Ichthyol.* 16:167–171.

Parkin, M. 2010. Economics, 9th edition, global edition. Upper Saddle River, NJ: Pearson. 784 pp.

Penson, J. B., Jr., O. T. Capps, Jr., C. P. Rosson III & R. T. Woodward. 2010. Introduction to agricultural economics, 5th edition. Upper Saddle River, NJ: Pearson/Prentice-Hall. 417 pp.

Rennie, H. G. 2002. A geography of marine farming rights in New Zealand: some rubbings of patterns on the face of the sea. PhD diss., University of Waikato. 404 p.

Rosland, R., O. Strand, M. Alunno-Bruscia, C. Bacher & T. Strohmeier. 2009. Applying dynamic energy budget (DEB) theory to simulate growth and bio-energetics of blue mussels under low seston conditions. *J. Sea Res.* 62:49–61.

Rushton, J. 2009. The economics of animal health and production. Wallingford, UK: CABI Publishing. 364 pp.

Sara, G. & A. Mazzola. 2004. The carrying capacity for Mediterranean bivalve suspension feeders: evidence from analysis of food availability and hydrodynamics and their integration into a local model. *Ecol. Modell.* 179:281–296.

Secretan, P. A. D. 2003. The availability of aquaculture crop (stock mortality) insurance. USDA Risk Management Agency publication. Starkville, MS: Mississippi State University. 73 pp.

Secretan, P. A. D. 2008. Aquaculture insurance industry risk analysis processes. In: M. G. Bondad-Reantaso, J. R. Arthur & R. P. Subasinghe, editors. Study on understanding and applying risk analysis in aquaculture. FAO fisheries and aquaculture technical paper no. 519. Rome: FAO. pp. 229–245.

Stevens, C., D. Plew, N. Hartstein & D. Fredriksson. 2008. The physics of open-water shellfish aquaculture. *Aquacult. Eng.* 38:145–160.

Theodorou, J. A. 2001. Regulation and monitoring of shellfish aquaculture in Europe. In: P. A. Read, T. F. Fernandes, K. L. Miller, A. Eleftheriou, M. Eleftheriou, I. M. Davies & G. K. Rodger, editors. The implications of directives, conventions and codes of practice on the monitoring and regulation of marine aquaculture in Europe. Aberdeen, Scotland: Fisheries Research Services Publications pp. 55–57.

Theodorou, J. A. 2002. Current & future technological trends of European seabass–seabream culture. *Rev. Fish. Sci.* 10(3-4): 529–543.

Theodorou, J. A., A. Kotsonis, P. Sorgeloos, J. Viaene & I. Tzovenis. 2010a. Risk assessment of seabass and seabream aquaculture based on insurance claims in Greece. In: Proceedings of the fifteenth biennial conference of the International Institute of Fisheries Economics & Trade, July 13–16, 2010, Montpellier, France: economics of fish resources and aquatic ecosystems: balancing uses, balancing costs. Compiled by Ann L. Shriver. Corvallis, OR: International Institute of Fisheries Economics & Trade.

Theodorou, J. & I. Tzovenis. 2004. Aquaculture insurance. In: J. Teugels & B. Sundt, editors. Encyclopedia of actuarial sciences, vol. I. Chichester, UK: John Wiley & Sons, pp. 86–90.

Theodorou, J. A. & I. Tzovenis. 2007. Shellfish farming in Greece. In: Abstracts of the 10th International Conference on Shellfish Restoration (ICSR), Vlissingen, The Netherlands, 12–16 November 2007.

Theodorou, J. A., I. Tzovenis, P. Sorgeloos & J. Viaene. 2010b. Risk perceptions and risk management strategies of the Greek mussel farmers. In: Proceedings of the fifteenth biennial conference of the International Institute of Fisheries Economics & Trade, July 13–16, 2010, Montpellier, France: economics of fish resources and aquatic ecosystems: balancing uses, balancing costs. Compiled by Ann L. Shriver. Corvallis, OR: International Institute of Fisheries Economics & Trade.

Theodorou, J. A., I. Tzovenis, P. Sorgeloos & J. Viaene. 2012. Risk management of farmed mussel harvest bans due to HAB incidents in Greece. In: P. Pagou & G. Hallegraeff, editors. Proceedings of the 14th international conference on harmful algae. Hersonissos, Crete, Greece, 1–5 November 2010. International Society for the Study of Harmful Algae (ISSHA) and Intergovernmental Oceanographic Commission of UNESCO. pp. 267–269.

Theodorou, J. A., J. Viaene, P. Sorgeloos & I. Tzovenis. 2011. Production and marketing trends of the cultured Mediterranean mussel *Mytilus galloprovincialis* Lamarck 1819, in Greece. *J. Shellfish Res.* 30:859–874.

Thong, N. T. 2012. An inverse almost ideal demand system for mussels in Europe. *Mar. Resour. Econ.* 27:149–164.

Tveteras, R. 1999. Production risk and productivity growth: some findings for Norwegian salmon aquaculture. *J. Prod. Anal.* 12:161–179.

Tveteras, R. 2002. Industrial agglomeration and production costs in Norwegian aquaculture. *Mar. Resour. Econ.* 17:1–22.

Tveteras, R. & G. E. Battese. 2006. Agglomeration externalities, productivity and technical inefficiency. *J. Reg. Sci.* 46:605–625.

Valderrama, D. & C. R. Engle. 2001. Risk analysis of shrimp farming in Honduras. *Aquacult. Econ. Manage.* 5:49–68.

Vlamis, A., P. Katikou, D. Petridis & J. A. Theodorou. 2012. Production and harvesting management of Greek cultured mussels linked to toxic episodes' occurrence due to lipophilic toxins: optimization possibilities. In: P. Pagou & G. Hallegraeff, editors. Proceedings of the 14th international conference on harmful algae. Hersonissos, Crete, Greece, 1–5 November 2010. International Society for the Study of Harmful Algae (ISSHA) and Intergovernmental Oceanographic Commission of UNESCO. pp. 270–272.

Zanou, B., C. Anagnostou & E. Papathanassiou. 2005. Seeking the factors to stimulate the users in the coastal zones planning: case study: open discussions with mussel farmers in the Axios River (GR). *Medit. Mar. Sci.* 6:107–115.