

# **Risk Analysis of the Mediterranean Mussel Farming in Greece**

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# ACKNOWLEDGEMENTS

*As*

*"Life is a Risk"*

*(Zorbas The Greek)*

*and*

*"Knowledge comes*

*through practice..."*

*the*

*"Great spirits have always encountered*

*violent opposition from mediocre minds..."*

*(Albert Einstein)*

In the early years (mid 80s – 90s) of the Mediterranean Marine Aquaculture industry, mainly with production of sea-bass, sea-bream and mussels, the majority of the scientific effort on this arising industry had to deal with zootechnical and scientific gaps in order to increase the production. Following the achievement of these goals, approximately at the end of the last century, the need for optimization of the production processes and for the elimination of the uncertainties of the system has been, then, emerged. Due to my involvement in both sectors (industry and academia) I realized the need for *Risk Analysis* and perceived it as a challenge to make a link between aquaculture and economics. A preliminary survey in the literature highlighted the scarcity of this type of studies regarding Mediterranean aquaculture. Therefore, I adapted analytical techniques from engineering, business management and agriculture topics. Furthermore, the need to develop this type of studies was also recognized by FAO and GESAMP by publishing training manuals (2008), which served as guidelines for application in indicative case studies. In addition, at the same time, ISO identified the need for the development of an International Standard for Risk Management, and this was given in 2009 by upgrading and improvement of the Australian and New Zealand Risk Management Standard AS/NZS 4310:2004 to a new international version, i.e “Joint Australian and New Zealand AS/NZS ISO 31000 (2009)”. As far as Greece was concerned, while trying to fill the gap on risk analysis and management of the industry, I shared the idea and was seeking support from my colleague Dr Ioannis Tzovenis (PhD in Biotechnology, Gent University) and Prof. Dr Patrick Sorgeloos (ARC, Gent University) who was the one who introduced me to Prof. Dr ir. Jacques Viaene (Agricultural Economics, Gent University) who kindly accepted to supervise my work due to his expertise in the field of Agricultural Economics.

Prof. Viaene introduced me to risk analysis focusing on economic view, and showed me the way to conceptualize my initial idea and transform it into data. He also encouraged me to study, organize and go in more detail in agricultural socio-economics and risk modeling.

My initial PhD effort was on “*Risk Analysis of Mediterranean Aquaculture in Greece*” including both fish and mussel farming. However, since fish farming has different structure and operating processes I decided to divide these two individual works and finally focused on mussel farming. Thus, this multidisciplinary and inter-scientific collaboration could not be totally accomplished to TEI of Epirus & W. Greece, where I work, and for this reason I joined Gent University for further support. I would like to express my gratitude to all the technical and administrative staff of the library of the School of Bioscience Engineering of Gent University, the Department of Agricultural Economics and the ARC, especially Mr Marc Verschraeghen, for their hospitality and the kind support to this effort. My thanks also goes to Prof. Peter Bossier, head of ARC, for his administrative and scientific advises to complete the present thesis. The results of this research work have been presented with a delay, despite the fact that research work has been completed earlier. In any case, I believe, that the present approach, although it is not classified as a breakthrough in the field, still is somewhere within the cutting edge of the international knowledge. Its practical value is the conclusion of the recommended risk management policies. As the proposed working framework is interactive, it can be continuously up-graded, giving valuable risk analysis knowledge on special fields, such as that of the current economic crisis management strategy.

Furthermore, the multilevel and multidisciplinary approach of this effort, which seems to be perfectly linked with the multi-tiered diagnostic methodology developed by Ostrom (Nobel Prize winner in Economics, 2009) to explore the polycentric governance of complex economic systems. It can be used as an input to verify the socio-ecological systems models that have recently become “hot” topics in evolutionary economics and further analyze the socio-technological transitions of the aquaculture industry.

Last but not least, I would also like to thank my friends and colleagues Dr Panos Dendrinis,

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This effort is dedicated to the loving memory of my father Apostolos who encouraged me  
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Messologi, 3-4-2015  
John (Ioannis) Theodorou

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## LIST OF ABBREVIATIONS

adj R <sup>2</sup>	Adjusted R <sup>2</sup>
AOAD	Areas Organized for Aquaculture Development
Apr	April
AS/NZ	Australia/New Zealand
ASP	Amnesiac Shellfish Poisoning
Aug	August
<i>B</i>	Beta Coefficient
BMPs	Better Management Practices
CFP	Common Fisheries Policy
(C)	Consequence
<i>C</i>	<i>Celsius</i>
<i>C</i>	Intercept
<i>ca.</i>	<i>Circa</i>
Dec	December
CumExpVar	Cumulative Explained Variance
Dept	Department
DSP	Diarrheic Shellfish Poisoning
EBIT	Earnings Before Income Tax
EEC	European Economic Community
e.g.	Example
EPAL	Operational Program of Fisheries ( <i>in Greeks</i> )
ESD	Ecologically Sustainable Development
EU	European Union
Expvar	Explained Variance
FAO	Food and Agriculture Organization of the United Nations
FEAP	Federation of European Aquaculture Producers
Feb	February
FGM	Federation of Greek Maricultures
Fig.	Figure
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
G.P.	General Partnership (company)
Ha	Hectare
HABs	Harmful Algal Blooms
Hp	Horse Power
Jan	January
<i>i.e.</i>	In Other Words
IOPC	International Oil Pollution Compensation



## LIST OF ABBREVIATIONS (*continue*)

ISO	International Standard Organization
Kg	Kilogram
(L)	Likelihood
L.P.	Limited Partnership (company)
m.	Meter
<i>M.</i>	<i>Mytilus</i>
MANOVA	Multivariate Analysis of Variance
Mar	March
MS-Excel	MicroSoft-Excel
Nov	November
NBRL	National Biotoxin Reference Laboratory
NSS	Greek National Statistic Service
Ns	Non Statistically Significant
<i>O.</i>	<i>Ostrea</i>
Oct	October
PD	Presidential Decree
PSP	Paralytic Shellfish Poisoning
<i>Py</i>	Price per Unit of Output (euros/tonne)
R <sup>2</sup>	Coefficient of Determination
R&D	Research and Development
SD	Standard Deviation
Sep	September
SEest	Standard Error of Estimation
sp.	Species
spp.	Species (plural)
T	Ton
t/ha	Ton per Hectare
TVP	Total Value Product
TC	Total Costs
TVC	Total Variable Costs
TFC	Total Fixed Costs ( <i>total monetary value of fixed inputs</i> )
UV	Ultra Violet
<i>V.</i>	<i>Venus</i>
<i>Y</i>	Amount of Output
VIF	Variance Inflation Factor
Yr	Year
$\phi$	Diameter

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# CHAPTER 1

INTRODUCTION\*

TO THE MEDITERRANEAN  
MUSSEL FARMING IN GREECE  
& THESIS OBJECTIVES

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\*Adapted from: Theodorou, J.A., J. Viaene, P. Sorgeloos & I. Tzovenis. 2011. Production and Marketing Trends of the cultured Mediterranean mussel *Mytilus galloprovincialis* L. 1819, in Greece. *Journal of Shellfish Research*, Vol. 30, No. 3, 859–874.

## 1.1 INTRODUCTION

Farming of the Mediterranean mussel *Mytilus galloprovincialis* Lamarck 1819, is the pioneer, 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 increases 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 modern development of the Greek shellfish farming sector (since nothing has been reported in between the ancient times and the mid '50s) 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 1984) 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 (up to 1984) 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 and 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 big 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).

## 1.2 OBJECTIVES AND RESEARCH QUESTIONS

The aim of the current work is:

- i) to demonstrate the major technical and economic achievements of the Greek mussel farming sector, before the Greek financial crisis culminated (2010), providing valuable background data to evaluate the sectors' adaptations under the Greek financial crisis new business environment (Chapter 1). New business environment refers to new legislation (incorporates EU directives on marine, public health, and product processing, environmental monitoring), no new permit issuing as the coastal spatial planning is stalled for many years now, no cash flow support due to recent financial crisis (McKinsey & Company, 2012; Theodorou et al., 2014b).
- ii) to evaluate the suitability of the new "Joint Australian and New Zealand Standard AS/NZS ISO 31000:2009 Risk Management Standard" as a methodological tool for the risk analysis of the mussel farming sector in Greece (Chapter 2).
- iii) to highlight the industry's major constraints and most probable risks in an effort to contribute towards sustainability of the sector (Chapter 3).
- iv) to assess the risk management strategies that are used by the producers to share their risks. In this case (Chapter 3), the following questions need to be addressed:
  - a) what are the risks that are covered by the farmers themselves and managed efficiently at farm level?
  - b) what are the risks that are not affordable to the producers and have to be shared through alternative strategies such as insurance schemes and public compensations?

- v) to provide required strategies to cover the gaps on the risk management policies. Such outcomes to mitigate the economic losses are concluded from an in depth study in Chapter 4 of the risk factors affecting the profitability of the Greek mussel farms. In addition the identified risk of the HABs harvesting bans is examined as a threat at the farm level giving the seasonal range of its severity in Chapter 5.
- vi) to share the created knowledge (Chapter 6) from the synthesis of the previous deliverables as risk management strategy perspectives to the stakeholders (farmers, industry, administrators, scientists).

### **1.3 GREEK MUSSEL FARMING**

#### **Industry location**

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. 1.1). 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 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 semi closed embayment in midwest Greece (Ionian Sea). Small farming sites and shellfish grounds are also found in the Saronikos Gulf, East Attica, Limnos and Lesvos islands (Paspatis & Maragoudaki, 2005).

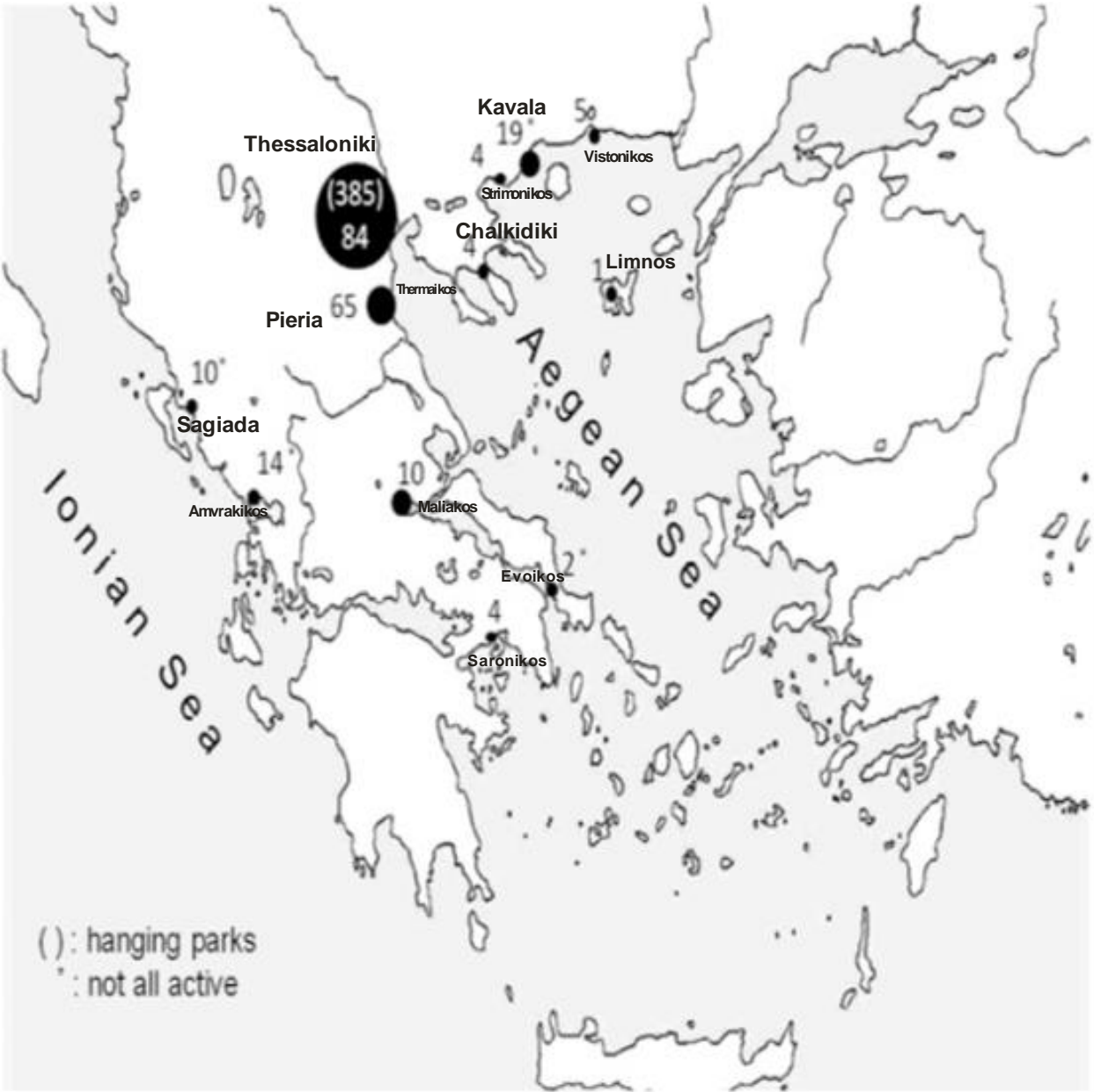


Figure 1.1. Location of mussel farms in Greece (Source: Theodorou et al., 2011a).

## **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 (Figure 1.2).

### ***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 non submerged (1–2m above sea level) mussel bunches. The latter are ropes, which provide space for mussels to attach and grow, that hang from a submerged horizontal line stretching vertically just over the bottom. The overall device is made up of rectangular grids (153 X 100 m) installed at a certain distance to each other

(approx. 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 soon) (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). New legislation illegalized pre-existing technology. But as the system is multi-tiered (see Ostrom, 2010) this happens in theory only. As the demand for export product increases and the natural productivity is available, mussels are illegally produced and then legalized to be marketed, in quantities that the ecosystems' capacity some times could not afford it (Konstantinou et al., 2012; Konstantinou & Krestenitis 2012). 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 (approx. 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.

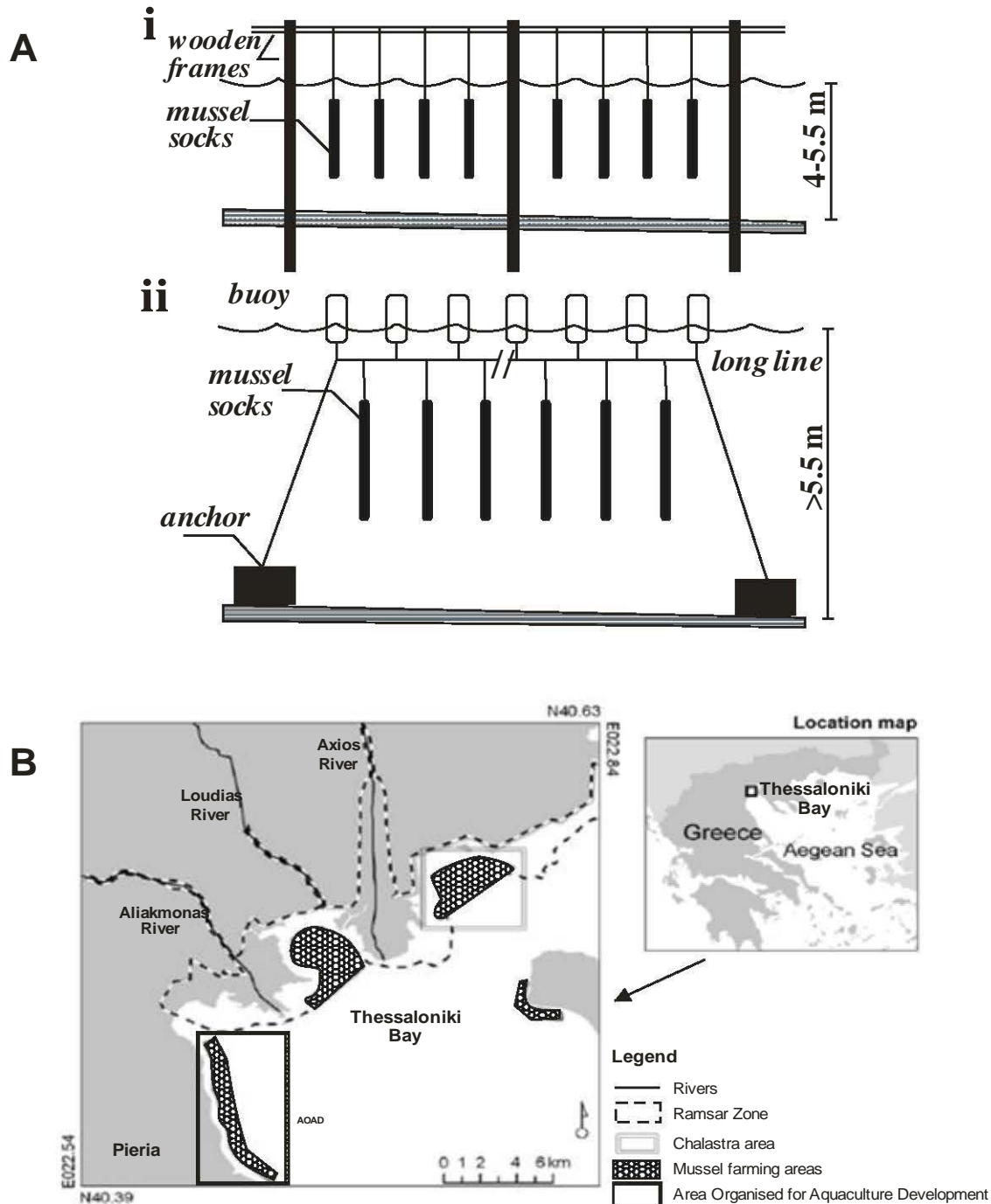


Figure 1.2. (A,B). (A) Major cultivation systems used for mussel farming in Greece: i) hanging parks ii) single floating long line system. (B) Hanging parks that most of them operated with expired licences, located in the area of Chalastra, Thessaloniki Bay. Mussel farms along the Pieria coastline are operated within the recently established 1<sup>st</sup> Area Organised for Aquaculture Development (AOAD) (generic plan adapted from Alexandridis et al., 2008).

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).

#### **1.4 MUSSEL FARMING BUSINESS**

In Greece (up to 2009), there was 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 1.3A. 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 1.3B.

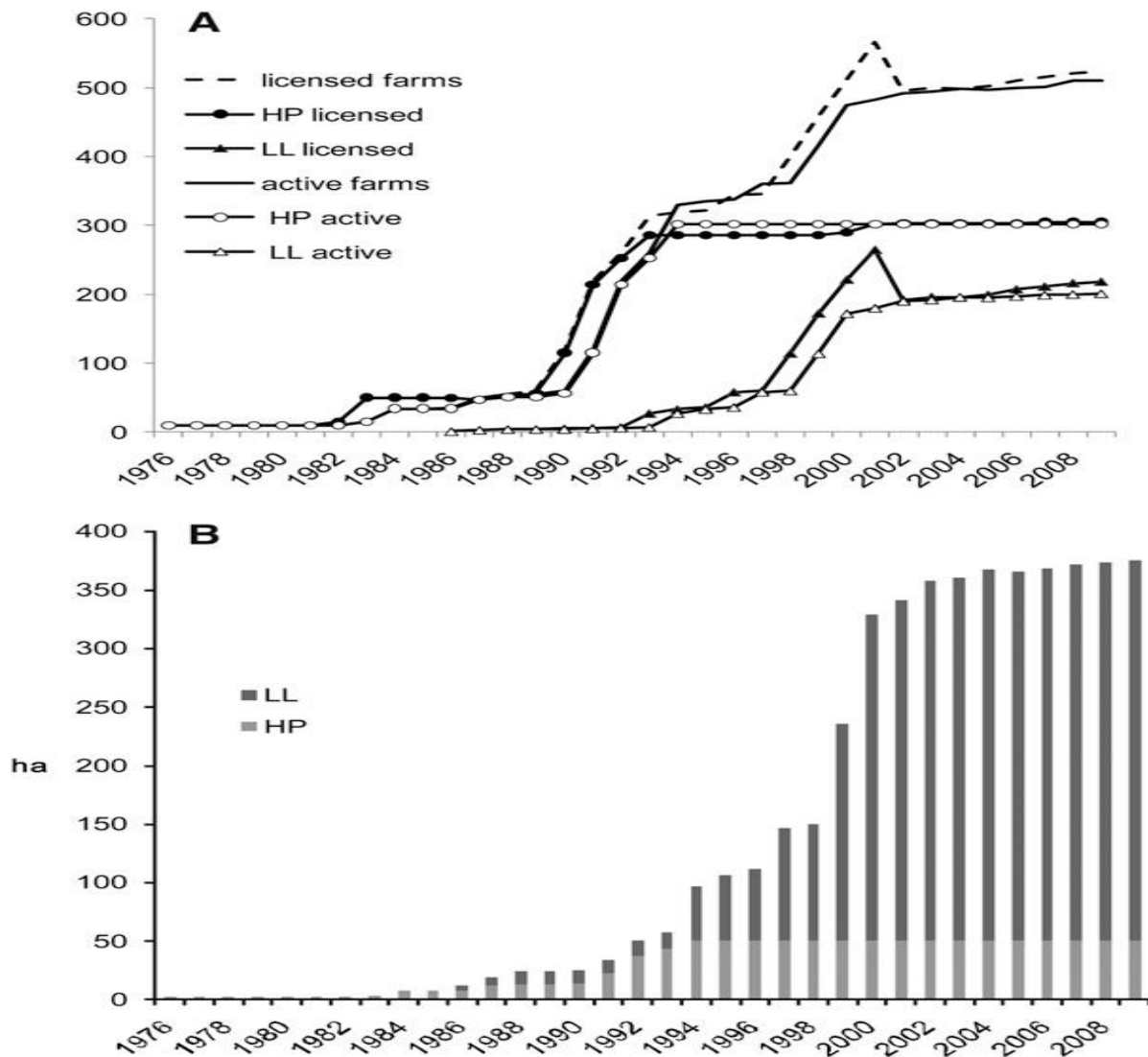


Figure 1.3. (A, B) Evolution of licenses (A) for mussel farming in Greece and farming area (B). HP, hanging park farm type; LL, single floating longline farm type (Source: Theodorou et al., 2011a).

In Figure 1.4, 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<sup>2</sup>, the hanging parks achieved an annual productivity of up to 400 t/ha. Such installations

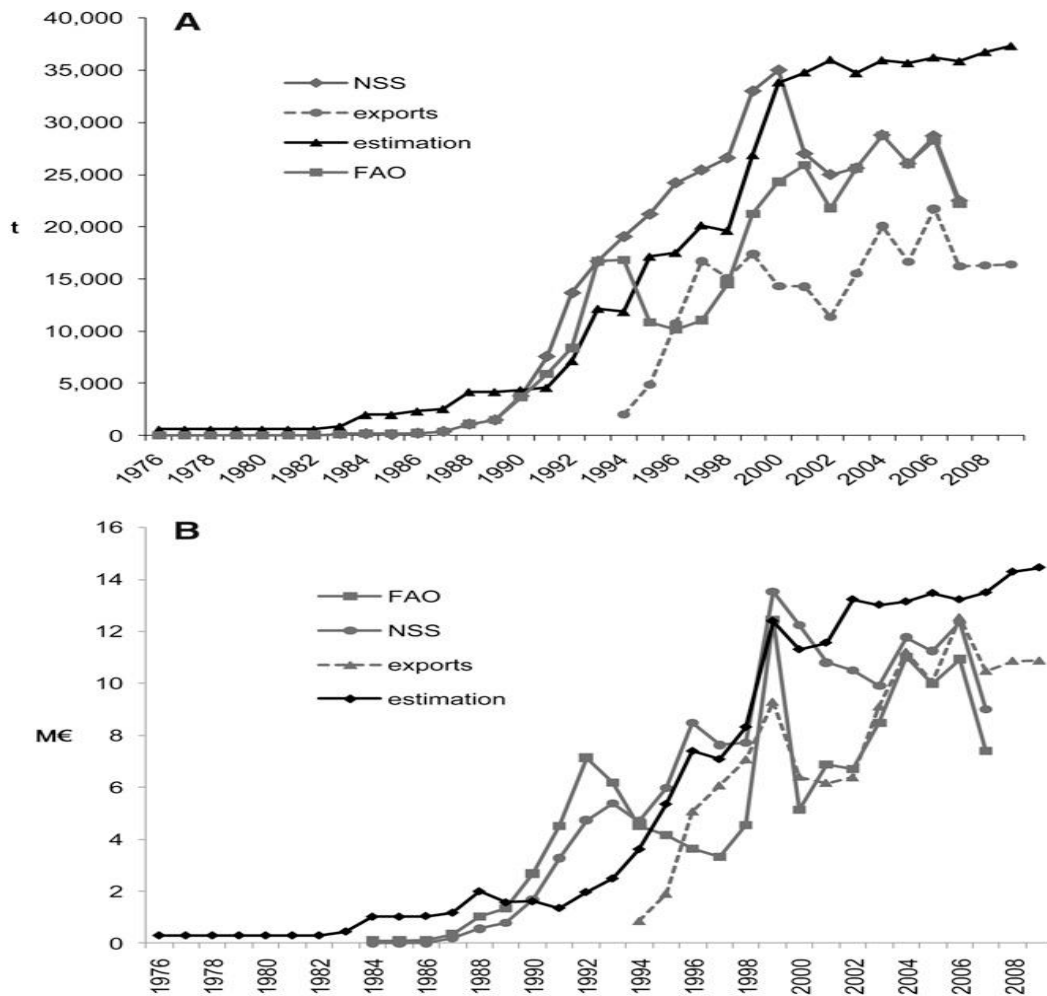


Figure 1.4(A, B). Evolution of Greek mussel farming in actual volume (A) and value (B) plotted against declared data from national and international organizations. export, mussel commercial exports according to the Greek Ministry of Development; FAO, Food & Agriculture Organization (Rome); NSS, National Statistics Service (Greek)(Source: Theodorou et al., 2011a).

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 (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. 1.5).

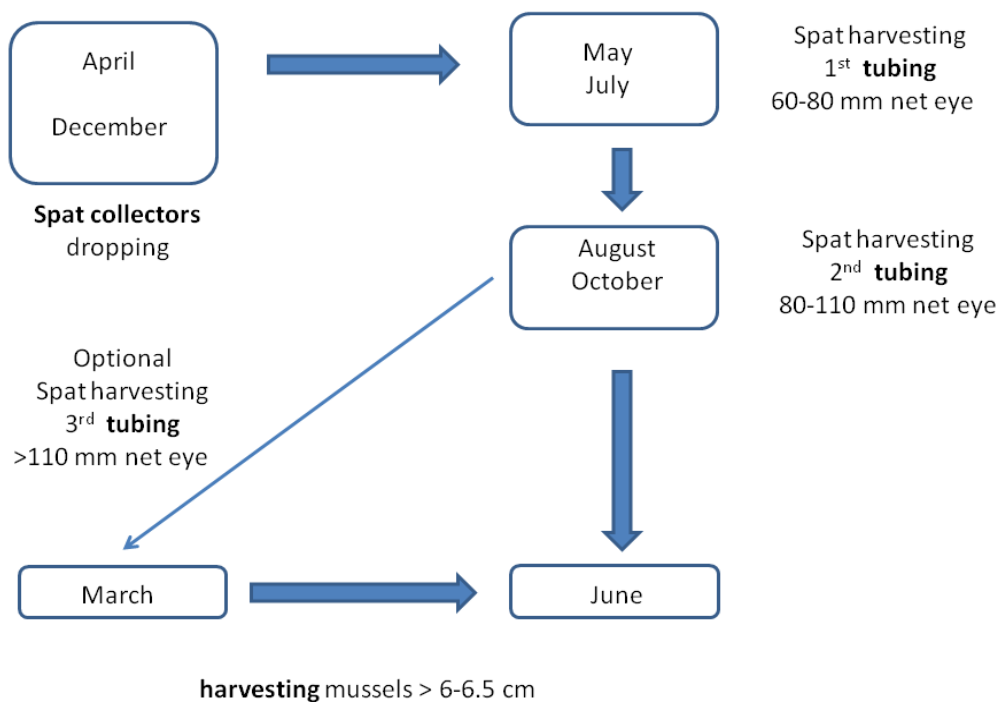


Figure 1.5. Typical generic production model of the Greek mussel farming.

Spat collectors of 2–2.5m 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 socks (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. The juveniles (>35 mm) are easily detached manually from the ropes, collected, and transferred to pergolari. These are plastic, cylindrical nets, 3–3.5m long, with a net eye of 60–80mm attached on a polyethylene rope hung from the single line every 0.5 m (201/100m line or 5,400/ha). They are formed manually with the help of polyvinylchloride cylindrical tubes with a diameter ranging from 40–60mm. 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 (Figure 1.6). 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).

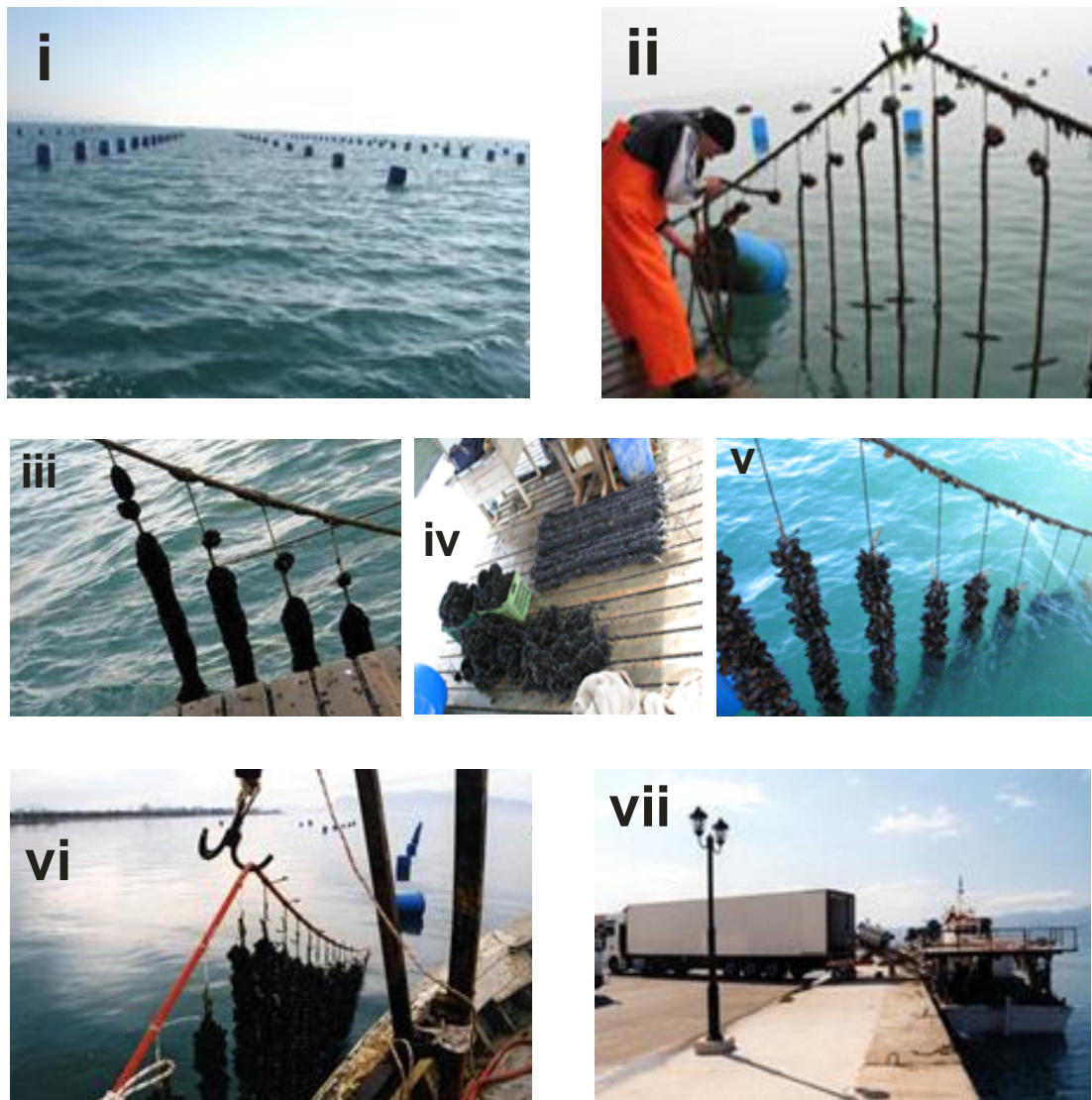


Figure 1.6. (i) Typical long line mussel farm, (ii) spat collectors placement, (iii) spat collection harvesting, (iv) mussel tubing, (v) mussel socks-pergolaris, (vi) on-growing, (vii) mussel harvesting/landing to export (Source: authors archive).

### **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 3 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 (up to 3 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. 1.7A) and variable operating costs (Fig. 1.7B) 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 variable cost, other than the depreciation of machineries and equipments (42%), is labor. Despite mechanization efforts applied recently, the work is still labor intensive, and salaries and wages represent 34% of the total variable 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 variable 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 and others (7%) sum up the rest of the variable costs.

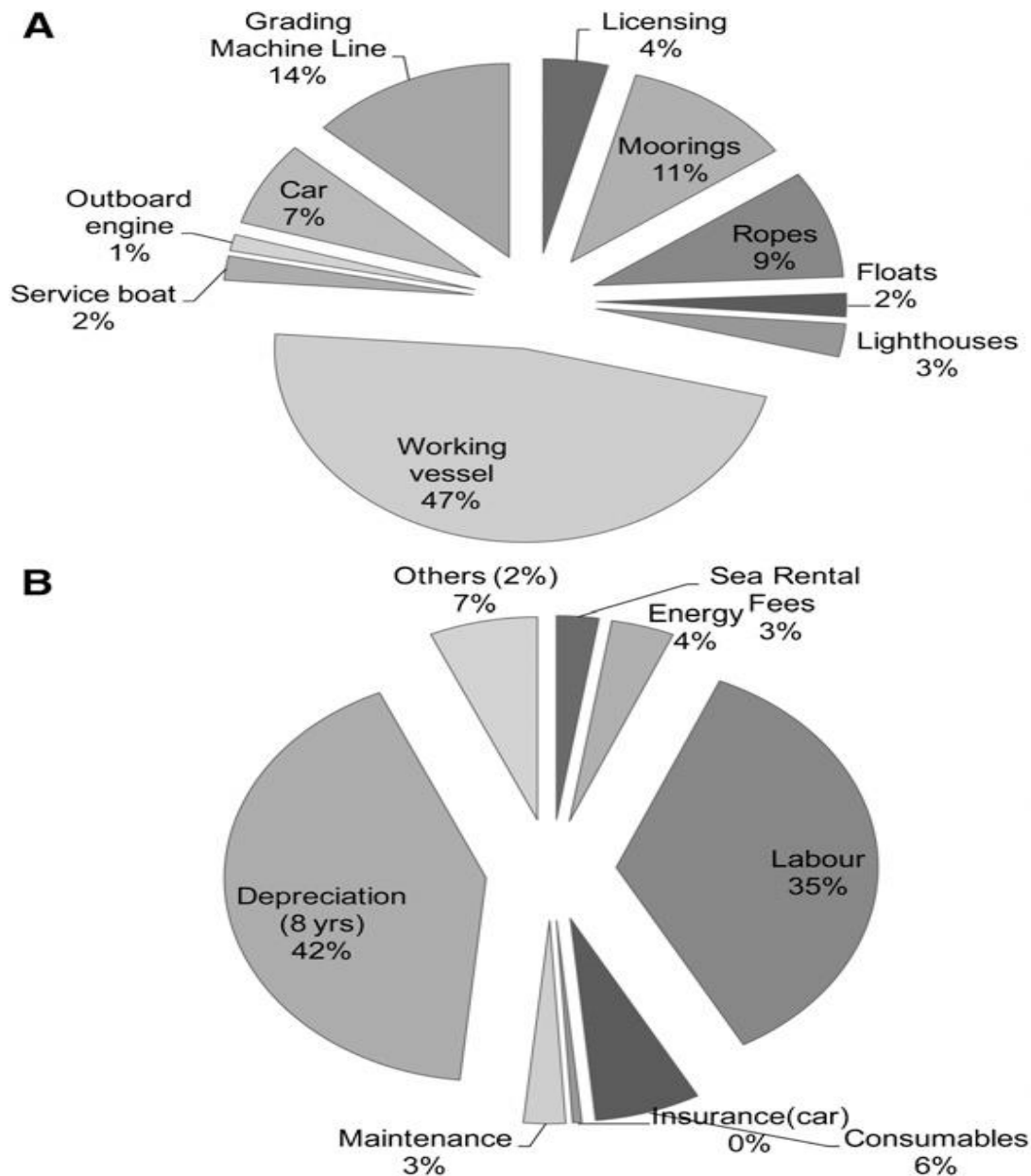


Figure 1.7. (A, B) Average fixed costs of Greek mussel farms per hectare (A) and average variable costs of 1–4-ha mussel farms (B). Depreciation estimated as variable cost referring to use of machines & equipment (Source: Theodorou et al., 2010b; 2011a).

### **Profitability**

Looking at the sensitivity analysis by Theodorou et al. (2010b), the break-even prices (minimum income needed to cover the fixed and variable costs including depreciation (Adams et al., 2005)) for profitable mussel farming in Greece are quite high (Fig. 1.8). Ex-farm bulk prices, however, have remained stagnant for a decade now and are quite low

(range, €0.30–0.60/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.

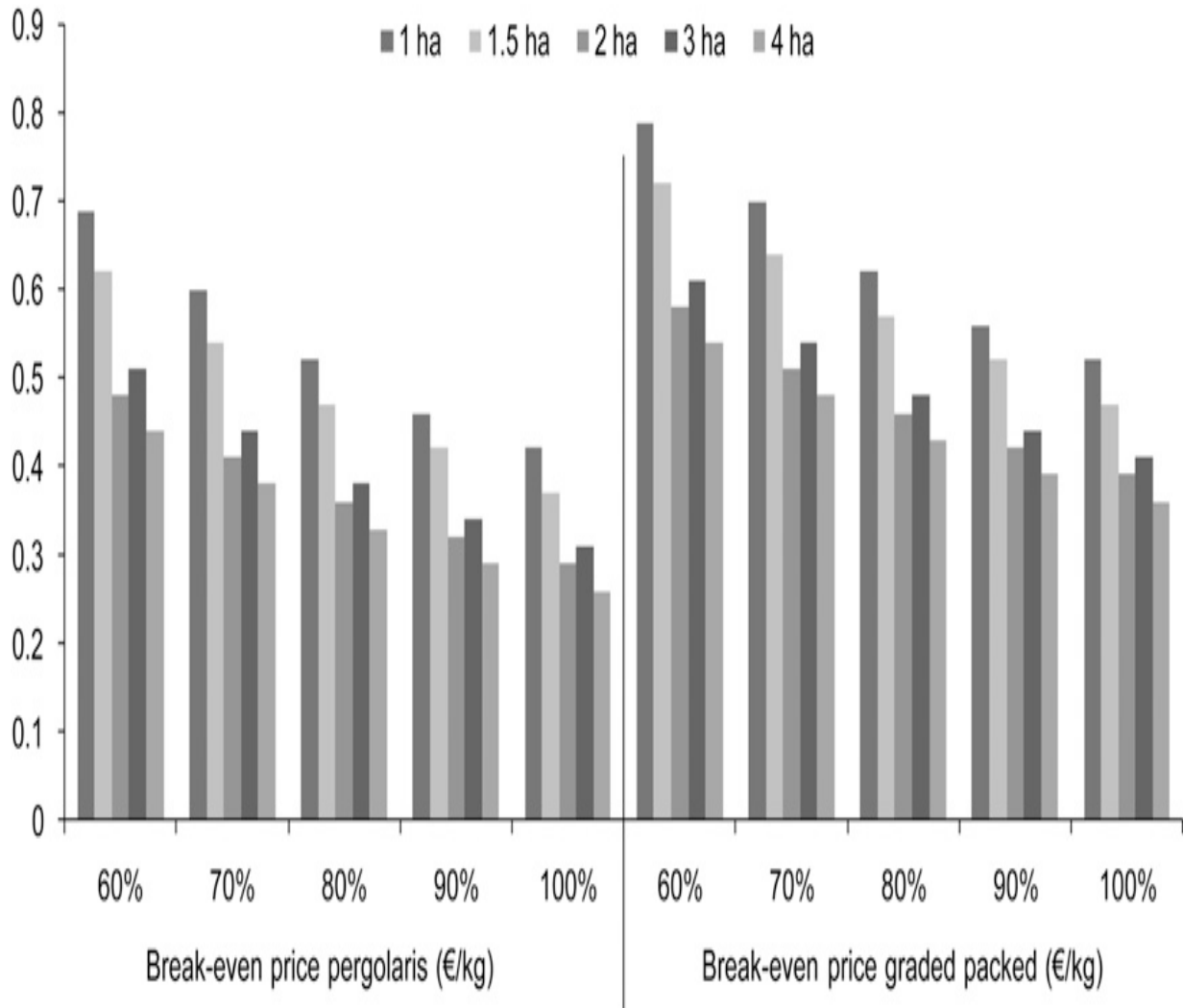


Figure 1.8. Break-even price for Greek mussel farm profitability depending on different farm size (1–4 ha) and different production effectiveness (percent of annual production capacity) (Source: Theodorou et al., 2010b;2011a).

### Marketing channels

The distribution network from the farm to the fork is presented in Figure 1.9. 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. In 2010,

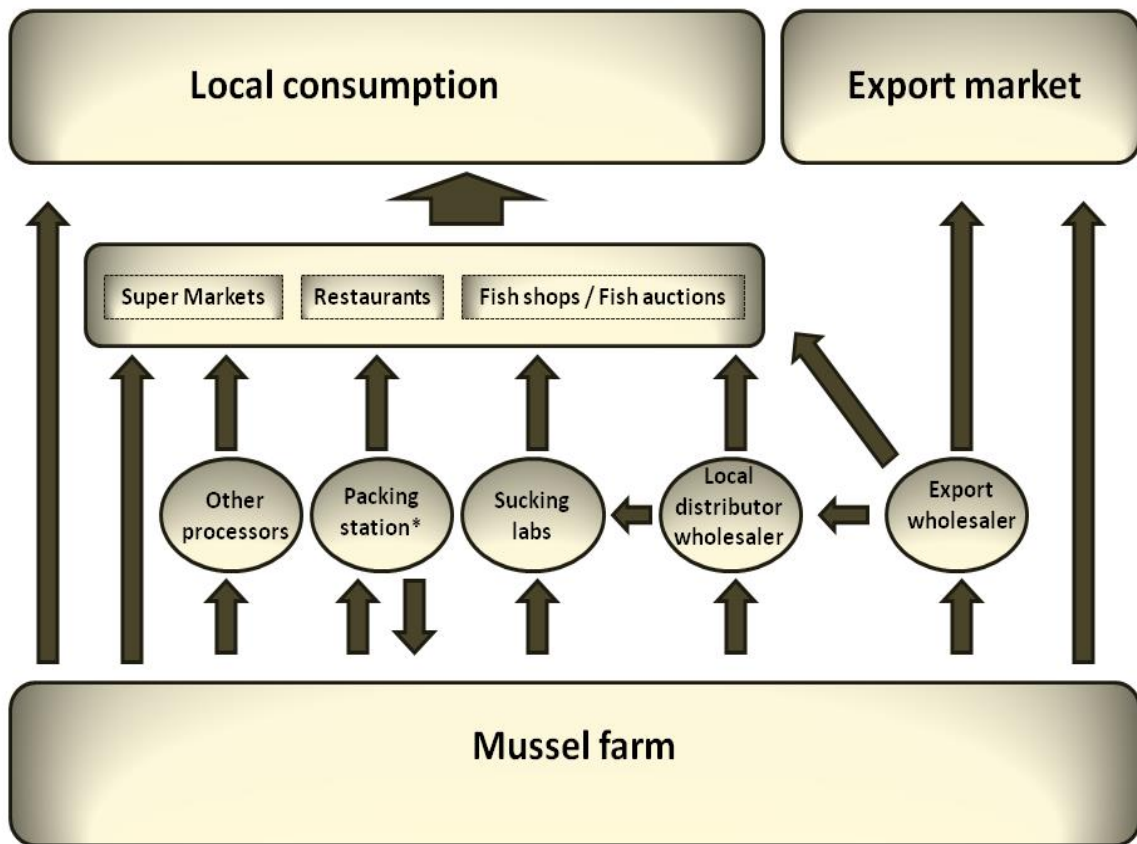


Figure1.9. Market structure of Greek mussel farming. Import channels not included as they are wholesale and not production related (Source: Theodorou & Tzovenis 2007; Theodorou et al., 2011a).

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 repackaging 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. 1.10A) was 16,230 t, and value approached €10.48 million (Fig. 1.10B, data from National Statistic Service). The majority of Greek mussel production has been export oriented, with Italy as its major destination (Fig. 1.11), which received about 50% of the total export volume of live product, followed by France (33%) and Spain (14%). Countries such as the Netherlands, Romania, and Germany are niche spot markets absorbing limited quantities (Fig. 1.11). 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

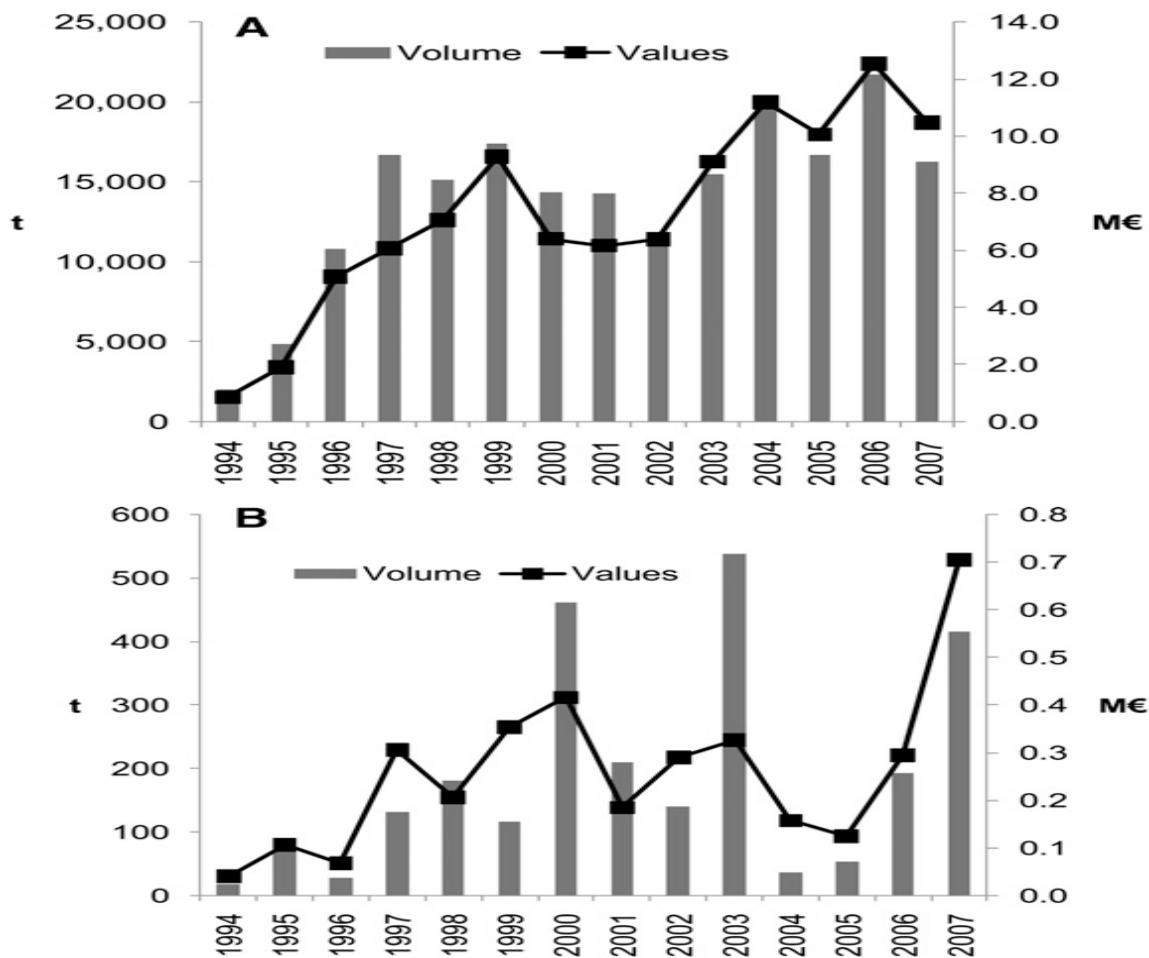


Figure 1.10. (A, B) Evolution of Greek mussel export (A) and import (B) (Source: NSSG;Theodorou et al., 2011a).

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, 2007a).

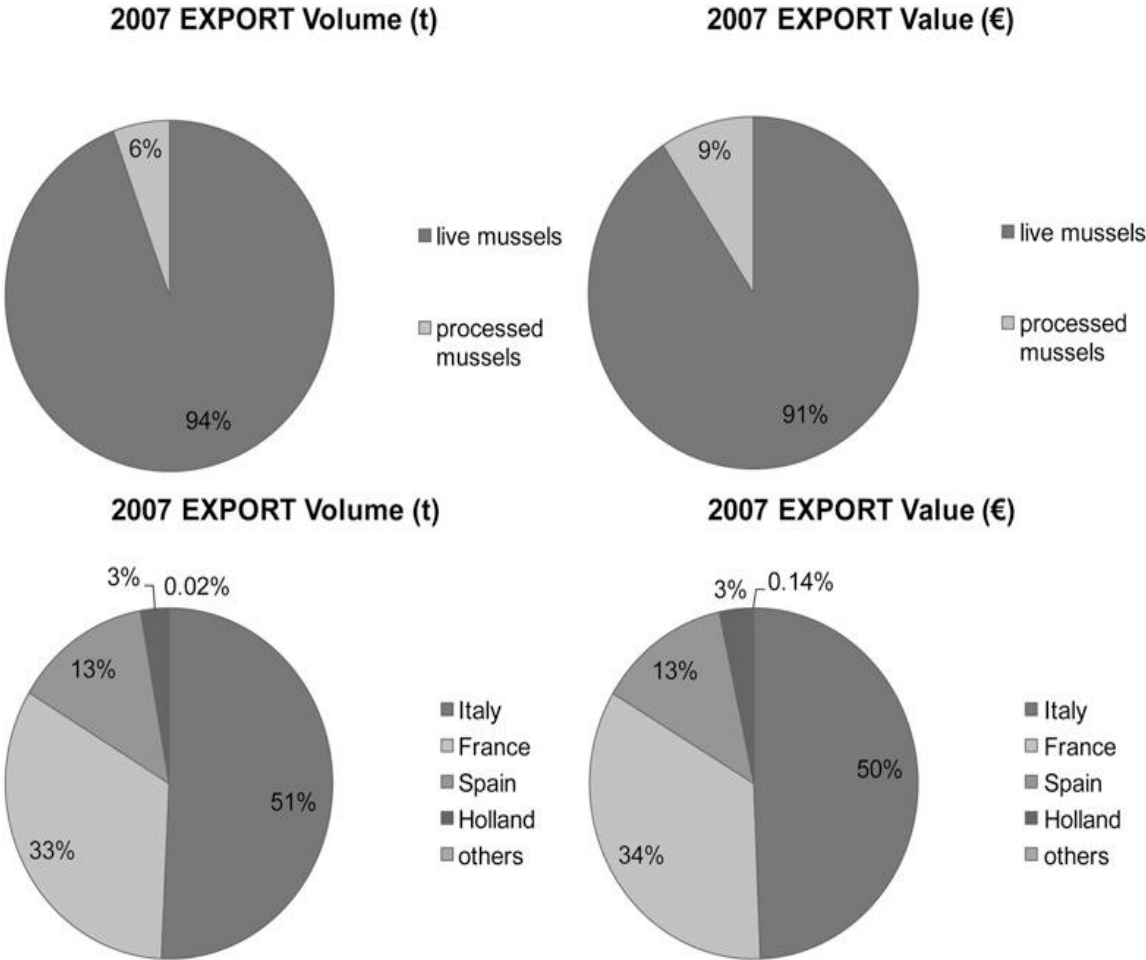


Figure 1.11. Analysis of the Greek export market for 2007 (Source:NSSG; Theodorou et al., 2011a).

### ***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 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, especial 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 (approx. 700 t in 2005 vs. 7,000 t in 1994 (Koutsoubas et al., 2007)). 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 imports of live product (almost all imported from Italy and Spain; Fig. 1.12) 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. 1.12 and 1.13). 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 1.13, 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. 1.9).

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.

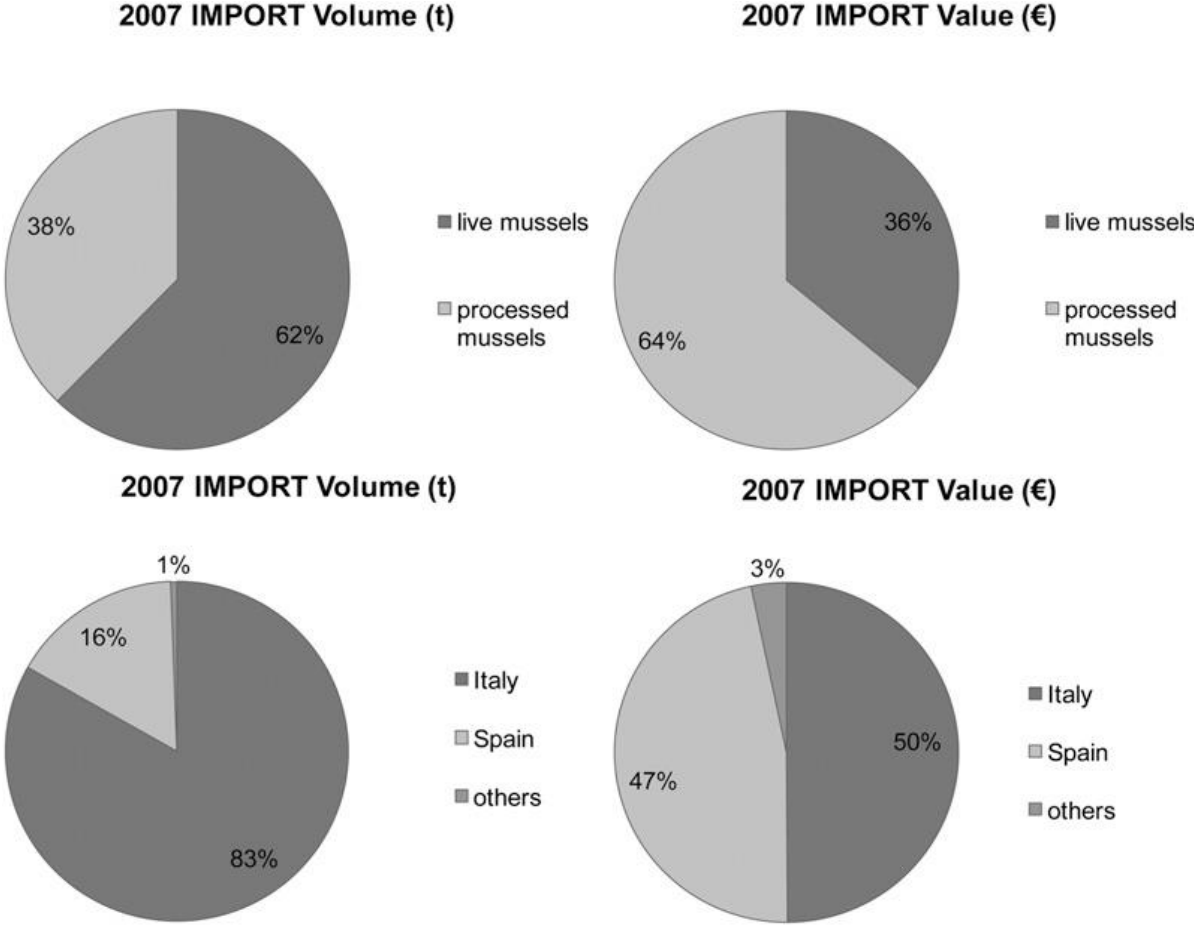


Figure 1.12. Analysis of the Greek mussel import market for 2007 (Source: NSSG; Theodorou et al., 2011a).

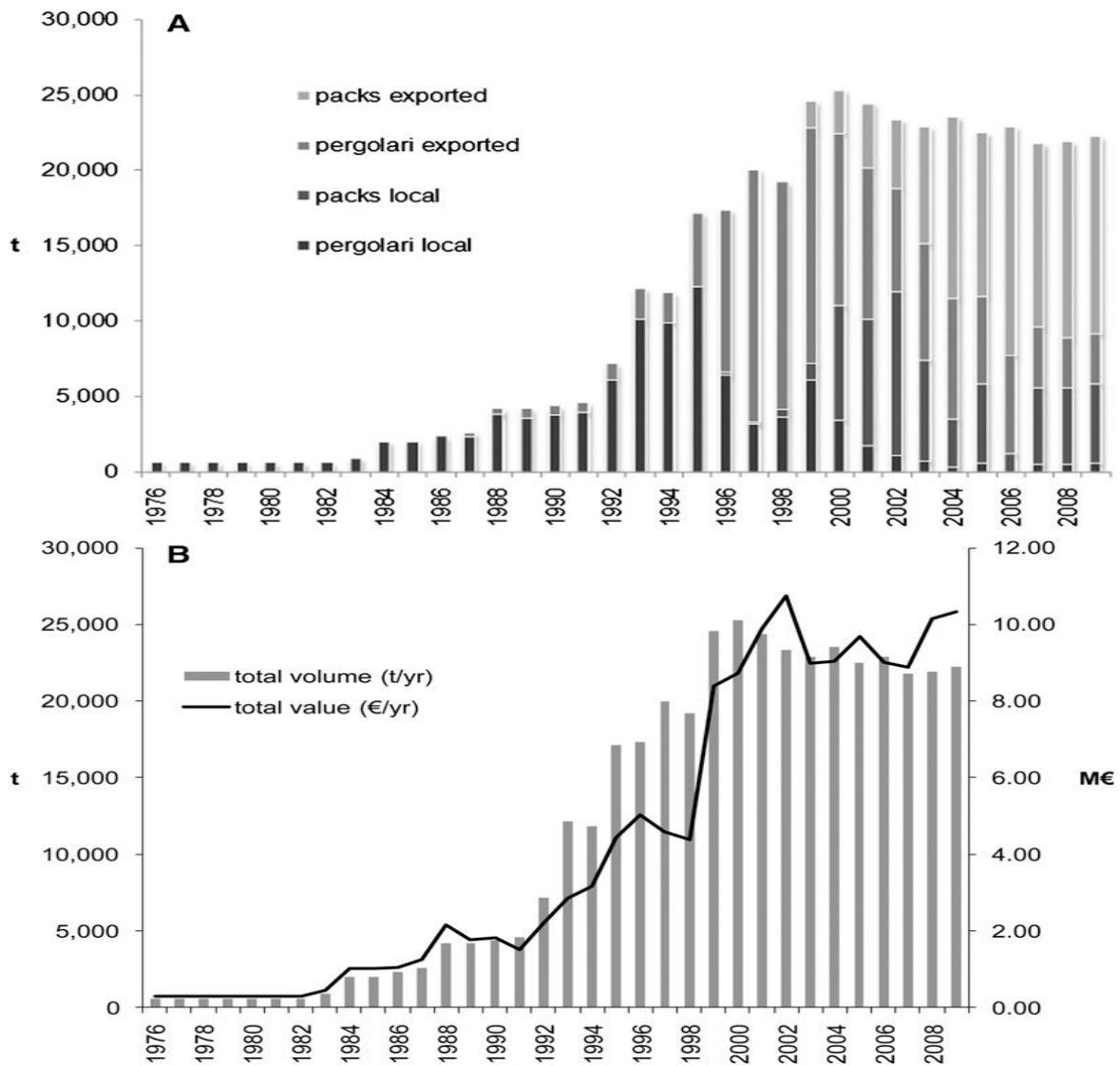


Figure 1.13 (A, B). Evolution of production volume (A) and market value (B) of Greek mussel farming based on different practices and ex-farm market prices. Packs, product packed in 10-kg sacks; pergolari, an entire mussel bunch, including biofouling; local, product consumed locally (Source: Theodorou et al., 2011a).

## 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 around.

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 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 (Areas Organised for Aquaculture Development). The spatial planning of the marine coastal areas, will resolve several conflicts between users, and will promote the sustainability of the different activities (mainly tourism and aquaculture) (Theodorou et al., 2015c). Furthermore, they will secure the property rights of the “commons” by setting rules for the use of the marine environment to the private sector (such as aquaculture enterprises). These measures are necessary in order to promote the aquaculture development as AOADs will protect the sectors investments in the sea. An example is the recent acquisition(2014) by a foreign investor (Italian) of several farms in Pieria (where the 1st AOAD for mussel mussels was established in 2013) activating the Common Spatial Planning Framework for Aquaculture (Common Ministerial Decision No 31722/2011, FEK 2505 ratified on 4 November 2011).

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, Figure 1.13 (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. 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).

## **1.5 CHALLENGES 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, 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, 2007a). 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 (2008) tested a range of MAP under refrigeration and concluded that a mixture of CO<sub>2</sub>:N<sub>2</sub>:O<sub>2</sub> 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.

### **Market Channel Development**

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 fisheries and agriculture. This background dictates their attitude. They are very individualistic between themselves showed in their reluctance to associate but as they need more insight in what they do (being hunters of the marine) many accept scientist or engineers suggestions in an effort to survive better and to be more competitive to each other. 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).

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).

### **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,b), smooth scallops *Chlamys varia* Linnaeus 1758 (Tsiotsios, 2008) and *Flexopecten glaber* Linnaeus 1758 (Lykakis & Kalathakis, 1991; Tsiotsios, 2008; Theodorou et al., 2010), 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 *Modiolus barbatus* 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

fanmussel *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 non indigenous, 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).

## **1.6 CONSTRAINTS**

### **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 utmost 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 years (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.

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 draw backs 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).

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. If insurance policies are needed to secure the sustainable development of shellfish culture in Greece, it has to be defined what are the risks that have to be covered and how. A thorough mussel farming risk analysis 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.



# **CHAPTER 2**

**GREEK MUSSEL FARMING  
RISK ANALYSIS OBJECTIVES  
& METHODOLOGY**

## 2.1 INTRODUCTION

Ever since the early 70s, aquaculture is the most rapidly growing sector of the animal food production in the world (Aerni, 2004; FAO, 2014). It contributes about half (45.6%) of the world's fish supply for human consumption (FAO, 2011; 2014). The bivalve mollusc sector represents approximately 25% of the global aquaculture output (excluding aquatic plants) by volume and 13 % by value in 2010 (FAO, 2011). The volume of cultivated bivalves has risen from just 1 million tons in 1970 to almost 14.4 million tonnes in 2011 (Mc Leod, 2007; Bondad-Reantaso et al., 2008; FAO, 2011; 2013). The cultivation approach is based on the principles of the capture-based aquaculture (Ottolenghi et al., 2004), where the "raw" material, or seed, is collected from natural stocks in the wild and the growing takes place extensively in suitable farming areas of adequate natural productivity to support the production (Costa-Pierce, 2002).

Mussel farming hence, depends on the local natural primary productivity, and faces risks similar to those of the agriculture sector. Consequently, the theoretical risk research experience and the corresponding management from terrestrial agri-business (agriculture, livestock, forestry, conservation) (Huirne et al., 2000; Harwood, 2000; Hardaker et al., 2004; Huirne et al., 2007), has to be applied to the capture based aquaculture.

Because the existing risk methodology background comes from the land-based agri-farming, there is limited knowledge about the risk sources or risk management strategies used to support the financial sustainability of the bivalve shellfish sector (Theodorou & Tzovenis, 2004; Le Grel & Le Bihan, 2009; Ahsan & Roth, 2010; Le Bihan & Pardo, 2010; Le Bihan et al., 2013). Aquaculture risk management is more diverse than agriculture as you may have for the same species a wide range of culture media (freshwater, saltwater), systems

(intensive, extensive), technologies (land based, offshore; captured based, hatchery produced) and species (freshwater, saltwater). In addition you have new technologies that are under a semi-academic pilot testing. Modern aquaculture has less than four decades development in contrast with the agrifarming and livestock production that there is cumulative experience of several thousands years. The biological life cycle of domesticated terrestrial animals such as pigs, chickens, cattles, goats and sheeps are well known comparing with even the well established main stream aquatic species such as shrimps, salmon, trout, seabass, seabream. Furthermore new potential species are introduced for mass production while continuous technical innovations change the way of producing, generating together with the new opportunities also risks such as diseases. While for the terrestrial animal health there is well developed health test and vetereniary medicaments, for the aquaculture the testing techniques are still under developing as new knowledge coming through the recent experience. In addition as in the terrestrial animals it is possible to control the health of each animal (pig, cow, etc) in the flock separately in the aquatic farming this is happening based on indicative samples that may not always guarantee the absence of the effective threats (pathogens agents). As a consequence insurance is not always available for certain type of risks in aquaculture or available in high rates or high self insurances (Secretan 2003; van Anrooy et al., 2006).

## **2.2 OBJECTIVES**

The main objectives of this study are to identify the major risk sources for mussel farming in Greece and to highlight the industry's risk management priorities. Greece has a leading position in Mediterranean aquaculture especially in marine fin fish (Theodorou

et al., 2015c) but no sector has yet a developed tool-set or even bibliography on this subject. Several “acts of God” in the past have shown that the activity is vulnerable to disaster due to the absence of recovery from losses plans. In the early stages of Greek mariculture, especially in the seabass/bream sector (Theodorou, 2002), most risk assessment depended on information extrapolated from individual case studies, usually from other countries with more experience (Norway, Scotland) or from studies of other species (salmon) (Stead & Laird, 2001; Theodorou & Tzovenis, 2004). Unfortunately, aquaculture can be quite location- or production-system-specific and thus widespread generalisation usually does not work.

Furthermore insurance claims data for bivalve farming, which would reveal activity risks in order to be used for risk management planning in Greece, is lacking (Secretan, 2003; Theodorou et al., 2010c,d).

As a result, an alternative analytical tool for Greek mussel farming had to be investigated and tested. Benchmarking other industries on how to approach similar problems where limited data is available (Crawford 2003; Cooper et al., 2005; Bondad-Reantaso et al., 2008) indicated that a generic risk analysis model may be the suitable tool in this case. For this reason, evaluation through application of a generalised framework that can be used for multiple purposes, such as identify knowledge gaps and milestone information; link technical and socioeconomic issues at different levels; give a structure to answer, update and revise key questions; and provide a plan for the relations and responsibilities of the contributed stakeholders is necessary. A generalised framework can be used as a flexible working mind-map that supports the methodological steps required for effective decision making (Crawford, 2003; Fletcher et al., 2005).

The new Joint Australian and New Zealand Standard AS/NZS ISO 31000:2009 Risk Management Standard was selected to be tested as an advanced methodological tool for the present study, and is also a technical objective of the thesis.

For this purpose several criteria (Purdy, 2010) examined the risk management efficiency of the Standard:

- i) Accountable risk performance must be measured at each stage of the examined industry process, giving the levels of acceptance and providing a range of management treatments.
- ii) Risk limits must be clearly defined and comprehensive, and provide targets for the relevant treatment strategies to reach.
- iii) Each task must focus on a certain source of risk, and its possible risk management must be applied up to a certain level.
- iv) The risk management process must be considered as the heart of the risk analysis study.
- v) Every step must be developed through continuous risk communication between stakeholders (producers, governmental administrators, scientists, etc.).

Furthermore, the whole concept of the working framework for the risk analysis of the Greek mussel farming sector, must comply with the 11 effectiveness principles of the Joint AS/NZS ISO 31000 (2009) Standard (Lalonde & Boiral, 2012) such as:

1. Creates and protects values;
2. Contribute as an integral part of all organizational process;
3. Represents a part of the decision making;
4. Explicitly address uncertainty;
5. Is methodological and on time structured;
6. Created based on the best available information & data available;
7. Is structured as tailor made to the examined organization;

8. Take into the account the human dimension including sociocultural factors;
9. Is transparent and inclusive;
10. Is dynamic iterative and responsive to changes;
11. Contribute on the continual improvement of the organization;

## **2.3 METHODS**

In this context, the present work aims to evaluate through application a risk analysis framework that considers technical and socioeconomic factors at different levels of Mediterranean mussel farming of Greece, to be used as a tool by the sector's decision makers to systematically identify and evaluate critical areas for the risk management of the industry. In addition, the study illustrates how this framework will allow mussel farmers and stakeholders to focus on the most important sources of risks and the most effective risk-sharing management strategies. As stakeholders in the Greek mussel industry were considered mainly the farmers/producers, and to a lesser extent the relevant administrators (fishery authorities, veterinary services, local government), suppliers, wholesalers, outsourcing processors (de-shelling facilities, purification facilities, logistics etc.), bankers, insurance offices (public or private actuaries, loss adjusters, policy makers) and local society. It has to be mentioned here that the insurance industry had no data for the activity (in contrast with the fish farming sector where data were available) and consequently no involvement so far.

### **2.3.1 Theoretical Background**

As there are several definitions about risk analysis and risk assessment by different stakeholders (Lane & Stephenson, 1998; Vose et al., 2001; Stephen, 2001; MacDiarmid &

Pharo, 2003; Hardaker et al., 2004; Goldstein & Carruth, 2004; OIE, 2004; FAO/WHO, 2004; Moreau & Jordan, 2005; Bartholomew et al., 2005; Muller-Graf et al., 2012), in practice the definition terms are related to the suitability of the tools in certain fields (Anonymous, 2005; 2009). In this thesis, the term 'risk' follows the term 'risk analysis' as used in its broadest sense, including a) risk assessment; b) risk management; and c) risk communication as proposed by Cooper et al. (2005) for the effective use of the AS/NZS 4360:2004 that is totally incorporated into the new Joint Australian and New Zealand Standard AS/NZS ISO 31000:2009 (making AS/NZS 4360 redundant) to manage risk in large projects and complex procurements (see Figure 2.1). Risk analysis integrates risk assessment (a) and risk communication (c) and is structured to support risk management (b) effectively (see Figure 2.1). In addition, the way the assessment process can be linked to risk management (GESAMP, 2008) is also demonstrated.

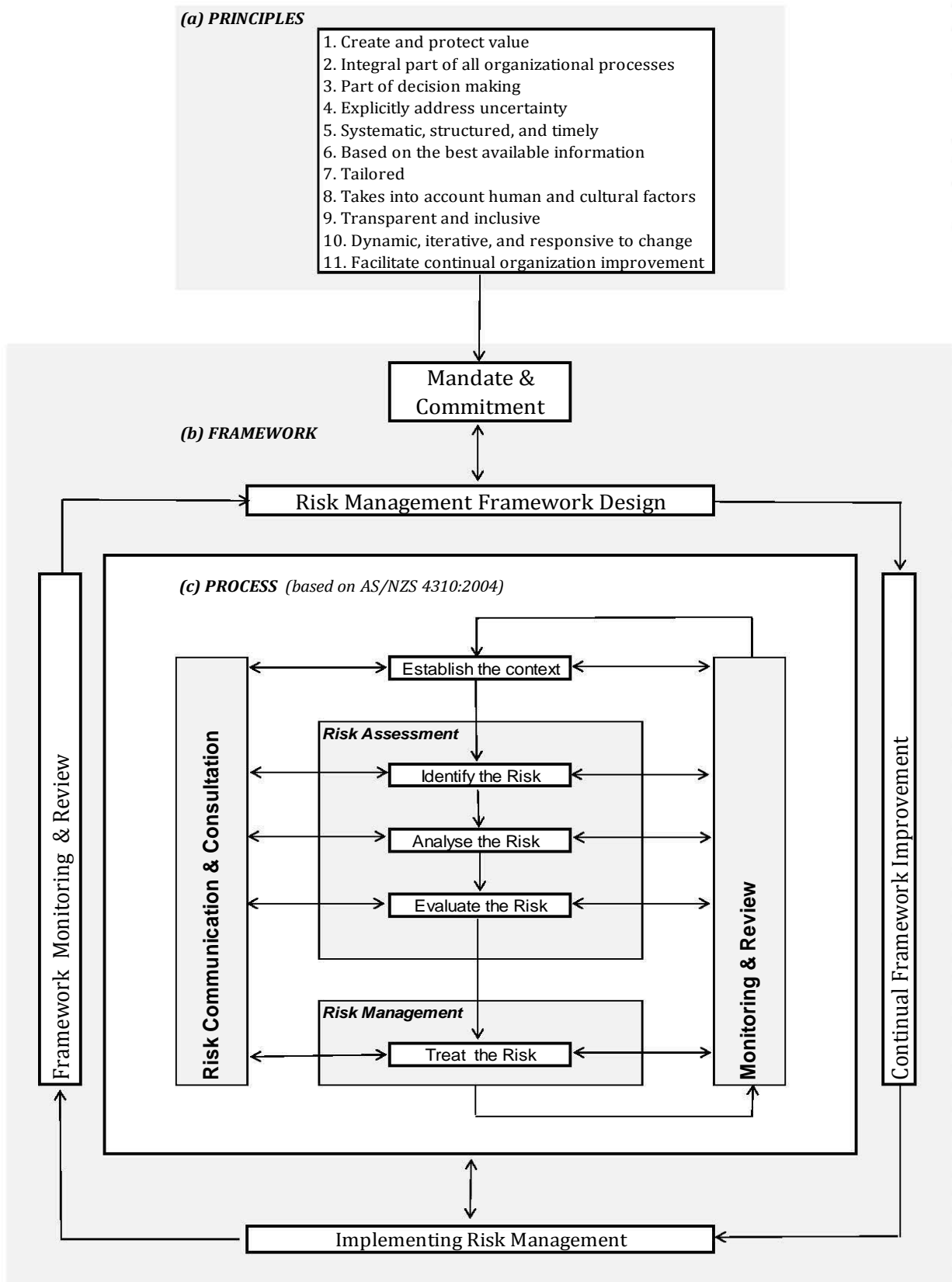


Figure 2.1. A generalized overview of the adapted AS/NZS ISO 31000 Risk Management Standard showing the relations between the added principles (a) for the effective and mandatory risk management framework development (b) to the existing process (c) of the earlier version of AS/NSZ 2431:2004.



## ***Risk Analysis***

Risk Analysis is a methodological tool, commonly defined by its adopted processes, used in several sectors more or less to answer the same questions: *What can go wrong?; How likely is that to happen?; How severe would be the consequences if it did?; What actions should be taken to reduce the likelihood of it happening, or to reduce the consequences?* (McDiarmid & Pharo, 2003).

Answers are usually provided by application of a common set of general principles:

- a. *hazard identification* (to identify issues that under certain conditions might cause damage or loss);
  - b. *risk assessment* (a process to evaluate the likelihood of a hazard occurring and calculating the consequences);
  - c. *risk management* (a process to prevent damages or limit them to acceptable levels);
- and
- d. *risk communication* (improvement of risk assessment and management through exchange of knowledge and experience between stakeholders) (Arthur, 2008).

There are various adoptions of the above generic principles aimed at dealing with environmental (Nash et al., 2005; 2008), financial (Valderrama & Engle, 2001), technological (Ayyub, 2003), and health & safety (Stephen, 2001; Vose et al., 2001; Zagmutt et al., 2013) risks. Modifications have to do with scale or approach (Stensland, 2013) using qualitative, semi-quantitative and/or quantitative analysis tools (Ayyub, 2003; Muller-Graf et al., 2012).

In order to assess the risks in all activities of the Greek mussel farming industry, i.e. in a holistic manner, working at different levels (farm units, associations, sector) and different sections (financial, technical, socio-economical, environmental) involving all interested parties, a flexible tool capable of multi-layered analysis was needed.

As such the Joint Australian and New Zealand Standard AS/NZS ISO 31000:2009 Risk management—Principles and Guidelines (Standards Australia and New Zealand, 2009) was selected (Figure 2.1). This is a managerial tool where risk strategy effectively manages the uncertain outcomes of the objectives (risk) by adding measurable principles to the risk management process at all levels of the decision making (Purdy, 2010; Lalonde & Boiral, 2012). The Joint AS/NZS ISO 31000:2009 is the upgraded international ISO (International Standard Organization) version of the earlier Australian and New Zealand Standard AS/NZS 4360:2004 on Risk Management.

The Joint AS/NZS ISO 31000:2009 incorporates the existing structure of the AS/NZS 4360:2004 (making the AS/NZS 4360 redundant) and enhances its effectiveness by improving risk management methodology through: *i.* adding new definition on risk (see below); *ii.* adding 11 new criteria to measure its effectiveness; *iii.* making risk strategies the mandatory outcomes of every level of management, enhancing the process by adding five more attributes; and *iv.* recommending the development of a wide risk framework.

This standard was used in this study, as its previous version (AS/NZS 4360, 1999; 2004) had worked effectively as a methodology to prioritise risk issues for aquaculture and fisheries management (Fletcher et al., 2004, 2005; Fletcher, 2005). Crawford (2003) also used it with success to qualify the impact of shellfish farming on the environment in

Tasmania, Australia. In addition, its generic form was suitable for managing the risks of large projects and complex procurements (Cooper et al., 2005).

### **2.3.1.1 Definitions**

#### ***Uncertainty***

Renn et al.(2003) defined uncertainty as *“the state of knowledge under which the possible outcomes are well defined but there is insufficient information to assign the likelihood to these outcomes”*. Uncertainty can be expressed in various types and forms, which has to be taken into account, including: a) uncertainty of knowledge (incomplete data, sample limitation, measurement error), b) variability of the results (deviation of the outcomes), c) descriptive difficulties (linguistic uncertainty, expression, poor definition) (Scheer et al., 2014), and d) cognitive difficulties (bias, sensory and perception uncertainty as a result of the mental process). Uncertainty is an integral part of the risk analysis process and its components (Anonymous, 2009).

#### ***Risk***

The concept of risk can be linked to *“an event where the outcome is uncertain”* (Aven & Renn, 2009) and referred to as *“the results of the uncertainty upon the objectives”* (Standards Australia & New Zealand, 2009). It can be defined as *“the potential of losses and rewards resulting from an exposure to a hazard (the potential to harm a target) or as a result of a risk event (encompasses the probability of exposure and the extent of damage)”* (Scheer et al., 2014). Consequently, risk can be expressed as the combination of the probability of an event and its consequences (ISO, 2002). It has certain characteristics that should be used in the risk assessment process. As it is an outcome of an uncertain

future, it cannot be defined neither in the past nor in the present. Risk becomes non-existent when the uncertainties are resolved (Ayyub, 2003).

### ***Risk Analysis***

As there are several definitions of risk analysis and risk assessment by different authors and stakeholders (Lane & Stephenson, 1998; Vose et al., 2001; Stephen, 2001; MacDiarmid & Pharo, 2003; Hardaker et al., 2004; Goldstein & Carruth, 2004; OIE, 2004; FAO/WHO, 2004; Moreau & Jordan, 2005; Bartholomew et al., 2005; Muller-Graf et al., 2011), in practice the definition terms are related with the suitability of the tools in certain fields (Anonymous, 2005; 2009). In this study, 'risk' is taken from the term '*risk analysis*' used in its broadest sense, including a) "risk assessment", b) "risk management", and c) "risk communication" as proposed by Cooper et al. (2005) for the effective use of the Australian and New Zealand Standard 4360:2004 on Risk Management (AS/NZS 4360:2004) (part of the the Joint AS/NZS ISO 31000:2009). Risk analysis integrates risk assessment and risk communication, and is structured to effectively support risk management. In addition, it demonstrates the way the assessment process can be linked to risk management (GESAMP, 2008).

### ***Risk Assessment***

Risk assessment is a technical and scientific process by which the risks of a given situation for a system are modelled and quantified. It determines the likelihood and the consequences of the exposure to a hazard (adverse event). Risk assessment can require and/or provide qualitative, semi-quantitative and quantitative data to the stakeholders for use in risk management (Ayyub, 2003; Muller-Graf et al., 2012).

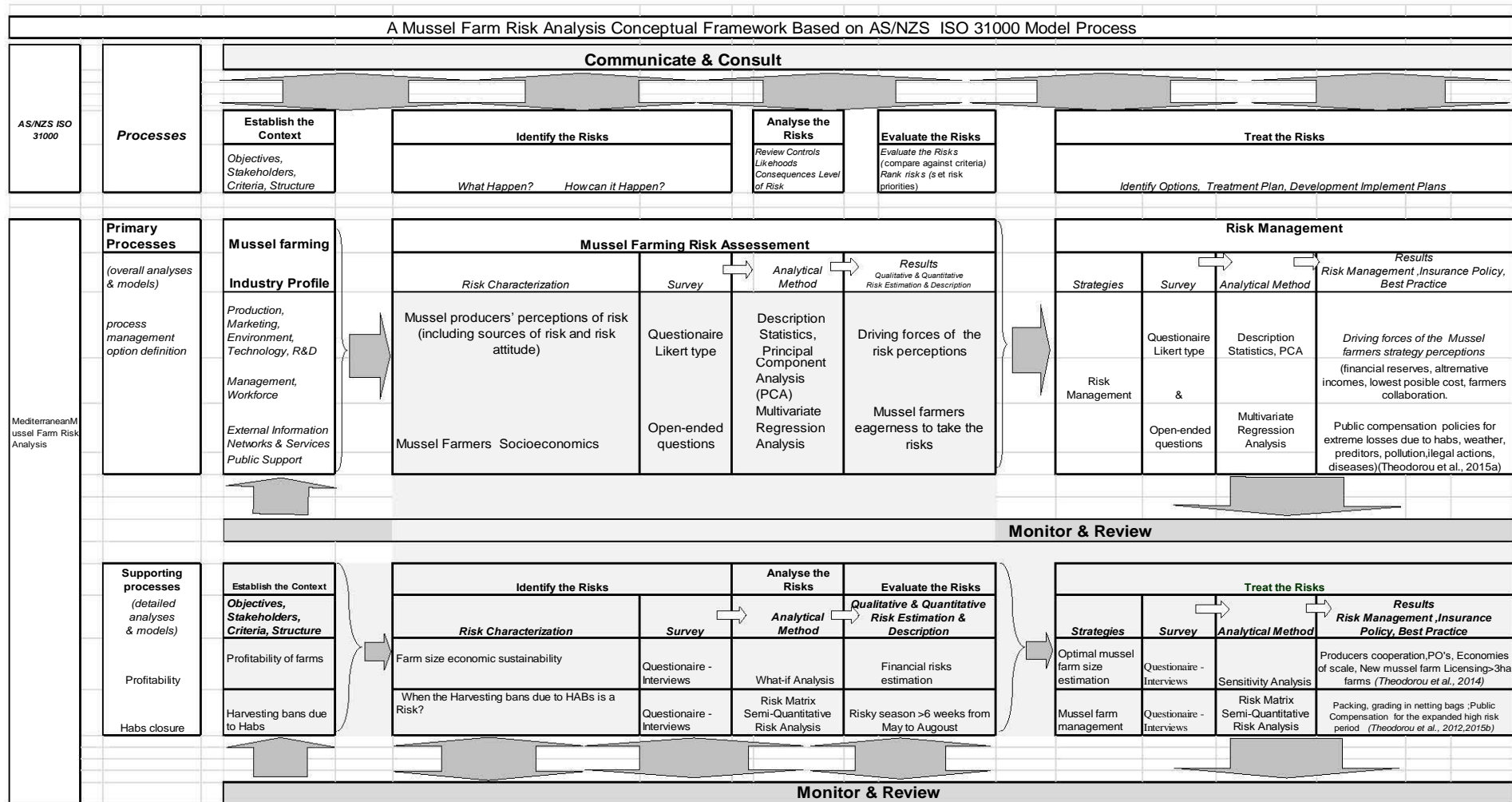


Figure 2.2 A working framework used to analyse the risks of the Greek mussel farming industry based on the AS/NZS ISO 31000 Model Process and the risk management guidelines by Cooper et al. (2005), for large projects and complex procurements.

## ***Risk Management***

Risk management is a process based on the results of the risk assessment of setting up actions and plans to control and eliminate the outcomes of the identified risks to acceptable levels (Cooper et al., 2005).

## ***Risk Communication***

Risk communication is an interactive process between the stakeholders to inform and evaluate the outcomes of risk assessment and risk management. It aims at the improvement of effectiveness of the overall risk analysis plan by a continuous upgrade and implementation of the process (Cooper et al., 2005; Hill, 2009; Anonymous, 2009).

### **2.3.2 Methodological Steps**

The generic form of the Joint AS/NZS ISO 31000:2009 was adapted to the specific Greek characteristics of all levels of the Mediterranean mussel farming business activities and industry function.

The working steps were as follows:

(1) Establish the context;

This refers to *“the structuring of the objectives and the scope of the risk assessment by using the combination of various elements at a range of different levels that act together for a certain reason”* (Cooper et al., 2005). In the case of the Mediterranean mussel farming industry profile in Greece (Figure 2.2), the context inputs include data facts and figures related to the Greek mussel farming sector’s growth and development. Data on bivalve shellfish landings and production harvests at a national level are insufficient (Kalaitzi et

al., 2007). As samples used the official published issues and was tried to identify what exactly officially reported. In addition it was tried to “clear the data” based on biological and empirical estimations about the capacities and the reporting volumes of each site. For this purpose supplementary data were obtained from literature (including grey), public administration and personal interviews-questionnaires. Grey literature referred to industry associations reports (Sougioultzis 1999; Protopapas & Theodorou 1995), fisheries authorities documentations (Giantsis 1999; Galinou-Mitsoudi 2004), public communications of aquaculture scientists and industry consultants (Koumiotis 1998; Kriaris 1999; 2001; Papoutsoglou 2002). Then was realized that the data has to be cleared even from the official sources as FAO, NSSG. In order to cover the gaps of the official statistics we had to ask farmers, local administrators and other stakeholders for estimations of production volumes in their area, what do they reported as production, etc. The questionnaires developed for the purposes of the Chapter 3 focused on the farmer perceptions for risks and losses but contained also questions on their farm structure, capacity and normal production ability for the year in question. These questions were straightforward and required an objective answer (numbers). Answers were not used directly but as aid to verify official or unofficial numbers in relation with biological data and published work. It was tried to avoid predetermined answers as well as with open ended questions it was tried to detect possible missing values.

Discrepancy between different data sets weakens national and international data monitoring. Inefficient statistical collecting systems are not a Greek phenomenon concerning fishery statistics in the European Union (EU) (The Economist 2008; Tsikliras et al., 2013). Discrepancies resulting from measuring systems (e.g., shocks (pergolaris) 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 near shore farming within protected natural reserve areas (Figure 1.2B), 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) (Theodorou et al., 2015c). In the current study, an effort has been made to develop an objective data series on production volume and value from 1976 up to the early stage 2009-10 of the greek economic crisis 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.

The context, based on a review of the existing status of the industry (Theodorou et al., 2011a), gives details about the natural and business environment of mussel farming in Greece as well as the production and marketing structure. The conclusion points out the major “sensitive” risk areas that have to be focused on in the next step of the assessment.



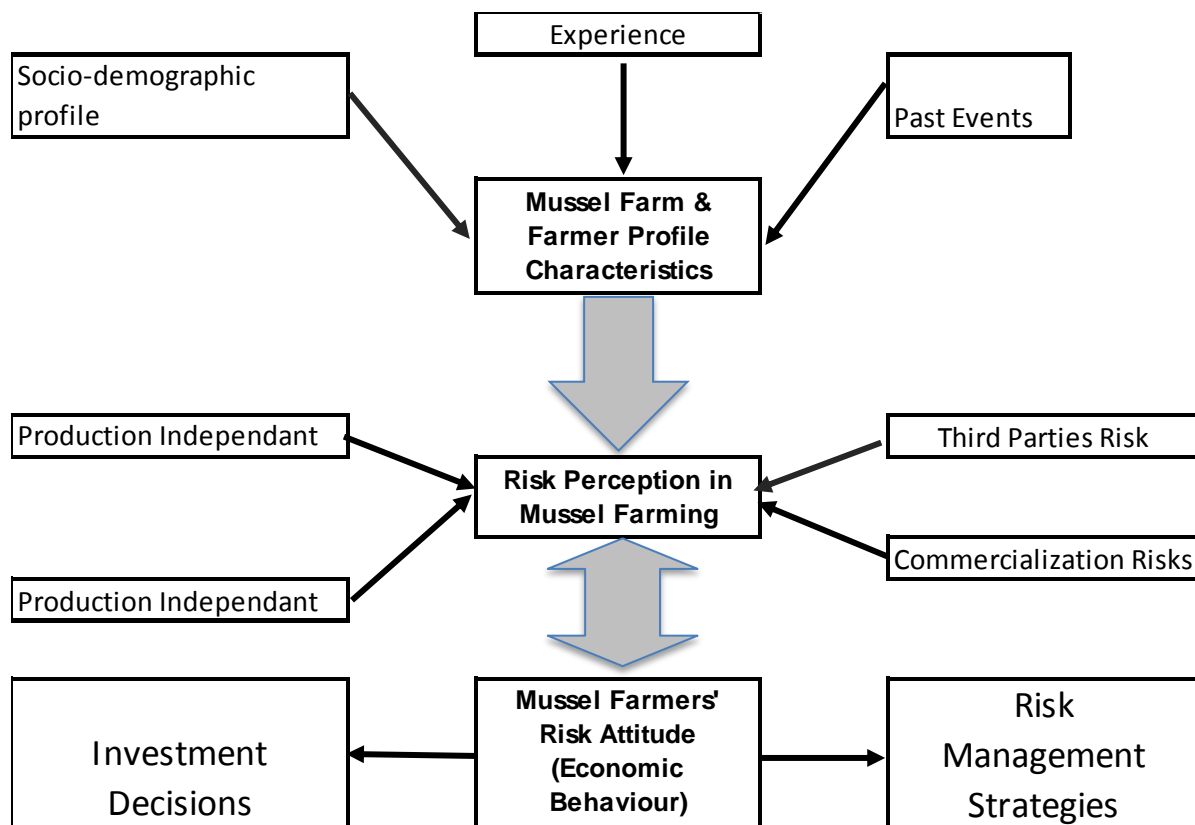


Figure 2.3. A framework for the economic/risk behaviour of the Greek Mussel farmers based on the risk categorisation by Theodorou & Tzovenis (2004) and the modifications of the Van Raaij's descriptive model (1981) by Ahsan (2011).

(2) identify the risks;

Risk identification, as has been demonstrated in several empirical studies (Kahneman & Tversky, 1979; MacCrimmon & Wehrung, 1986; Rabin & Thaler, 2001), must focus on the individual's risk perception estimation rather than on classical decision-making theory, as this seems inadequate to explain the risk choices individuals must make. They personalise risk decisions, and this makes risk behaviour subjective. Mussel farmers are exposed to a wide range of risks, including those that are production dependent (zoosanitary and zootechnical aspects), and production independent (pollution, aquatic animal attacks, weather impacts), as well as market risk (seasonal availability of the product and the quality) and third party (mussel farm environmental impact, consumer

and public health). Farmers' risk attitude is also strongly influenced by their past experience, their socio-demographic background, and the history of farm losses (past events).

Determine what could happen that would affect mussel farming, based on the research framework of the Van Raaij's (1981) descriptive model, modified and especially adapted to examine the risk behaviour of the Greek mussel farmers (Figure 2.3). Information used in the risk characterisation and identification process includes analysis of empirical data based on the mussel farmers' experience (Theodorou & Tzovenis, 2004). Since mussel farming has more or less the characteristics of agri-farming, the mussel farmers' risk attitude, risk perceptions and socioeconomic profiles also were taken into account (Figure 2.4), as demonstrated in similar studies for the primary sector (Meuwissen et al., 1999; Meuwissen et al., 2001; Le Grel & Le Bihan, 2009; Le Bihan et al., 2010, Theodorou *et al.*, 2010a; 2011a; Ahsan & Roth 2010; Le & Cheong, 2010). Mussel farm size (ha) and capacity (tonnes) may vary as the system is extensive and based on the primary productivity of each location. The same farm area in different locations may have different production capacity despite that the licensing refers to maximal capacity as opportunity rather than actual production.

(3) analyse the risks;

The risks were defined by using a range of analytical tools, depending on the data availability. Usually the first stage is to identify the risks qualitatively (using nominal or descriptive scales for describing the likelihoods and consequences of the risks), followed by a semi-quantitative (allocating numerical values to the descriptive scales, which are then used to derive quantitative factors) and/or quantitative (use numerical ratio scales for likelihoods and consequences) approach (Cooper et al., 2005).

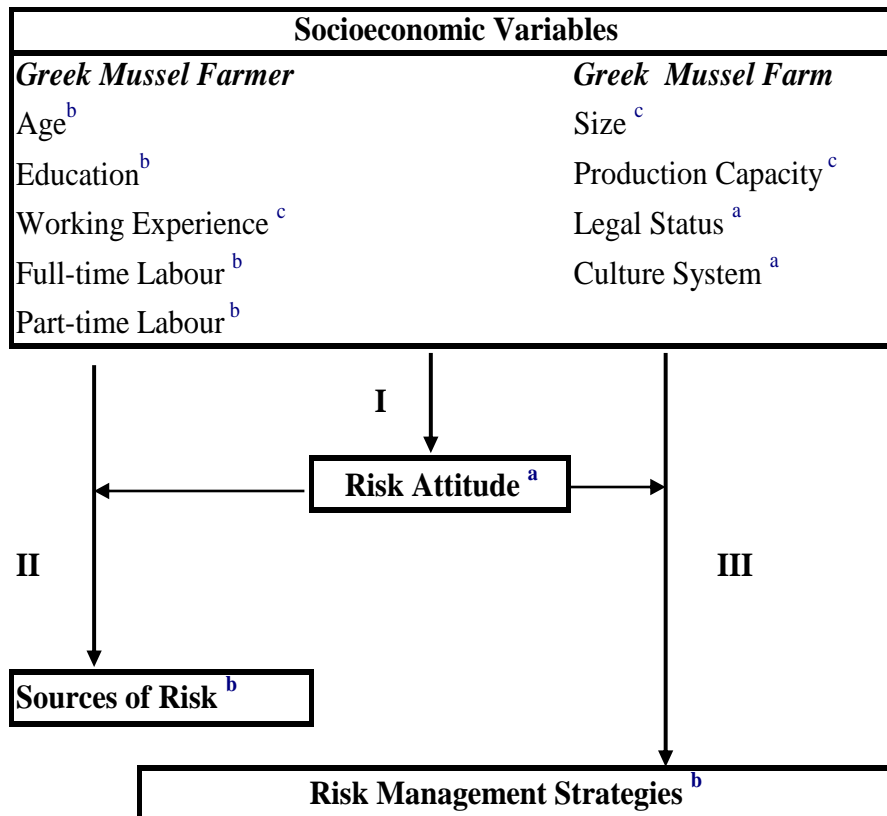


Figure 2.4. Risk analysis plan based on the socioeconomic variables of the Greek mussel farmers and their risk attitude to identify the risk sources and to select the suitable management strategies: I) attitudes towards risk; II) perceptions of sources of risk; III) perceptions of risk management strategies. <sup>a</sup> Non-metric variable / nominal scale; <sup>b</sup> Non-metric variable / ordinal scale; <sup>c</sup> Metric variable (adapted from Meuwissen et al.,1999).

In order to accomplish the above tasks, mussel farmers were asked to complete a questionnaire, and an interview survey was carried out on mussel farm sites all around the country. The developed material was then extensively examined by industrial and scientific experts in order to ensure that the taxonomy and the terminology of the risk analysis was clear and understandable during the communication among the stakeholders (MacDiarmid & Pharo, 2003; Theodorou et al., 2010a). The possible sources of risk were given on a Likert-type questionnaire, where mussel farmers were asked to evaluate the possible risks on a scale 1-5 (minimum- maximum) (Meuwissen et al., 2001; Malhotra, 2004).

Financial data from commercial companies and suppliers' data regarding mussel farm economics were also used, and were cross-checked with the mussel farmers' opinions on the questionnaire and during the interviews. Enterprise budgets of different farm sizes, culture schemes, and management options were assessed for financial viability. Sensitivity analysis, as described by Kam & Leung (2008), followed the budgeting processing in order to examine how the changes in the key production and management variables affect financial performance (e.g. profitability).

The effects of harmful algal blooms (HABs) on the industry were identified, given the critical season and duration that the problem is a risk for the industry, by using the principles of the AS/NZS 4360(1999) standard as modified by Fletcher et al., (2004) for an Ecologically Sustainable Development (ESD) of aquaculture. Similar applications by the same researchers have been used successfully in fisheries (Fletcher, 2005; Fletcher et al., 2005).

An estimation of the financial risks of different mussel farm sizes in relation to the major sources of risks and suitable risk mitigation strategies could provide a tool for a continuous review and improvement of risk management, as the basic framework has already been developed and could be easily updated by future parameter changes.

(4) evaluate the risks;

This stage of the risk analysis process generates a prioritised list of risks and a detailed understanding of their impacts on the activity. The results from a typical Likert-type questionnaire identifying risk sources and the corresponding risk attitude of the Greek mussel farmers were analysed and the risks were prioritised by using descriptive statistics and Principal Component Analysis (Meuwissen, 2000; Malhotra, 2004). Multi-

regression models were also developed, linking the risk sources and risk management with the social-economic background and the relative risk attitude of the Greek mussel farmers (Theodorou et al., 2015a).

In addition, the financial risks of different mussel farm size were evaluated by using What-if Analysis. A scenario-based analysis was developed for studying farms of different sizes and production levels, focusing on possible changes in the fixed costs and variable costs, according to Kam & Leung (2008). The seasons that the mussel harvesting bans were catastrophic for the sector were highlighted semi-quantitatively by using a risk matrix analysis (Theodorou et al, 2012). Also the risk-ranking effects on mussel farming operational costs has been evaluated by a similar approach.

(5) treat the risks;

The treatment of risk involves the identification of the most appropriate strategies for dealing with its occurrence (Joint AS/NZS ISO 31000:2009). It refers to the actions that have to be taken in order to eliminate exposure to the risk outcomes. Methodologically, this working step requires input from the outcomes of the previous risk evaluation (4) effort.

The strategies for dealing with the risks were summarised by Baccharini et al., (2004):

(i) Avoidance – avoid actions that could cause risk to rise.

(ii) Reduction – take actions that mitigate or reduce the probability of a hazardous event to occur.

(iii) Transfer – partial or whole risk transfer to a third party.

(iv) Retention – accept risk and its consequences.

Risk-management strategies were identified using a methodology similar to that used with sources of risk, i.e. using Likert-type questionnaire plus additional open-ended questions during interviews in order to cross-check the responses. Again descriptive statistics and the Principal Component Analysis were used to prioritise the risk-management strategies (Malhotra, 2004; Le Grel & Le Bihan, 2009). In addition, multi-regression models were developed to link risk management with the social-economic and the relative risk attitude of the Greek mussel farmers.

(6) monitor and review the whole process;

During the risk analysis study, a continuous monitoring and review of the whole process takes place as the implementation of the initial framework working plans might raise new questions and issues to be addressed. A supporting process in this context, based on the same protocol, could provide further details about the system and boost the initial effort.

In this study a new need came to surface during risk analysis; i.e. to survey supplementary targets–risks in order to manage the primary risks identified effectively. The role of the harvesting bans due to incidents of HABs was examined using semi-quantitative tools and the same working protocol.

The effect of a farm's size on its financial sustainability was investigated by using the principles of financial analysis, following the same risk-analysis supporting process. Supplementary support to evaluate the primary process was given by the mussel farmers' socioeconomic survey. The supporting processes (detailed analysis and models) presented here could be further investigated if there is a special need or question to

answer. Finally, their range could be expanded if another risk is identified and needs further analysis in the future.

(7) communicate and consult on the outcomes.

Risk communication is an interactive process between risk assessors, risk managers and the rest of stakeholders (mussel farmers, producers' cooperatives, academia, public administration, other authorities) that targets the clear understanding of the results of the risk analysis. It is a transparency and continuous improvement tool, necessary to eliminate uncertainties that normally exist in the whole risk analysis working plan. The present study constitutes the communication outcome, prepared as a consultation tool, an integral part of the processes of the conceptual framework according to the Joint AS/NZS ISO 31000:2009 Management Standard.

## **2.4 OUTLINE OF THE THESIS**

The generic approach of the risk management standard tool (AS/NZS ISO 31000:2009) used has the advantage of being easily adapted to the specific national characteristics of all levels of business activities and the sector function (Figure 2.5). A conceptual framework was developed (Chapter 2), based on data set needs regarding development (Chapter 1), production, profits and losses (Chapter 4), as retrieved by surveys through distributed questionnaires or interviews during site-visits, as well as by collecting data from national and international authorities. Intensive pre-testing of the developed communication material before use, by a range of industrial and scientific experts, ensured that the taxonomy and the terminology of the risk assessment were clear and understandable by the stakeholders. Data input covered technology, farm size, farmer

A Mussel Farming Risk Analysis Conceptual Framework Based on AS/NZS ISO 31000 Model Process Chapter (2)

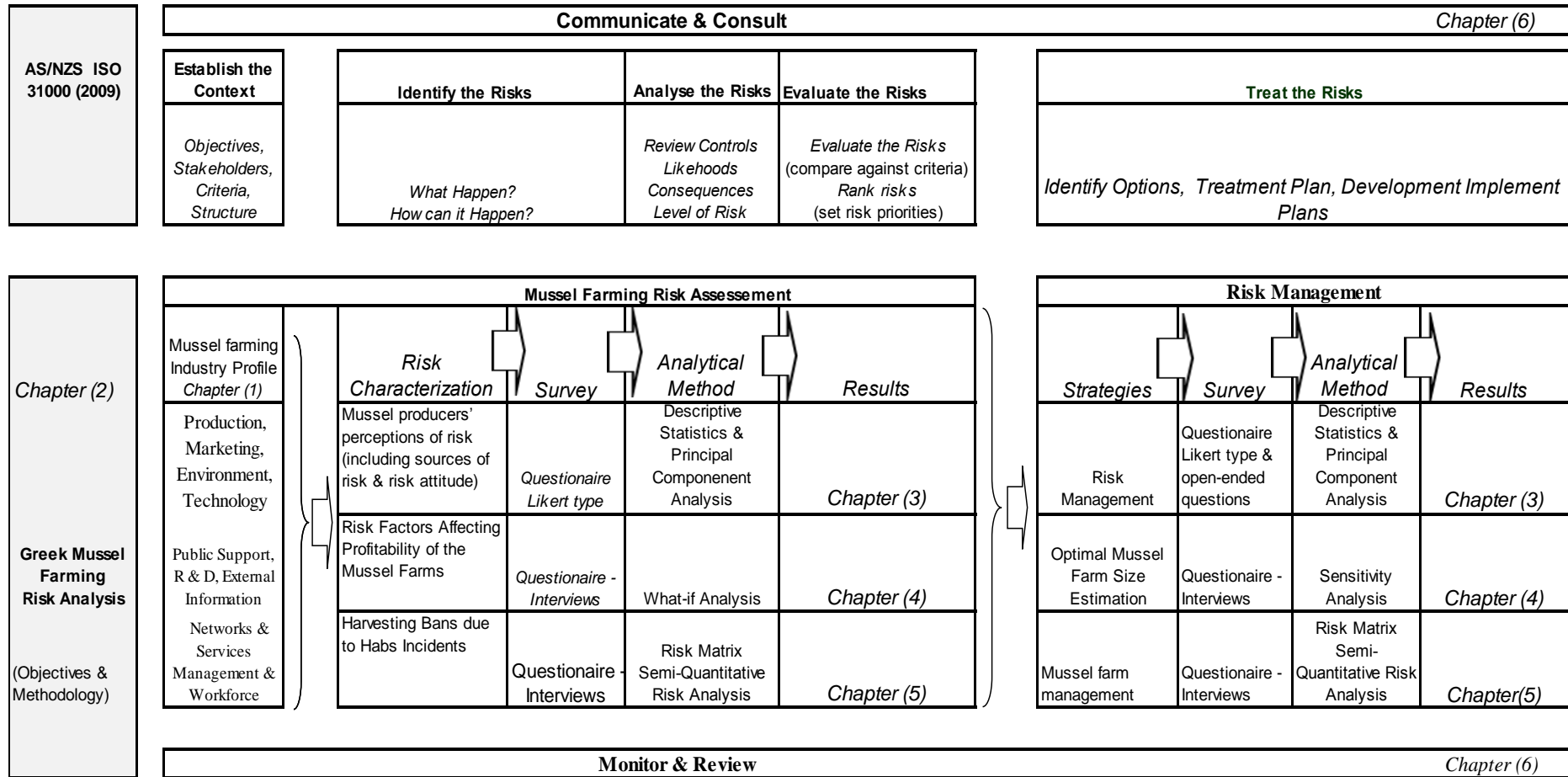


Figure 2.5 Overview of steps and data required for Risk Analysis of Mediterranean Mussel Farming in Greece based on AS/NZ ISO 31000: 2009 Model Process, with references to chapters of the thesis.



risk attitude, risk management strategies, risk perceptions and socioeconomic profiles (Chapter 3). In addition, supplementary support to answer research questions about the magnitude of specific risks identified by the survey, such as the harvesting bans due to harmful algal blooms (HABs) were analysed, to support the whole risk management process (Chapter 5). The conclusions of this study (Chapter 6) highlight the risk management priorities based on farmers' experiences and could serve as a tool for developing policies to address certain risks both at the state and private level.

The structure of the thesis follows the steps of a risk analysis study based on AS/NZS ISO 31000:2009 Standards Model process (2009) as presented in Figure 2.5. Specifically, it consists of the following processes:

- (1) establish the context;
- (2) identify risks;
- (3) analyse risks;
- (4) evaluate risks;
- (5) treat risks;
- (6) monitor and review; and
- (7) communicate and consult.

First, the bivalve shellfish industry in Greece reviewed in Chapter 1 giving also details about the infrastructure of the sector.

A risk management framework was applied to demonstrate the required research steps to analyze the risks of Mediterranean mussel farming in Greece; and this is presented in Chapter 2.

The risk perceptions and the management strategies of the Greek mussel farmers are presented separately in Chapter 3.

A supporting process that focused on risks factors affecting profitability is demonstrated in Chapter 4.

In Chapter 5, the mussel harvesting bans due to HAB incidents in Greece, identified as a major risk by the primary process detailed in Chapter 3, were analysed in depth for their potential economic and other implications to the industry.

Finally, in Chapter 6, the results of the risk analysis are summarized, giving a synthesis of risk assessment and risk management in Greek mussel farming. The analytical efficiency of the AS/NZS ISO 31000 Risk Management Standard for sectorial studies is also discussed.

Monitoring and review were carried out during the whole process of the thesis. Risk Communication as a principal component of the risk analysis process, has been indirectly contributed to this effort, with several actions taken for the dissemination of the results, as demonstrated in similar studies (e.g. De Vos, 2005), i.e. 1) expert guidelines and opinions on research model parameters; 2) oral presentations in conferences organized by both scientific and producers organizations such as the World Aquaculture Society-WAS (Theodorou et al., 2006c), the International Institute of Fisheries Economics & Trade- IIFET (Theodorou et al., 2010a,b,c), the International Society for the Study of Harmful Algae-ISSHA (Theodorou et al., 2012), the European Aquaculture Society-EAS (Theodorou et al., 2011b), 3) written papers in scientific journals (Journal of Shellfish Research, Theodorou et al., 2011a; 2014a), 4) industry communications (Global Aquaculture Advocate, Theodorou & Tzovenis 2011; Shellfish News-CEFAS, UK, Theodorou, 2012) and finally 5) the present thesis.

# **CHAPTER 3**

**AN EMPIRICAL STUDY OF THE RISK PERCEPTIONS  
AND RISK MANAGEMENT STRATEGIES OF THE  
MEDITERRANEAN MUSSEL FARMERS IN GREECE**

### 3.1 INTRODUCTION

Aquaculture, is a relatively new sector of the primary production industries, and faces potential threats similar to those of the terrestrial agriculture. However, there is an extensive theoretical as well as practical risk-management research sufficient for agriculture (Huirne et al., 2000; 2007; Anderson, 2003; Hardaker et al., 2004; van Winsen et al., 2013; 2014; Wauters et al., 2014), livestock (Meuwissen, 2000; Meuwissen et al., 2001; Flaten et al., 2005; van Winsen et al., 2013; 2014; Wauters et al., 2014), forestry (Stordal et al., 2007), innovation adoption practices (Greiner et al., 2009; Wauters & Mathijs, 2013). On the contrary, in aquaculture, seem to lack empirical knowledge to address any possible practical implications in relation to risk (Theodorou & Tzovenis, 2004; Bergfjord, 2009; 2013; Le & Cheong, 2010; Ahsan, 2011; Zagmutt et al., 2013). Moreover, as aquaculture is very diverse in terms of cultured species (finfish, shellfish, seaweeds), environments (freshwater, marine), systems (offshore, inshore, land based), and practices (extensive, intensive, semi-intensive), the range of hazards and the perceived risks are fairly complicated (Bondad-Reantaso et al., 2008). Recently, in order to fill-in the gap of knowledge in the European bivalve shellfish field, attempts were made by several researchers working with different species, such as mussels in Denmark (Ahsan & Roth, 2009; 2010) or oysters in France (Le Grel & Le Bihan, 2009; Le Bihan & Pardo, 2010; Le Bihan et al., 2010; 2013), to combine quantitative investigations regarding the influence of motivations and risk perceptions, especially those on the risk management of the bivalve shellfish sector.

As the Mediterranean mussel farming in Greece matures as an industry, producing close to the countries' upper limits of 35 000-45 000 tonnes/year, there is a strong demand for sustainable strategies. Focus is on the optimization of crucial management issues,

including risk management and the development of insurance policies to support this effort (Theodorou et al., 2011a). To analyse the risks of the Greek mussel farming the AS/NZS ISO 31000 Risk Management principles were followed, given in Chapter 2 for the primary process of working framework (Figure 2.2).

The aim of the present work was to provide, through an exploratory analysis of data from a Mediterranean mussel farmers survey in Greece, empirical insights of the Greek mussel farmers' risk perceptions and risk management approaches, their motivations and how social and economic characteristics relate to the Greek mussel farm risk strategies.

## **3.2 MATERIALS & METHODS**

### **3.2.1 Theoretical Background**

How agricultural farmers make decisions in the uncertain environment of the primary production has been econometrically approached by Just & Pope (1978;1979) and Antle (1987) through analysis of the agri-farmers' choices in relation to their impact on the expected output and its variability. In aquaculture, a similar methodology has been applied by Tveterås (1999; 2002a) and by Asche & Tveterås (2005) in their study of the salmon industry in Norway. They showed that certain, identified, inputs may cause an increase or decrease of risk.

In addition to this knowledge, Le Bihan et al. (2010) suggested that attitudes towards and perceptions of risk have to be taken into account since behavioural impact in the risk-based decision-making studies of aquaculture is under-documented.

Ahsan (2011), reviewing research methodologies, risk perception and the risk management strategies of shrimp farmers in Bangladesh, concluded that the expected utility framework from classical decision-making theory was unsuitable (in order to approach the risk behavior of the shrimp farmers). According to the utility theory,

different procedures to determine risk attitude should all yield identical outcomes; in this case, a range of empirical studies indicates a variety of results since it fails to explain the individual's observed behavior (subjective risk and risk perceptions) (Kahneman & Tversky, 1979; MacCrimmon & Wehrung, 1986; Rabin & Thaler, 2001). Bergfjord (2009) on the other hand, working with the risk perception and risk management of the Norwegian salmon industry, found it difficult to develop and test a firm hypothesis within aquaculture context since there is a gap of knowledge due to a lack of similar studies in the sector.

The risk perceptions of the farmers are strongly related with the characteristics of the farms and the farmers' social-demographic personal profile (van Winsen, 2014). The farmers risk perception shape their risk management strategies (economic/risk behavior) as shown by Van Raaij (1981) and verified by Flaten et al., 2005; Lien et al. 2006; Bergfjord, 2009; 2013; Le Bihan et al., 2010; Ahsan, 2011; Stensland, 2013; Le Bihan et al., 2013 within a range of agribusinesses. Parts of the Van Raaij's model (1981) explains how the economic behaviour (risk management strategies) of the individuals (farmers) is an outcome of their perceptions which are determined by the economic environment (production, market, legislation, national & global economy) and their personal socioeconomic characteristics (age, education, gender, farm size occupation, etc).

The present effort to study the economic behavior of the Greek mussel farmers is based on the principles of the Van Raaij's (1981) descriptive model, where the perceived operating environment determines economic behavior and keeps impacts on their personal welfare in mind (Lien et al., 2005).

### 3.2.2 Data Collection

The current research design and questionnaire development was strongly influenced by the empirical study Meuwissen et al. (2001) carried out for livestock producers in the Netherlands.

Data for this empirical study was collected using a questionnaire survey comprising sixty-five questions (variables) shared between four categories.

Seven questions refer to the *social-economic features of the farm and respondent* (farm surface, production, full/part time of labor and respondent's age, education and working experience) (Table 3.1).

Table 3.1. Descriptive statistics of the mussel farmers' questionnaire response (n=49) as a representation of the production capacity of Greece during the survey period of November 2008-February 2009.

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Respondents mussel farmers/total Greek managing production capacity (t)	31,068/45,403
Production representations (%)	68
Questionnaire respondents (no)	49*
Age of the respondents (18-30yr/31-40yr/41-50yr/51-60/61yr<) (%)	9/19/40/21/11
Working experience (yr)	13.9±8.1
Education (primary/secondary/higher)	12/61/27
Average production capacity per farm unit of the respondents (t)	214
Mussel Farmer respondent managing capacity range (min-max) (t)	50-12,000*
Mean farm size ownership per individual farmer including cooperative members (ha)	2.4 ±1.7
Full time labour (workers/mussel farm)	1.25 ±1.60
Part time labour (workers/mussel farm)	2.73 ±1.81
Culture system (long lines/hanging parks/mixed)(%)	92/6/2
Legal status of the mussel farm (personal/ general partnership-G.P. & limited partnership-L.P. companies/Ltd/SA) (%)	44/36/5/15

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*\*including 3 cooperatives, consisting of 6, 40 & 53 members, and representing a total production capacity of 1,200 t, 7,500 t & 12,000 t, respectively.*

In order to understand the mussel farmer's perception of their risk attitude five questions are used (eager to take risks...in production, in marketing, in farming (general),

financial issues, and on whether “I am willing to take more risks than other farmers”) of which the last one was included as a consistency check in the questionnaire (Table 3.2). Since all statements measure attitude towards risks relative to other farmers the term “*relative risk attitude*” is used (Table 3.3) according to Patrick and Musser (1997) and Meuwissen et al.,(2001).

Thirty-three questions refer to the *sources of risks* which are shared between “in-farm risk on production” (Table 3.5; five questions: IDs 1-5), “risks on technology” (Table 3.5; three questions: IDs 6-8), “ex-farm risks on farm economy” (Table 3.5; three questions: IDs 9-11), “ex-farm risk on production” (Table 3.5; six questions: IDs 12-17), “risks related to customer perception” (Table 3.5; five questions: IDs 18-22), “ex-farm risks related to government support” (Table 3.5; four questions: IDs 23-26), “financial risks” (Table 3.5; three questions: IDs 27-29) and “risks related to the family situation” (Table 3.5; four questions: IDs 30-33).

Fifteen questions refer to the “risk management strategies” which are shared between “in-farm investments” (Table 3.7; five questions: IDs 1-6), on “ex-farm investments” (Table 3.7; two questions: IDs 7-10), “insurance” (Table 3.7; three questions: IDs 11-13) “sale price” (Table 3.7; two questions: IDs 14-15).

Finally (Table 3.9), three questions (Which risks.... perceived as bearable? ,...would like to buy insurance?, and.... could be covered by governmental support?) make up the *open-ended questions* of the questionnaire.

The questions under *respondent's perception of their risk attitude, sources of risks* and *risk's management strategies* were prepared to be answered on a Likert type scale 1 to 5: 1(I do not agree) to 5 (I agree) for *respondent's perception of their risk attitude*; 1 (no



impact) to 5 (very high impact) for *sources of risks*; and 1 (not relevant) to 5 (very relevant) for *risk management strategies*.

The questions under *sources of risks* and *risk management strategies* were based on the opinion of four mussel farming experts, and pre-tested on five farmers of high education and experience profile, before being presented to the respondents.

Questionnaires were distributed to all Greek mussel farmers during the period November 2008-February 2009 and completed under guidance during a personal interview and site-visits.

### **3.2.3 Data Analysis**

In order to evaluate the relative importance of each question under the categories *respondent's perception of their risk attitude*, *sources of risks* and the *risk management strategies*, the responses were ranked by their mean ( $M_i$ ) in descending order ( $M_i \geq 4$ : important;  $3 \leq M_i < 4$ : high moderate;  $2 \leq M_i < 3$ : low moderate;  $M_i < 2$ : low).

Principal component analysis (PCA) is applied. The first is to the responses to the questions in each category (*social-economic features of the farm and respondent*, *respondent's perception of their risk attitude*, *sources of risks* and *risk management strategies*) in an effort to reduce possible collinearity. The second is as a linear dimensionality reduction technique, PCA substitute the original variables with a smaller number of linear combinations of those variables (uncorrelated factors) keeping also their maximum variance and project them into a lower-dimensionality space. The factor loadings indicated the weight of each variable to the corresponding axis forming while the produced factor scores per factor ( $F_i$ ) are the linear result of the initial variables with respect to this factor (Hair et al., 1998; Malhotra, 2004). In addition, in order to estimate the level of collinearity of the explanatory variables of the multi-regression analysis was

used the Variance Inflation Factor (VIF). Indeed, high or low VIF values represents high or low level of collinearity respectively, with a usual switching cutting off value of VIF=10 (Hair et al., 1998).

Finally, two stepwise multi-regression analyses were applied: the first among the factor scores of *social-economic features of the farms and respondent, respondent's perception of their risk attitude* as independent variables, and each factor scores of *sources of risks*, as dependent variables and the second among the factor scores of *social-economic features of the farms and respondent, respondent's perception of their risk attitude* and *sources of risks* as independent variables and each factor of *risk management strategies* as dependent variables (Hair et al. 1998).

The analyses were performed with the SPSS 17.0 (SPSS Inc., Chicago IL, USA).

### **3.3 RESULTS**

In total, 49 questionnaires were completed, three of them by representatives of farmer associations/cooperatives of 6, 40 and 53 members, respectively. It was estimated that the 49 respondents managed 68% of the Greek mussel production farming capacity, in farm ranging from 50 tonnes (small farms) up to 12000 tonnes (large cooperatives) with an average production capacity of 214 t per farm unit (Table 3.1).

#### **3.3.1 Greek Mussel Farmers Socioeconomics**

Most of the respondents (40%) are middle-aged (41-50 yrs), followed by 21% of older farmers (51-60 yrs) and 11% close to their pension age (61<yrs). Younger farmers are represented by 9% newcomers (18-30 yrs) and 19% between 31-40 years old; with working experience of 13.9±8.12 years. The majority of the respondents (61%) had

graduated from secondary education while 27% had a higher education degree, and the remaining 12% had only a primary education level.

Only 1.25±1.60 individual per farm work full time, with the preference, 2.73±1.81, being for part time labour. The major farm type operated by the respondents is the long line system (92%), followed by the hanging parks (6%) and the mixed systems (long lines together with hanging parks) (2%). The mean production capacity of each farm is about 225 ± 152 t. Most of the farms are operated under the legal status of the personal (self-employed) companies (44%), followed by 35% general partnership-G.P. & limited partnership-L.P. (in collaboration with other(s) person(s)) companies. Preference for more advanced schemes, such as the Limited Company-Ltd (5%) and the Société Anonyme-SA(Anonymous Company), is limited (15%).

Table 3.2. Principal component factor loadings of the social and economic variables of the Greek mussel farmers. Expvar%: % explained variance, CumExpVar%: % cumulative explained variance, with bold marking the important values (cut-off value of ±0.6).

	Factors		
	farm features	farm-manager education	working experience
Socio-economic variables	F1	F2	F3
Age	-0.19	<b>0.87</b>	0.23
Working Experience	-0.02	0.01	<b>0.99</b>
Education	-0.08	<b>-0.80</b>	0.16
Farm size	<b>0.87</b>	-0.08	0.03
Production capacity	<b>0.93</b>	-0.01	-0.04
Full time labour	<b>0.71</b>	-0.26	0.00
Part time labour	<b>0.77</b>	0.34	-0.10
Eigenvalues	2.79	1.59	1.05
ExpVar%	39.92	22.73	15.01
CumExpVar%	39.92	62.65	77.66

The PCA extracted three factors with eigenvalues higher than one, explaining 77.6% of the total variance (Table 3.2). Using a cut-off value of 0.60 for the factor loadings, factor 1 (Table 3.2: Expl. Var. 39.92%) expressed social-economic variables associated with the

*farm features* (farm size, production capacity and labor force (full/part time)) and factor 2 (Table 3.2: Expl. Var. 22.73%) expressed variables associated with the *farm-manager education* (education and age, with a reverse relationship between the age of the mussel farmer and his educational background. This is because the young farmers had more opportunities to access the educational system than the older farmers as the country gradually modernized and joined the European Union). Factor 3 (Table 3.2: Expl. Var.: 15.01%) expressed the *working experience* of the farm-manager.

### 3.3.2 Perceptions of Relative Risk Attitude

Table 3.3 indicates that Greek mussel farmers are more eager to take risks in a field that they understand better that is in the course of their everyday work in the farm (63.27±26.57%) there including also their every day deals with wholesalers for their harvest (62.45±27.88%). When asked if they would take risks in financial issues for instance asking for a bank loan to finance modernization, or flexibility in dealing with wholesalers the Greek farmers showed a moderate attitude scoring a little below average

Table 3.3. Greek mussel farmer eagerness to take risks. Figures are means (n=49) of responses to questionnaires.

Scale		Eager to take risks in production	Eager to take risks in marketing	Eager to take risks in financial issues	Eager to take risks in farming in general	Eager to take risks more than others	Farmer risky attitude *
1-5	Mean	3.16	3.12	2.43	3.02	2.98	2.94
	Std	1.33	1.39	1.40	1.20	1.23	1.21
1-100 %	Mean	63.27	62.45	48.57	60.41	59.59	58.86
	Std	26.57	27.88	27.99	23.98	24.66	24.26

(\*): mean of all responses by each farmer

(48.57±27.99%). Their overall stance regarding risky attitude was over average (58.86±24.26%) coinciding with their eagerness to take more risks than the others in the same business (59.59±4.66%).

The PCA in Table 3.4 gives one factor with 86.44% of the total initial variation (Table 3.4: Expl. Var. 86.44%), which is best described as the *relative risk attitude* as a result of the varimax rotated principal component factor loadings for the Greek mussel farmers eager to take risks.

Table 3.4. Risk ranking by mean scores of the questionnaire responses (n=49) and principal component factor loadings for the farmers' eagerness to take risks. Expvar%: % explained variance, CumExpVar%: % cumulative explained variance, SD: standard deviation, with bold marking the important values (cut-off value of ±0.6).

Eager to take risks...	Rank By Mean	Mean	SD	Factor Loadings
				Relative Risk Attitude (F1)
in production	1	3.16	1.33	<b>0.91</b>
in marketing	2	3.12	1.39	<b>0.92</b>
in farming in general	3	3.02	1.20	<b>0.98</b>
more than other farmers*	4	2.98	1.23	<b>0.98</b>
financial issues	5	2.43	1.40	<b>0.84</b>
Eigenvalues				4.3
ExpVar%				86.44
CumExpVar%				86.44

\*consistency check, included at a different place in the questionnaire.

The mussel farmers *relative risk attitude* was measured in order to investigate the farmers' eagerness to take risks, and it demonstrated that they are comfortable with taking risks in production (3.16± 1.33) and marketing (3.12±1.39), sectors that are more familiar to them than financial issues (2.43±1.40). Greek mussel farmers tend not to take financial risks as they do consider themselves unknowlegeable about the relevant processes. They are eager to take more risks than the others (2.98±1.40).

### 3.3.3 Risk Sources

The mussel farmers responses to the likert-type questionnaire survey are presented as

Table 3.5 Percentage distribution (%) scores of the mussel farmers likert-type responses on the categories (1: relevant to 5: not relevant), mean values and standard deviation for the different type of risk sources in the questionnaire survey.

ID	Risk Sources	Rank By Mean	Mean	SD	Scores (%)				
					1	2	3	4	5
10	Ex-farm mussel price	1	4.49	0.82	0.00	2.04	14.29	16.33	67.35
31	Disability/ health of farmer	2	4.20	1.17	4.08	4.08	22.45	6.12	63.27
7	Vessel availability	3	4.18	1.47	14.29	2.04	6.12	6.12	71.43
13	Harmful algal blooms(HABS)	4	4.12	1.11	0.00	14.29	12.24	20.41	53.06
30	Health situation of farm family	5	4.02	1.13	4.08	4.08	24.49	20.41	46.94
11	Absorption of the supply	6	3.94	1.03	0.00	12.24	18.37	32.65	36.73
5	Production cost	7	3.92	0.73	0.00	0.00	30.61	46.94	22.45
25	Environmental Policy-AOAD	8	3.86	1.32	10.20	6.12	14.29	26.53	42.86
8	Grading machines availability	9	3.65	1.38	12.24	10.20	12.24	30.61	34.69
23	Public Authorities Services	10	3.65	1.45	14.29	12.24	4.08	32.65	36.73
27	Changes in interest rates	11	3.49	1.43	8.16	28.57	4.08	24.49	34.69
32	Family relations	12	3.49	1.32	14.29	8.16	14.29	40.82	22.45
2	Recruitment seed availability	13	3.41	1.15	8.16	12.24	26.53	36.73	16.33
6	Technology availability	14	3.41	1.21	10.20	10.20	26.53	34.69	18.37
16	Freshwater availability	15	3.41	1.17	4.08	22.45	22.45	30.61	20.41
3	Mussel meat yield	16	3.33	1.20	8.16	18.37	22.45	34.69	16.33
28	Ability to redeem loans	17	3.33	1.49	14.29	24.49	6.12	24.49	30.61
9	Labour availability	18	3.29	1.43	20.41	8.16	14.29	36.73	20.41
26	New licences availability	18	3.22	1.37	16.33	16.33	14.29	34.69	18.37
33	Division of tasks within family	29	3.22	1.43	20.41	10.20	16.33	32.65	20.41
21	Media	21	3.20	1.62	24.49	16.33	4.08	24.49	30.61
1	Weather impact	22	3.08	1.22	10.20	22.45	32.65	18.37	16.33
4	Fouling organisms	23	2.98	1.03	2.04	38.78	26.53	24.49	8.16
15	Predators	24	2.86	1.65	36.73	6.12	16.33	16.33	24.49
24	Governmental support removal	25	2.86	1.40	22.45	20.41	22.45	18.37	16.33
20	Health & safety	26	2.73	1.44	28.57	22.45	8.16	30.61	10.20
14	Pollution	27	2.47	1.37	36.73	12.24	28.57	12.24	10.20
19	Environmental impact	28	2.37	1.41	42.86	12.24	18.37	18.37	8.16
29	Sea rental	29	2.18	1.27	40.82	24.49	16.33	12.24	6.12
18	Illegal actions	30	2.02	1.25	46.94	24.49	16.33	4.08	8.16
22	NGOs	31	1.90	1.08	53.06	14.29	22.45	10.20	0.00
12	Transports	32	1.86	1.12	57.14	10.20	24.49	6.12	2.04
17	Diseases	33	1.76	1.20	61.22	22.45	0.00	12.24	4.08

percentage distribution (%) scores for the different type of risk sources in Table 3.5. The descriptive statistics in Table 3.5 identify the major risk sources that affect mussel farming in a descending scale of importance. The mean value of the five most important risk sources are ex-farm prices ( $4.49 \pm 0.82$ ), the disability/health of the operator ( $4.20 \pm 1.17$ ), vessel availability ( $4.18 \pm 1.47$ ), HABs ( $4.12 \pm 1.11$ ) and farmer's family health ( $4.02 \pm 1.13$ ). Finally sources with scores from 27 to 33 represent risks with average values of less than  $2.47 \pm 1.37$ , estimated to have a low moderate risk impact on mussel farming and refer to pollution, environmental impact, sea rental, illegal actions, environmental NGOs, transports and diseases. Through Principal Component Analysis (PCA) the original 33 sources of risks were reduced to 10 major risk factors explaining 80.07 % of the total initial variation. The most important factor 1 (Table 3.6: Exp.Var. 16.69 %) is best described as "*personal welfare*" and is related with the health status of the farmers and his family, the families member relations and the division of the tasks within the family, since the work is still remaining craftwork labor intensive. The second most important factor 2 (Table 3.6: Exp.Var. 14.17%) is described as "*financial*" and related with the ability of the farmer to manage the changes in interest rates and to redeem the loans. Consequently these opportunities are directly related with the working force employment and boat availability, as the negligible banking support effects directly the cash flow and the investment decisions of the farmers.

The ex-farm price is negative related with the seed recruitment as possible "*excess seed availability*" drives at large volumes of the marketed product that effects negative the "*supply-demand*" relation as well as in some cases drive to overload the production capacity of mussel farms and consequently undervalue the meat yield quality of the product. Based on the previous assumptions the factor 3 (Table 3.6: Exp.Var. 9.06%) is best described as "*market risk*".

Table3.6. Principal component factor loadings for risk sources. Expvar%: % explained variance, CumExpVar%: % cumulative explained variance, SD: standard deviation, with bold marking the important values (cut-off value of  $\pm 0.6$ ).

Risk Sources variables	Factors									
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
Ex-farm mussel price	0.15	0.07	<b>0.80</b>	0.12	0.14	0.14	0.02	0.15	-0.04	0.06
Disability/ health of farmer	<b>0.72</b>	0.02	0.14	-0.25	-0.03	0.28	0.34	0.01	0.26	0.09
Vessel availability	-0.36	<b>0.62</b>	-0.14	0.00	-0.34	0.04	-0.32	0.11	0.08	0.12
Harmful algal blooms(HABS)	-0.20	-0.23	0.13	0.02	0.15	-0.09	0.16	<b>0.79</b>	-0.09	-0.06
Health situation of farm family	<b>0.70</b>	0.07	0.09	-0.18	0.09	0.26	0.33	-0.02	0.30	0.02
Absorption of the supply	0.10	-0.10	0.54	0.04	0.52	0.34	0.13	-0.06	-0.05	0.07
Production cost	-0.06	0.43	0.58	-0.03	-0.27	0.13	0.20	-0.05	-0.20	0.09
Environmental Policy-AOAD	-0.14	-0.09	0.00	0.32	<b>0.65</b>	-0.07	0.07	0.19	-0.06	-0.14
Grading machines availability	-0.56	0.38	-0.13	-0.12	-0.30	0.14	-0.28	0.00	0.39	0.07
Public Authorities Services	-0.14	0.39	-0.10	0.49	0.36	-0.17	-0.15	0.11	0.00	-0.10
Changes in interest rates	0.32	<b>0.76</b>	0.01	-0.16	0.25	-0.05	-0.04	-0.07	0.12	0.08
Family relations	<b>0.89</b>	0.05	0.17	0.06	-0.06	0.16	-0.02	-0.05	-0.06	0.17
Recruitment seed availability	-0.12	0.25	<b>-0.76</b>	0.04	0.05	0.05	0.26	0.15	-0.13	0.05
Technology availability	-0.28	0.20	-0.07	-0.06	-0.16	0.06	-0.55	0.46	0.36	0.13
Freshwater availability	0.18	-0.03	-0.12	<b>0.74</b>	0.24	-0.13	0.34	0.11	0.04	0.17
Mussel meat yield	0.10	-0.26	-0.31	0.11	-0.14	0.04	<b>0.70</b>	0.02	-0.04	0.38
Ability to redeem loans	0.22	0.79	-0.08	-0.15	0.21	-0.03	-0.22	-0.08	0.11	-0.02
Labour availability	-0.25	<b>0.81</b>	0.16	0.00	-0.09	0.01	-0.07	0.07	-0.13	-0.14
New licences availability	0.26	0.16	0.12	0.04	<b>0.83</b>	-0.05	0.05	0.07	-0.04	0.06
Division of tasks within family	<b>0.90</b>	0.06	-0.05	0.18	0.03	0.10	-0.01	-0.02	-0.18	0.01
Media	0.27	-0.22	0.29	0.09	0.08	<b>0.68</b>	0.20	-0.19	0.12	-0.10
Weather impact	0.28	-0.16	0.04	0.35	0.12	0.22	<b>0.71</b>	0.06	0.05	-0.23
Fouling organisms	0.09	-0.05	0.08	0.04	0.02	0.04	-0.02	0.13	0.02	<b>0.95</b>
Predators	0.14	0.60	-0.02	-0.30	0.02	0.05	0.10	-0.11	-0.05	0.55
Governmental support removal	0.14	0.14	-0.16	0.09	0.00	0.00	-0.14	<b>0.80</b>	0.04	0.14
Health & safety	0.11	-0.13	-0.02	0.10	0.14	0.14	-0.02	0.11	<b>-0.89</b>	0.03
Pollution	0.19	-0.30	0.02	0.36	0.07	0.21	-0.09	0.21	<b>0.61</b>	0.03
Environmental impact	-0.10	-0.32	0.10	<b>0.83</b>	-0.02	0.25	0.09	-0.10	-0.06	-0.05
Sea rental	0.01	0.19	0.52	-0.30	0.01	0.42	-0.08	-0.34	0.21	-0.01
Illegal actions	0.37	-0.23	0.02	0.09	0.04	<b>0.61</b>	0.18	0.12	-0.17	-0.27
NGOs	0.16	0.18	0.12	-0.04	-0.05	<b>0.80</b>	-0.04	0.03	-0.03	0.26
Transports	-0.16	0.17	-0.21	-0.02	<b>0.64</b>	0.45	-0.16	-0.25	-0.10	0.12
Diseases	0.43	-0.35	0.31	0.56	0.14	-0.13	0.08	0.26	0.05	-0.28
Eigenvalues	6.50	4.68	2.99	2.65	2.18	1.83	1.70	1.46	1.33	1.12
ExpVar%	19.69	14.17	9.06	8.03	6.60	5.53	5.15	4.41	4.03	3.40
CumExpVar%	19.69	33.86	42.92	50.94	57.54	63.08	68.22	72.63	76.66	80.07

Factors 1 to 10 are best described as: *personal welfare, financial risk, market risk, environmental risk, institutional, social acceptance, climate risk, subsidies limitations, public health & safety, biofouling.*

The environmental impact of the mussel farming activity is related with the rainfall/freshwater availability as the rainfall effects the mussel farm it self due to nutrients load and fecal coliforms from the drainages and sewages and the factor 4



(Table 3.6: Exp.Var. 8.03%) is given as “*environmental risks*”. The licensing system of the mussel farms is directly related with the new rules for development of organized areas for aquaculture, including also the new rules for the infrastructures and product movement to the markets (ie veterinary inspection procedures and controls). As these related with institutional decisions, the factor 5 (Table 3.6: Exp.Var. 6.60%) is best referred as “*institutional*” risk.

Public opinion that is usually influenced or induced by NGOs and media publishing referred to the integrate coastal management such as competition for space with other activities ie conservation reserves (Konstantinou & Krestenitis, 2012) and/or possible shellfish consumption poisons due to illegal actions ie unauthorized harvesting of bivalve shellfish from polluted waters or during harvesting bans (Batzios et al., 2004; Economou et al., 2007) represented in factor 6 (Table 3.6: Exp.Var. 5.53 %) who is based described as “*social acceptance*”.

As the mussel meat yield is referred to the Condition Index (CI)(cooked meat weight / total animal wet weight X 100) and is the major quality indicator for the commercialization of the product (Nguyen 2012 b; Filgueira et al., 2014) and is dependent from the climate factor 7 (Table 3.6: Exp.Var. 5.15 %) is reported as “*climate risk*”. The possible limitation of the public support on the mussel harvesting bans due to habs incidents is best described on factor 8 Table 3.6: Exp.Var. 4.41%) as “*subsidies limitations*”. The negative effects of the pollution to the public health and safety is given the description of the factor 9 (Table 3.6: Exp.Var. 4.03 %) as “*public health and safety*” risk, while the fouling organisms is a threat to the image of the marketable product and best describe factor 10 (Table 3.6: Exp.Var. 3.40 %) as “*biofouling*”.

### 3.3.4 Risk Management Strategies

Table 3.7 demonstrates the mussel farmers responses to the likert-type questionnaire survey as percentage distribution (%) scores for the different type of risk management strategies.

Table 3.7 Percentage distribution (%) scores of the mussel farmers likert-type responses on the categories (1: relevant to 5: not relevant), mean values and standard deviation for the different type of risk management strategies in the questionnaire survey.

ID	Risk Management Strategies	Mean	SD	Scores (%)				
				1	2	3	4	5
4	Financial credit reserves	4.84	0.43	0.00	0.00	2.04	12.24	85.71
8	Off farm employment (agri-farming, commerce, services)	3.65	1.65	22.45	4.08	10.20	12.24	51.02
1	Producing at lowest possible costs	3.65	1.18	10.20	0.00	30.61	32.65	26.53
3	Collaboration in production (horizontal)	3.53	1.40	16.33	4.08	20.41	28.57	30.61
15	Collaboration in trading - commerce (vertical)	3.47	1.53	18.37	10.20	14.29	20.41	36.73
10	Enterprise diversification (processing, fishing, distribution)	3.45	1.58	20.41	10.20	12.24	18.37	38.78
6	Participation in government supporting program	3.45	1.44	18.37	6.12	16.33	30.61	28.57
7	Off-farm investment (i.e. agri-tourism, stock market)	3.37	1.39	14.29	16.33	12.24	32.65	24.49
2	Applying strict hygienic-environmental rules	3.24	1.15	8.16	14.29	38.78	22.45	16.33
11	Buying boat insurance	3.24	1.48	18.37	16.33	14.29	24.49	26.53
12	Buying business insurance	3.10	1.45	20.41	18.37	10.20	32.65	18.37
9	Geographic dispersion	3.06	1.77	40.82	0.00	0.00	30.61	28.57
14	Price contracts for sales	2.65	1.55	40.82	6.12	12.24	28.57	12.24
13	Buying personal insurance	2.22	1.37	40.82	26.53	14.29	6.12	12.24
5	Species diversification (other species)	2.08	1.29	51.02	12.24	18.37	14.29	4.08

Table 3.7 shows the average values of the scores for risk management strategies generally opted by the Greek mussel farmers. The most preferred, or “*important*” strategy, was to ensure financial and credit reserves ( $4.84 \pm 0.43$ ). Strategies having “*low impact*” (scores less than 3) were ranked between 13 and 15. They included price contracts for sales, personal insurance policy and species diversification (other new species). The strategies scoring in between high and low values (ranked from 2 to 12) had a “*moderate impact*” with mean values far below the first preference ( $3.65 \pm 1.65$  to  $3.06 \pm 1.77$ ). Moderate impact strategies interestingly included farmer’s employment in other business (e.g. agribusiness, commerce), compressing costs to lowest possible, and collaboration between farmers either horizontally (by sharing equipment, supplies, labour, etc.) or vertically in trading and commerce. Other moderate impact strategies were enterprise diversification (in processing, fishing, distribution), participating in public support programs, off farm investments (e.g., agri-tourism, stock market), boat insurance policy, applying strict hygiene rules, business insurance policy and spatial diversification (geographic dispersion of the company).

As done with the sources of risk, the defined 15 risk management strategies variables were reduced by Principal Component Analysis (PCA) to 5 explaining 66.96% of the total initial variation. The five factors of risk management strategies could be best described in terms of importance (factor 1 to 5) as “*income certainty*”, “*company trust*”, “*insurance*”, “*collaboration*” and “*additional activities*”.

Mussel farmers seek “*income certainty*” (factor 1, Table 3.8: Exp. Var. 17.05 %) through *i*) off farm investment and employment, *ii*) on farm use of strict hygiene and environmental rules. Most preferred was “*income certainty*” through off farm investment and off farm employment with strict hygiene rules passing on a secondary priority since there is no alternative income to the production.

The innovation risks of “species diversification” (cultivation trials failure/loses etc.) that could be mitigated through external “public support” and/or “sales contracts”, were all grouped as “*company trust*” (factor 2, Table 3.8: Exp. Var. 15.44 %).

Table 3.8. Principal component factor loadings for risk management strategies. Expvar%: % explained variance, CumExpVar%: % cumulative explained variance, SD: standard deviation, with bold marking the important values (cut-off value of  $\pm 0.6$ ).

Risk Management Strategies	Risk Management Strategies Factors				
	F1	F2	F3	F4	F5
Financial credit reserves	0.51	-0.16	-0.22	0.31	0.46
Off farm employment (agri-farming, commerce, services)	<b>0.85</b>	0.17	-0.21	-0.12	-0.10
Producing at lowest possible costs	0.39	-0.11	0.11	<b>-0.68</b>	0.25
Collaboration in production (horizontal)	-0.01	0.03	0.33	<b>0.63</b>	0.39
Collaboration in trading - commerce (vertical)	0.33	0.05	0.07	<b>0.74</b>	0.10
Enterprise diversification (processing, fishing, distribution)	-0.02	-0.36	0.18	0.03	<b>-0.72</b>
Participation in government supporting program	-0.08	<b>0.66</b>	0.03	0.00	0.20
Off-farm investment (i.e. agri-tourism, stock market)	<b>0.75</b>	0.17	0.22	0.12	-0.09
Applying strict hygienic-environmental rules	<b>-0.66</b>	0.17	-0.04	0.01	-0.01
Buying boat insurance	0.06	-0.20	<b>0.81</b>	0.28	-0.06
Buying business insurance	0.13	0.11	<b>0.75</b>	-0.51	-0.05
Geographic dispersion	-0.10	-0.09	0.21	0.06	<b>0.69</b>
Price contracts for sales	0.03	<b>0.80</b>	-0.08	0.19	-0.08
Buying personal insurance	-0.18	0.38	<b>0.67</b>	0.14	0.36
Species diversification (other species)	0.10	<b>0.76</b>	0.08	-0.08	-0.03
Eigenvalues	2.56	2.32	1.95	1.89	1.32
ExpVar%	17.05	15.44	13.02	12.63	8.81
CumExpVar%	17.05	32.50	45.52	58.14	66.96

Factors F1 to F5 described as: *income certainty, company trust, insurance, collaboration and additional activities.*

Factor 3 (Table 3.8: Exp. Var. 13.02 %), was described as “*insurance*”; refers to the willingness of the farmers to buy personal, business and boat insurance.

Factor 4 (Table 3.8: Exp. Var. 12.63 %) was described as “*collaboration*” and refers to horizontal and vertical collaboration between farmers (production and trading respectively) and their objective to produce at the lowest possible cost (presumably through some sort of collaboration).

Finally the factor 5 (Table 3.8: Exp. Var. 8.81%) that was best described as “*additional activities*”, grouped together enterprise diversification through other activities (such as fishing, processing and distribution networks) and geographic dispersion of the activities.

The responses to the *open ended questions* (Table 3.9) showed that all mussel farmers were familiar with management of the daily farming operating risks during their routine works (100%). They expressed interest in buying insurance tailor made for their boats (44.9%) and for protection from the weather impacts (14.3%). The farmers wanted also public funds to be used to compensate losses caused by extended harvesting bans due to harmful algal bloom incidents (79.6%), predator attacks (57.1%), weather impact (51%), pollution (26.5%), diseases (8.2%) and illegal actions (8.2%).

Table 3.9. Results of open-ended questions (% of respondent questions).

Risk sources variables	Which risks perceived as bearable?	Which risks would you like to buy insurance for?	Which risks could be covered by public/government support?
Weather impact	0	14.3	51.0
Harmful algal blooms	0	0.0	79.6
Pollution	0	2.0	26.5
Predators	0	0.0	57.1
Diseases	0	0.0	8.2
Illegal actions	0	0.0	8.2
Uninsured Boat	0	44.9	0.0
Farming in general, (routine production handling)	100	0.0	0.0

### 3.3.5 Effects of the Socioeconomic Characteristics

The relationships between the perceptions of the risk sources, the relative risk attitude and the socioeconomic characteristics were analysed through a stepwise regression analysis model in Table 3.10.

Table 3.10. Stepwise multi-regression analysis for the risk sources factors (i) according to social-economic and relative risk attitude factors of Greek mussels farmers.

Social-economic and relative risk attitude factors	VIF	Risk Sources Factors											
		Coeff.	personal welfare	financial risk	market risk	environ-mental risk	Institu-tional	social accept-ance	climate risk	subsidies limit-ations	public health safety	bio-fouling	
		<i>c</i>	ns	-3.86	ns	ns	ns	ns	-3.65	ns	ns	ns	ns
1. Relative risk attitude	1.02		2.75	ns	ns	ns	ns	ns	1.62	ns	ns	ns	ns
2. Farm features	1.06		ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
2. Farm-Manager	1.20	<i>bi</i>	ns	2.43	ns	-1.06	ns	ns	-0.90	ns	ns	ns	ns
2. Working Experience	1.01		1.53	-1.11	0.95	1.08	ns	1.03	0.75	ns	0.60	ns	ns
3. Legal status	1.25		ns	2.20	ns	ns	ns	ns	ns	ns	ns	ns	ns
3. Culture system	1.21		ns	ns	ns	ns	ns	3.41	ns	ns	ns	ns	ns
R <sup>2</sup>			0.36	0.47	0.11	0.25		0.20	0.43		0.10		
adj R <sup>2</sup>			0.33	0.43	0.09	0.22		0.17	0.39		0.08		
SEest			4.11	3.91	2.74	2.28		2.27	2.51		1.83		

1 refers to *relative risk attitude factor*, 2 to *socio-economic factors* and 3 to *the other variables*.

VIF: Variance inflation factor (cut off value=10, Hair et al., 1998) of explanatory variables (social-economic and relative risk attitude factors); *c*: intercept & *b*: beta: statistically significant coefficients R<sup>2</sup>: coefficient of determination; adj R<sup>2</sup>: adjusted R<sup>2</sup>; SEest: standard error of estimation; ns: non statistical significant coefficient (0.05≥p).

Farmers' perception about their personal welfare is related to relative risk attitude and working experience; financial risks perception were strongly related with the socioeconomic factors (education, experience) and with the legal status of the company; perception on market risks related to farmers' experience; perception on environmental risks were negatively related with the education level, as more educated farmers had better management practices, and positively with the experience level, as past events gave a false self-confidence to the farmers; perception on the social acceptance of the activity was positively related with the culture system and the experience of the farmer; climate risks were positively related with the relative risk attitude and the experience of the mussel farmers and negatively with their education; public health and safety were positive related with the farmers' experience.

Table 3.11 presents the results of a stepwise multi-regression analysis model developed for the risk management strategies versus socioeconomic background and risk factors (values only for statistically significant betas). Income certainty was negatively related with environmental risks and pollution. Similarly, the company trust was negatively related with institutional risks, climate risk and farm characteristics. Insurance was positive related with the pollution. In contrast, the farmers' collaboration was negatively related with the biofouling and the social acceptance of the activity.

Table 3.11. Stepwise multi-regression analysis for risk management strategies factors (*i*) according to social-economic, risk sources and relative risk attitude factors of Greek mussels farmers.

social-economic, risk sources & relative risk attitude factors	VIF	Risk Management Strategies Factors					
		<i>Coeff.</i>	income certainty	company trust	Insurance	Col-labo-ration	additional activities
		<i>c</i>	ns	ns	ns	ns	Ns
1. Personal welfare	1.03		ns	ns	ns	ns	Ns
1. Financial risk	1.20		ns	ns	ns	ns	Ns
1. Market risk	1.31		ns	ns	ns	ns	Ns
1. Environmental risk	1.15		-0.383	ns	ns	ns	Ns
1. Institutional risk	1.31		Ns	-0.292	ns	ns	Ns
1. Social acceptance	1.03		Ns	ns	ns	-0.225	ns
1. Climate risk	1.15		Ns	-0.278	ns	ns	ns
1. Subsidies limitations	1.42		Ns	ns	ns	ns	ns
1. Public health & safety	1.34	<i>bi</i>	-0.654	ns	0.593	ns	ns
1. Biofouling	1.12		Ns	ns	ns	-0.349	ns
2. Farm features	1.17		Ns	-0.522	ns	ns	ns
2. Farm-Manager Education	1.03		Ns	ns	ns	ns	ns
2. Working experience	1.14		Ns	ns	ns	ns	ns
3. Legal status	1.04		Ns	ns	ns	ns	ns
3. Culture system	1.06		Ns	ns	ns	ns	ns
4. Relative risk attitude	1.09		Ns	ns	ns	ns	ns
R <sup>2</sup>			0.42	0.45	0.31	0.28	
adj R <sup>2</sup>			0.40	0.41	0.30	0.25	
SEest			0.17	1.83	1.71	1.80	

1 refers to risk sources factors, 2 to socio-economic factors, 3 to other variables and 4 to relative risk attitude factor.

VIF: Variance inflation factor (cut off value=10, Hair et al., 1998) of explanatory variables (social-economic and relative risk attitude factors); *c*: intercept & *b<sub>i</sub>*: beta: statistically significant coefficients R<sup>2</sup>: coefficient of determination; adj R<sup>2</sup>: adjusted R<sup>2</sup>; S<sub>Est</sub>: standard error of estimation; ns: non statistical significant coefficient (0.05≥p).



### 3.4 DISCUSSION

In this study, we tried to use similar phrasing and question types for the “meaning content” of the mussel farmers risk perceptions, to the existing but limited literature, mainly on the terrestrial agribusiness (Meuwissen et al., 2001). Consistency in wording improves the comparability between datasets of different studies (Greiner et al., 2009), eliminating also the inconsistencies of the responses (Fausti & Gillespie, 2006; Pannell et al., 2006). It simplifies also the work for inter-sector and cross-national comparisons, eliminate as it could be possible, the variability of the used methodologies (Fausti & Gillespie, 2006; Flaten et al., 2005). In addition, the clear and understandable risk communication with the farmers has been a catalyst for the effectiveness of the survey and further analysis of the results. Extensive pre-testing of the questionnaire before use, in terms of the comprehension of the risk terminology used to structure the questions, was carried out targeting to the elimination of the linguistic uncertainty throughout the process.

#### 3.4.1 Perceptions of Risks

Most of the respondents agree that a major source of risk is the “*price*” as the limited variation of the standard deviation to less than 1 indicates their high level of consensus. The price was critical for the viability of the of most farms, since the production cost increased markedly (oil price, taxes and wages) while the prices remained stable for more than a decade (Theodorou et al., 2011a; 2014a). Similar findings as with the Greek farmers were also reported by Ahsan & Roth (2010) for the Danish mussel producers, as they were almost totally dependent from the export market demand in The Netherlands (Nguyen, 2012a, b). Le & Cheong (2010) showed that price variability in Vietnam were

the greatest concern of Vietnamese catfish producers, while in Norway the futures price were found by Bergfjord (2009) as the major concern of salmon producers. In contrast, oyster farming in France was not sensitive to price risks compared with other farming sectors, as the local market demand has been traditionally well established (Le Bihan et al., 2010; 2013).

Mussel farming is a labour intensive activity and requires a lot of physical work by the farmers in an extreme, in some cases, weather environment on the vessels. As most of mussel farms were micro-enterprises (Theodorou et al., 2014a), the health status of the operator and his family is a critical risk factor for the business sustainability, since the mussel farm owners are directly involved with field works.

The vessel availability (in fact a suitable boat equipped with modern equipment such as star wheels, French type grading machines, etc.) was a third major source of risk of the mussel farming, since without these tools it is very difficult for the farms to compete in production (Theodorou et al., 2011a).

The mussel harvesting bans due to Harmful Algal Blooms (HABs) were the fourth major source of risk, since they cancel any marketing plan, especially during the harvesting periods (Theodorou et al., 2011a,b; 2012; Vlamis et al., 2012).

In the other end, and in contrast to the majority of the aquatic animal husbandry sources of risks (Georgiadis et al., 2001; Murray & Peeler, 2005; Peeler et al., 2007; Theodorou et al., 2010c) diseases were a less important source of risk since there has never been any serious case of losses up to now (Karagiannis & Angelidis, 2007; Karagiannis et al., 2013). Similar findings were reported by Ahsan & Roth (2010) for the emerging mussel sector in Denmark, which is a relatively new industry without disease problems at the moment. The situation is the opposite in France where shellfish pathogens and summer mortality

due to high temperatures, destroyed several times the production of the sector (Huvet et al., 2010; Garcia et al., 2011; Pernet et al., 2012). Consequently, the way of evaluating the risk sources in the bivalve shellfish sector depends on the local experiences.

Low impact had also the mussel transportation losses. Most of the Greek production of Mediterranean mussels is sold alive, taking 1-3 days to deliver to the export destinations (Angelidis, 2007a). Despite that, losses were limited in certain batches and thus not considered as a disastrous event.

The non-governmental environmental groups' political pressures were affordable, since the activity is environmental friendly and eco-sustainable. However, due to sites positioned within *Natura* Environmental Protected Areas, several terms regarding the operational code of practices might introduce a future risk task (Angelidis, 2007b; Konstantinou et al., 2012; Latinopoulos et al., 2012; Karagiannis et al., 2013). Illegal actions, despite that always have a risk loss had only limited effects being isolated events and of a controllable seasonal cost (not disastrous). Sea rentals for this type of activity were kept affordable for long and were not considered an important risk.

### **3.4.2 Perceptions of Risk Management Strategies**

The most preferred response of the Greek mussel farmers for a risk management strategy (with limited variability having standard deviation  $< 1$ ) was found to be the creation of financial reserves to cope with unforeseen adversities, and survive financially until the next season. These practises may include personal or family bank savings, and/or bank credit achieved through long-term good business cooperation with them, and keeping their farm in a financially healthy state. Prioritise liquidity and solvency were also considered very important by the Danish mussel farmers (Ahsan & Roth, 2010). Their income certainty from alternative sources such as off farm employment was preferred as

a risk mitigation strategy. Mussel farming is a seasonal activity and extra cash from other sources could cover possible losses from the “uncertain” production. Complementary jobs in different occupations offer some insurance, by reducing farm income variability (Dickey & Theodosiou, 2006). These responses were not surprising, as pluri-activity and multiple job holding were structural features of the farm households in Greece and usually, involve more members of the household than just the farmer (Kizos, 2010; Kizos et al., 2011).

In Denmark, to produce at the lowest possible cost was considered as the most important risk management strategy by the Danish producers (Ahsan & Roth, 2010). Similar preference, as the third most important strategy, following that of alternative income, had also the Greek producers. Despite that the Greek mussel farmers do not have strong cooperative culture as the Danish producers (Ahsan & Roth, 2010), they suggested horizontal collaboration could mitigate losses, achieve benefits of scale, and reduce financial risks though minimized operating cost and increased depreciations of fixed variables (Cush & Varley, 2013; Theodorou et al., 2014a). Finally, diversification seems to be least priority for the Greek mussel farmers’ as their traditional stance does not allow for easy adoption of novel technology, let along their need for new markets opening. Yet again, the limited suitable space available in Greece for new species such as benthic (clams, oysters), explains the limited preference for this strategy.

From the rest of the strategies, with moderate or very low impact, it was noteworthy that private insurance policies were not priority. Although at present, hedging/insurance services do not cover the industry demands in Greece, Greek producers would be willing to have specific products for the mussel farming. For instance, they wish to buy insurance for their working vessel and/or for weather impact on the mussel farm installation, equipment and animal stock. Similar viewpoints for the risk-transfer mechanisms were

shared by the French oyster farmers showed by Le Bihan et al., (2013). They support the demand for tailor made specific hedging products for the European bivalve shellfish sector, as the market has so far failed to cover this “gap”.

The Greek mussel farmers showed a reluctance for agreements with wholesalers offering them stable price long-term contracts. This attitude might be attributed to the a) unsuitability of these “modern tools” to meet the demands of the sector; b) the complicated structure and the questionable reliability of these agreements; c) farmers background which renders them suspicious against modern business tools, possibly needing more time to familiarised and be convinced.

The Greek producers suggested through their responses to the open ended questions that bearable risks for them were those related with the conventional self-protective mechanisms within the farm, as they feel familiar with the routine daily practices to prevent losses. This is in accordance with their responses to the questionnaire showing that they were used to face risks in production and in general farming activities, doing their best to maximize incomes. It is a common approach in agribusiness worldwide, that farmers have confidence in their supervising of their own production activities (Meuwissen et al., 2001; Le & Cheong, 2010).

Demands for public compensation of losses by the Greek mussel farmers were posed also for causes of disaster not directly relevant to the activity. These might refer to irreversible phenomena or large unpredictable disasters due to weather (e.g. tsunami, heat waves, anoxia, and radioactivity), extended harvesting bans due to harmful algal blooms, pollution (e.g. oil spills), predator attacks (e.g. sea turtles), diseases, and illegal actions (e.g. sewage, radioactivity release). Presently, no insurance policy exists for the Greek mussel farming sector rendering the business vulnerable to operational risks (Theodorou et al., 2011a). At European level compensation is available through the

European Fisheries Fund only for cases of major disasters, concerning the livestock protection or the human health. Recently (2014) through the article 57 of the EU Regulation 508/2014 the EC further expands insurance compensation (covered by the European Maritime & Fisheries Fund) of the aquatic farmed animal stock losses due to causes such as natural disasters, weather impacts, water quality and diseases. At a global level, for the cases of oil pollution losses could be covered by the International Oil Pollution Compensation (IOPC) fund (Le Bihan et al., 2013).

### **3.4.3 Relationship between Risks & Mussel Farm/Farmer Socioeconomic**

#### **Characteristics**

Experienced mussel farmers as they become elderly, pay attention on their personal welfare, feeling that they have to improve their living standards, as well as their insurance and pension benefits. It seems to be on the top of their priorities, since the mussel farming is a high risk occupational activity with intensive craftwork contribution. Mussel farmers were less familiar with the financial management issues and less willing to take risks in this field. This attitude is related with the education of the farmer and the legal status of the company. Educated farmers have the skills to negotiate bank loans and are familiar to work in larger company schemes. In addition, the negative attitude of the mussel farmer is further boosted by the usual discouraging response of the bankers to their financial demands. The latter view the bivalve shellfish sector as a high risk profile investment due to its extensive nature leading to marginal profitability and unpredictable variability of outcomes (Commission of the European Communities, 2009; Theodorou et al., 2014a). As the whole Greek economy recently was exposed to the western economic crisis, the limited exposure of the sector to bank loans had an advantage rather than disadvantage effect. In addition, the export orientation of this marine farmed

product as a seafood for human consumption, upgraded the image of the activity to the financial instruments (McKinsey & Company, 2012; Theodorou et al., 2014b).

However, it would be important to study the adaptations of the Greek mussel farmers' risk attitude under the new crisis conditions and to compare them with the present results referring to the pre-crisis period.

Experienced mussel farmers are familiar with the market risks as they know how to manage the technical aspects and the extensive administration paperwork induced by the public health awareness and the export nature of the product (Theodorou, 2001a,b; Angelidis, 2007a,b).

The environmental risks were viewed as a threat from the experienced farmers, while educated farmers understand better the local and the global environmental changes (Karageorgis et al., 2005; 2006) and hence contribute as stakeholders to mitigate adversities via interdisciplinary actions, such as spatial planning and development of best management practices (Zanou et al., 2005; Konstantinou & Krestenitis, 2012; Latinopoulos et al., 2012; Kontogianni et al., 2012).

The social acceptance of the mussel farming is related with the mussel culture systems and the working experience (culture tradition) of the farmers. Hanging parks for instance, i.e. the first mussel farm installations that were established close to the shore and within environmental protected areas (Alexandridis et al., 2006; 2008), due to long term institutional failures, (lack of Intergraded Coastal Zone Management), generated social conflicts (Kochras et al., 2000; Latinopoulos et al., 2012; Konstantinou et al., 2012).

The long term weather impact (i.e. "dry" or "wet" year) was characterised as a potential risk source by the farmers, as they knew from their past working experience how to compare, and practically project, the expected harvested meat yield based on their weather observations. The mussel producer's experience (especially within a certain

farm site) is important to identify possible pollution sources that could affect the public health and safety. In both cases the mussel farmers working experience, is the most influential socioeconomic component, that effects the identification of the risks, as it significantly contributes to the evaluation of all the factors of risk sources.

#### **3.4.4 Relationship between Risk Management & Farm/Farmer Socioeconomic Characteristics**

The income certainty of the mussel farmers could be threatened by public health and safety issues caused from several environmental risks (e.g. increased microbial, virus, heavy metal concentration loadings to unacceptable levels for human consumption).

The company trust is threatened in cases where the farm characteristics (e.g. water quality classification) could be affected by institutional risks (e.g. legislation changes for the water quality approved zones) or climate issues (e.g. heavy rainfalls) (Angelidis, 2007b).

Insurance policies might be instrumental in mitigating public health and safety risk issues. Mussel producers in order to be protected from possible threats e.g. due to poisoning from contaminated mussel consumption (Economou et al., 2007) they have to be covered by a certain type insurance policy.

Farmers could cooperate in order to solve collective problems in production and marketing of mussels, such as social acceptability of the final product's quality marred by biofouling. Support of concerned research actions in academia for instance, could provide solutions to the problems, e.g. by developing best management options to avoid or minimize losses in the future(Adams et al., 2011; Sievers et al., 2014). The challenge for the Greek mussel farming could be to get organised at larger schemes (e.g. larger



companies or producers organizations) to achieve the benefits of scale economics that efficiently support these actions (Theodorou et al., 2014a,b).

Mussel farming is a socially supported local aquaculture activity in Greece that provides a supplementary income to the coastal society members (Zanou et al., 2005; Konstantinou & Krestenitis, 2012; Kontogianni et al., 2012). In addition, the sector confounded in certain regions due to limited availability of locations with suitable environmental conditions, gives a niche producers competition, assigning to the local governance a major role for the industry development as most of the mussel farmers are local habitants (Latinopoulos et al., 2012; Konstantinou et al., 2012). On the other hand, several rules and directives are coming through EU and the National Legislation to be applied at national level, in some cases not “well fitted” with the local mussel farming “tradition” (Theodorou, 2001a; Konstantinou & Krestenitis, 2012; Jouanneau & Raakjær, 2014). People sharing culture heritage transfer unified perceptions through generations limiting the development of large variability in mentalities. Such common beliefs tend to get integrated after all in prevailing socioeconomics through either formal rules or informal norms of behaviour (North, 1993). As a result, the political pressure of the producers is applied to the different levels of local governance system described in detail by Konstantinou & Krestenitis (2012) for Chalastra a major mussel production area in Northern Greece. The developed (and still developing) model reflects these facts. According to North (1993) if the institutional framework thus developed promotes piracy then it is this exactly organisational scheme that would emerge finally. If otherwise productive activities are promoted then these schemes would ultimately prevail (see conclusion of next Chapter 4).

The polycentric system of approach developed by Ostrom (Ostrom et al., 2007; Ostrom 2007; 2009; 2010; 2011; Ostrom & Cox, 2010), and further elaborated by followed

studies (McGinnis, 2011a,b; McGinnis & Ostrom, 2014) could be verified in the case of the mussel farming in Greece. In the afore mentioned socio ecological system framework, the social and ecological interactions (as identified in the present risk assessment) could be used as an input/outcome of a polycentric governance system explaining what makes the industry up to the present time viable, despite the lack of spatial planning (Alexandridis et al., 2006; 2008). It also demonstrates the local adaptation of the sector as a response to the any external changes occurred through institutional changes. The social factor is a local priority in most of cases, since it provides employment to the local communities supporting also the politicians during elections. This is visible when comparing the government election seasonal pattern in Greece (every 3-4 years approximately since 80's) and the industry expansion due to licencing approvals in the past 3 decades (Theodorou et al., 2011a). In addition mussel farmers as a local lobby try to orient the institution to the way that they could have a profit or an opportunity in the future (mainly related with the farm sites availability or subsidies), a common situation in financial history as noticed by North (1993).

The outcomes of the present empirical risk analysis study could be further expanded through the verification of the Ostrom's (2011) socio ecological framework, providing answers about the roles and the effects of the multi-organizational and multilevel institutional governance on the mussel farming local economic activity.

### **3.5 CONCLUSION**

The risk perception and the risk management strategies of the Greek mussel farmers, have been empirically studied in relation to the socioeconomic background of the farmers and their farm characteristics. It was found that:

- The most important socioeconomic characteristic of the mussel farmers for the identification and evaluation of the possible risk sources was working experience.
- The mussel farmers were more familiar with the risks related to their daily farm work in production and marketing, rather than with economics they don't have in depth knowledge, experience or relative skills.
- The major risk sources were related with personal welfare and financial risks. As mussel farming is still an intensive craftwork any physical disability or health problem has direct effects on the farm management. The financial risks were related with the price stagnation and difficulty of the farmers to react. Mussel farmers prefer to use as risk mitigation strategies the development of financial credit reserves and income certainty from other sources. Insurance is welcomed but not used as there are not tailor made products in the market.
- Mussel farmers would like to buy specific insurance contracts for their working vessels and for weather impacts. They suggested that low probability but not bearable high impact/catastrophic risks, such as major weather disasters, extended harvesting bans due to HABs, pollution, predators attack, diseases and illegal actions, have to be covered by public funds. Finally, farmers' attitude and comments on loss compensation bring up the need to develop a more effective and versatile insurance system. In practice, they apply in farm insurance through best management practices under their own control. Results refer to the pre-financial crisis mussel farmers' needs for risk sharing strategies. Current farmers' approach in the new business environment has to be investigated to identify the industry's adaptations and likely new demands. Stakeholders could

avail on such knowledge to improve or develop more efficient risk mitigation strategies and insurance policies for the Mediterranean mussel aquaculture.

- The outcomes of this empirical study meet the objectives of the thesis following the guidelines (Purdy, 2010) for the risk management efficiency of the framework (in Chapter 2): i) The risk performance has been measured setting also management priorities ii) Risk limits has also been quantified on the risk management preference strategies iii & iv) Chapter 3 focused on risk identification and set priorities on the risk management policies applied by the producers v) The development of the empirical study based on the risk communication between stakeholders through the questionnaire responses and the personal interviews survey as well as with the dissemination of the results (Theodorou et al., 2010a).
- Chapter 3 efficiently represents the primary process for risk assessment (Figure 2.2). It is based on the risk attitude of the Greek mussel farmers in relation to their socioeconomic variables in order to provide the required knowledge for build up risk management decisions (Figure 2.4) as demonstrated in the van Raaij (1981) modified descriptive model (Figure 2.3) in Chapter 2. In addition, identify the analytical needs for a further secondary supported process to examine the profitability (Chapter 4) and the role of HABs on the losses (Chapter 5), as the rest of the major identified sources of risks mitigated with already existing practices (as explained in the introduction of the next Chapter 4).

# CHAPTER 4

## RISK FACTORS AFFECTING THE PROFITABILITY OF THE MEDITERRANEAN MUSSEL *MYTILUS* *GALLOPROVINCIALIS* LAMARCK 1819, FARMING IN GREECE\*

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**\*Adapted from:**

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## 4.1 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., 2011a). Mussel farming has less flexibility for site selection than the marine fish (sea bass/bream) on-growing industry which is the major marine farming activity in Greece (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 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 was taken 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 with usual methods. Hence, following the primary process of the working framework (Figure 2.2) originated from the AS/NZS ISO 31000 Risk Management Standard in Chapter 2, a study of the mussel farmers' risk perceptions was conducted (see Chapter 3) based on structured questionnaires and personal interviews of a large number of mussel farmers (n=49). 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 two decades (Theodorou et al., 2011a; see Chapter 1). The aforementioned study (Chapter 3) highlighted the research question generated by the primary process of the working framework (Figure 2.2): "Why mussel farmers consider ex-farm prices as a major source of risk?". The present effort (Chapter 4) as a secondary process of the working framework model (Figure 2.2) aims to provide the relevant answer(s).

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. Farm size moreover, is an administrative risk as the state licenses small size farms to many applicants while the new farmers realise it shortly after operations were launched (it might also take more than 3-4 years for the permit to be issued). So they have either



to expand (buy other farms by paying added values) or to quit or to cheat in order to survive (Theodorou et al., 2015c).

A sensitivity analysis, as described by Kam & Leung (2008), was conducted to determine how changes in key production and management variables (enterprise budgets according to Engle & 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.

## **4.2 MATERIALS & METHODS**

### **4.2.1 Research 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.

### **4.2.2 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 with 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 hypothetical scenario (see below) of a range of culturing operations (assigning 1–6 ha each) located in the same area (similar natural conditions and transportation costs) using similar technology and typical production methods. Most of the farmed mussels are exported live so there are no “by products”. This is due to the fisheries background of most farmers that have no aspirations for diversification of the production. This is expected to change as the new generation of farmers are more educated and modern market acquainted.

Profit ( $\pi$ ) 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:

$$\text{Profit } (\pi) = \text{TVP} - \text{TC} = \text{TVP} - \text{TVC} - \text{TFC} = P_y * Y - \text{TVC} - \text{TFC} \quad (1), \text{ where}$$

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

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

$Y$  is the amount of output (harvested mussels in tonnes) at any level of farm size,

$P_y$  is price per unit of output (€/tonne),

$TC$  is *total cost* representing the total monetary value of all costs of production and can be written as

$$TC = TVC + TFC \quad (3)$$

$TVC$  is *total variable costs* representing total monetary costs for the variable inputs used in mussel production, and

$TFC$  is *total monetary value of fixed inputs* used for production.

Sensitivity analysis was carried out according to Kam & 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 exist. 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 source, 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, are 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.

#### **4.2.3 Data Collection**

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 during the period of October-December 2008.

Farm 1, was established through Public/EU funding support, with an annual production capacity of 220 t/yr, located in Molos, Maliakos Gulf. Farm 2, (50 t/yr) was located in Ag. Ioannis, Maliakos Gulf. Farm 3, (100 t/yr) located in Molos, Maliakos (Public/EU funded). Farm 4, (300t/yr) was located in Amvrakikos Gulf. Farm 5, (160t/yr) located in Sagiada, Ionian Sea. Farm 6, (300t/yr) was located at Spercheios Estuaries, Maliakos. Farm 7, (100t/yr) and Farm 8, (200 t/yr) (Public/EU funded) were located at Thermaikos Gulf. Farms were not homogenous from site to site as they operated in different local conditions such as exposure to the waves, and consequently they use different construction standards including also specifications and size of the working vessels. In addition, there is a variable distance from ports that seriously affects the energy consumption and the labor time cost. Some of them were Public/EU funded. All farms were operated under the same production protocol as described by the environmental rules in their operating licenses and in their sea rental contracts. Growth of mussel seed (20mm) per final product (6cm) was about 1:7 in terms of bulk weight (t) for all farms. Fixed costs, such as equipment and boats, were obtained from industry suppliers that more or less are the same all around the country, and from the book keeping of all eight farms included in the survey. Business plans of the these farms having approved as Public/EU funded projects, including invoicing of the fixed assets and the constructions

works, were also investigated and were taken into account in order to have a clear view about the variation of the investment costs.

Variable costs were collected from the book keeping of all farms within a 10 year period. Information on oil consumption and daily operations were obtained after discussion with farm owners and captains of the vessels. The energy requirements were depended on the size and the type of the vessel, the power of the engine, the distance covered, the local weather conditions, the type of the work (harvesting is more energy consumed than tubing), the manpower (wages, insurance, working hours, working crew number), the consumables and maintenance of the equipment used in the farm.

The financial efficiency of the different operation scales was estimated by an hypothetical scenario developed to homogenise the variability of several factors such as the location productivity (production capacity), energy consumption (type of work, working trip duration), labour cost (wages, insurance), equipment (grading machine and boat specification). The market prices used in the current financial analysis were means of price data obtained from the farmers as previously described, covering a period of over a decade of operations for a range of bulk, ex-farm prices of graded and packed products. Production and management assumptions for a hypothetical operation were established according to Adams et al., (2005) with the aid of eight experts who were either consultants or key opinion leaders in administration/academia, most of them with previous industrial experience. A Microsoft Excel spreadsheet was developed so that, given the production design and management assumptions the capital investment, operating expenses, and profitability could be estimated from. Because mussel farming is a labour-intensive activity, an effort also was made to estimate the profit-maximizing level of labour 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, labour, energy, and consumables).

#### **4.2.4 Baseline Assumptions of the Analysis**

##### **4.2.4.1 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 miles 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 long-lines, 100 m length, placed 10 m from each other. All long-lines are constructed of 26-mm-diameter, UV-resistant polypropylene ropes and are anchored laterally with concrete blocks (approx. 3 t). All long-lines 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. (2011a). Because labour is the major variable cost in mussel farming (Theodorou et al., 2011a), 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.

#### **4.2.4.2 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 were means of price data obtained from the farmers at the site visits, covering a period of over a decade of operations for a range of the bulk, ex-farm prices of graded, packed products. The same stands is carried out also for all costs data included in this survey. 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 years. 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.

Table 4.1. Investment Cost for a range of sizes of Greek mussel farms (values in €).

	<i>Farm size (hectares)</i>						
	<b>1</b>	<b>1.5</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
Licenses & 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
Lighthouses (floating lanterns)	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 (25hp)	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
<b>Total</b>	<b>295,686</b>	<b>309,169</b>	<b>332,576</b>	<b>351,618</b>	<b>388,508</b>	<b>406,399</b>	<b>430,517</b>
<b>EU/public subsidized 45%</b>	<b>133,059</b>	<b>139,126</b>	<b>149,659</b>	<b>158,228</b>	<b>174,828</b>	<b>182,879</b>	<b>193,732</b>
<b>Owner Contribution 55%</b>	<b>162,627</b>	<b>170,043</b>	<b>182,917</b>	<b>193,390</b>	<b>213,679</b>	<b>223,519</b>	<b>236,784</b>

## 4.3 RESULTS & DISCUSSION

### 4.3.1 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).

Average investment costs associated with different farm sizes are presented in Table 4.1.

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. 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 4.1 show that the total investment costs averages 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.

#### **4.3.2 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).

#### **4.3.3 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 4.2). 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.

Table 4.2. Operational costs for a range of sizes of Greek mussel farms at an annual basis when not subsidized by EU/public (values in €).

	<b>Farm size (hectares)</b>						
	<b>1</b>	<b>1.5</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b><i>Fixed Cost (FC)</i></b>							
Annual Leasing Fee	1,000	1,500	2,000	3,000	4,000	5,000	6,000
Permit amortization (10 years)	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 years)	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
<b><i>Total fixed costs (TFC)</i></b>	<b>49,436</b>	<b>51,421</b>	<b>53,694</b>	<b>58,160</b>	<b>62,679</b>	<b>67,219</b>	<b>71,164</b>
<b><i>Variable Cost (VC)</i></b>							
Energy	3,054	4,396	5,670	8,448	10,867	13,826	16,457
Labour (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
<b><i>Total Variable Cost (TVC)</i></b>	<b>30,001</b>	<b>38,375</b>	<b>47,072</b>	<b>65,094</b>	<b>85,328</b>	<b>103,320</b>	<b>121,006</b>
<b><i>Total Cost (TC=TVC+TFC)</i></b>	<b>79,437</b>	<b>89,796</b>	<b>100,766</b>	<b>123,254</b>	<b>148,007</b>	<b>170,539</b>	<b>192,171</b>

#### 4.3.4 Fixed costs

The annual fee for for leasing the sea site of the farm is about 1,000 €/ha. Insurance is applied only to the car, because insurance for vessels used in mussel farming is not compulsory (Theodorou et al., 2011a) (Table 4.2). The mean 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 4.2 shows the mean operational costs of a mussel farm

when there is not any external financial support. Table 4.3 demonstrates how this mean fixed cost differentiates when external support is available (EU and public funding),

Table 4.3. Operational cost of a size range of the Greek mussel farms when subsidized by EU/public (values in €).

	<i>Farm size (hectares)</i>						
	<b>1</b>	<b>1.5</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>Fixed Cost (FC)</b>							
Annual Leasing Fee	1,000	1,500	2,000	3,000	4,000	5,000	6,000
Permit amortization (10 years)	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 years)	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
<b>Total fixed costs (TFC)</b>	<b>32,803</b>	<b>34,255</b>	<b>35,910</b>	<b>39,132</b>	<b>42,382</b>	<b>45,644</b>	<b>48,354</b>
<b>Variable Cost (VC)</b>							
Energy	3,054	4,396	5,670	8,448	10,867	13,826	16,457
Labour (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
<b>Total Variable Cost (TVC)</b>	<b>30,001</b>	<b>38,375</b>	<b>47,072</b>	<b>65,094</b>	<b>85,328</b>	<b>103,320</b>	<b>121,006</b>
<b>Total Cost (TC=TVC+TFC)</b>	<b>62,805</b>	<b>72,630</b>	<b>82,983</b>	<b>104,226</b>	<b>127,711</b>	<b>148,964</b>	<b>169,360</b>

\* estimated as a fixed cost following national tax accounting legislation.

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.

#### 4.3.5 Annual Income & 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* ( $\pi$ ) 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 4.4 and 4.5, respectively. In all cases, 4–6-ha farms were profitable, with net *Profit* ( $\pi$ ) 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 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.

Table 4.4. Annual Income and profitability for a range of size of Greek mussel farms when not subsidized by EU/public (values in €).

<i>Annual Income and profitability</i>	<i>Farm size (hectares)</i>						
	<b>1</b>	<b>1.5</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
Production Yield (Y in tonnes)	106	154	202	299	395	492	588
Sales price (€/t)	Total Value Product ( $TVP=Py*Y$ )						
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 ( <i>TFC</i> )						
	49,436	51,421	53,694	58,160	62,679	67,219	71,164
	Total Variable Cost ( <i>TVC</i> )						
	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
	Pre-tax Profit ( $\pi$ ) = $TVP-TC$						
400	<b>-37,028</b>	<b>-28,110</b>	<b>-19,804</b>	<b>-3,738</b>	10,062	26,084	43,006
450	<b>-31,727</b>	<b>-20,399</b>	<b>-9,683</b>	11,202	29,821	50,662	72,403
500	<b>-26,426</b>	<b>-12,689</b>	437	26,141	49,580	75,240	101,801
550	<b>-21,125</b>	<b>-4,978</b>	10,557	41,081	69,338	99,818	131,198
600	<b>-15,824</b>	2,733	20,678	56,020	89,097	124,396	160,595
	Net Profit ( $\pi$ ) = $TVP-TC$ (income tax 25% )						
400	<b>-37,028</b>	<b>-28,110</b>	<b>-19,804</b>	<b>-2,803</b>	7,547	19,563	32,255
450	<b>-31,727</b>	<b>-20,399</b>	<b>-7,263</b>	8,401	22,366	37,997	54,303
500	<b>-26,426</b>	<b>-9,517</b>	328	19,606	37,185	56,430	76,350
550	<b>-21,125</b>	<b>-3,734</b>	7,918	30,811	52,004	74,864	98,398
600	<b>-11,868</b>	2,049	15,508	42,015	66,823	93,297	120,446
	Net Profit ( $\pi$ ) (%)						
400	<b>-87%</b>	<b>-46%</b>	<b>-24%</b>	<b>-2%</b>	5%	10%	14%
450	<b>-66%</b>	<b>-29%</b>	<b>-8%</b>	6%	13%	17%	21%
500	<b>-50%</b>	<b>-12%</b>	<b>0%</b>	13%	19%	23%	26%
550	<b>-36%</b>	<b>-4%</b>	7%	19%	24%	28%	30%
600	<b>-19%</b>	2%	13%	23%	28%	32%	34%

*Bold type in the table body indicates negative results*

Table 4.5. Annual Income and profitability for a range of size of Greek mussel farms when subsidized by EU (values in €).

<i>Annual Income and profitability</i>	<i>Farm size (hectares)</i>						
	<b>1</b>	<b>1.5</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
Production Yield ( <i>Y</i> in tonnes)	106	154	202	299	395	492	588
Sales price (€/t)	Total Value Product ( $TVP=Py*Y$ )						
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 ( <i>TFC</i> )						
	32,803	34,255	35,910	39,132	42,382	45,644	48,354
	Total Variable Cost ( <i>TVC</i> )						
	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
	Pre-tax Profit ( $\pi$ ) = $TVP-TC$						
400	<b>-20,396</b>	<b>-10,944</b>	<b>-2,020</b>	15,291	30,359	47,659	65,816
450	<b>-15,095</b>	<b>-3,234</b>	8,100	30,230	50,118	72,237	95,213
500	<b>-9,794</b>	4,477	18,221	45,170	69,877	96,815	124,611
550	<b>-4,493</b>	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 ( $\pi$ ) = $TVP-TC$ (income tax 25%)						
400	<b>-20,396</b>	<b>-10,944</b>	<b>-2,020</b>	11,468	22,769	35,744	49,362
450	<b>-15,095</b>	<b>-3,234</b>	6,075	22,673	37,588	54,178	71,410
500	<b>-9,794</b>	3,358	13,665	33,877	52,407	72,611	93,458
550	<b>-4,493</b>	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 ( $\pi$ ) (%)						
400	<b>-48%</b>	<b>-18%</b>	<b>-2%</b>	10%	14%	18%	21%
450	<b>-32%</b>	<b>-5%</b>	7%	17%	21%	24%	27%
500	<b>-18%</b>	4%	14%	23%	27%	30%	32%
550	<b>-8%</b>	11%	19%	27%	31%	34%	36%
600	1%	16%	24%	31%	35%	37%	39%

*Bold type in the table body indicates negative results*

### **4.3.6 Sensitivity Analysis**

#### **4.3.6.1 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 5.6. 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 breakeven price also changes. The break-even price decreases directly 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 4.6) 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., 2011a). Farms of 3–6 ha were profitable if export oriented at yields even down to 70% of capacity when subsidised. 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. 4.2), 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 4.5) in the export market.

Table 4.6. Sensitivity Analysis of Mussel Harvesting Yield (% capacity per farm size) for two scenarios (without and with EU subsidization). Break-even price: total production cost per tonne harvested.

Assumptions		Farm size (ha)						
		1	1.5	2	3	4	5	6
		Production Capacity (t/yr)						
		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	1248	985	841	695	630	583	549
	70	1045	819	698	571	515	474	446
	80	923	725	618	508	458	423	398
	90	826	650	555	458	414	381	359
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



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 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.

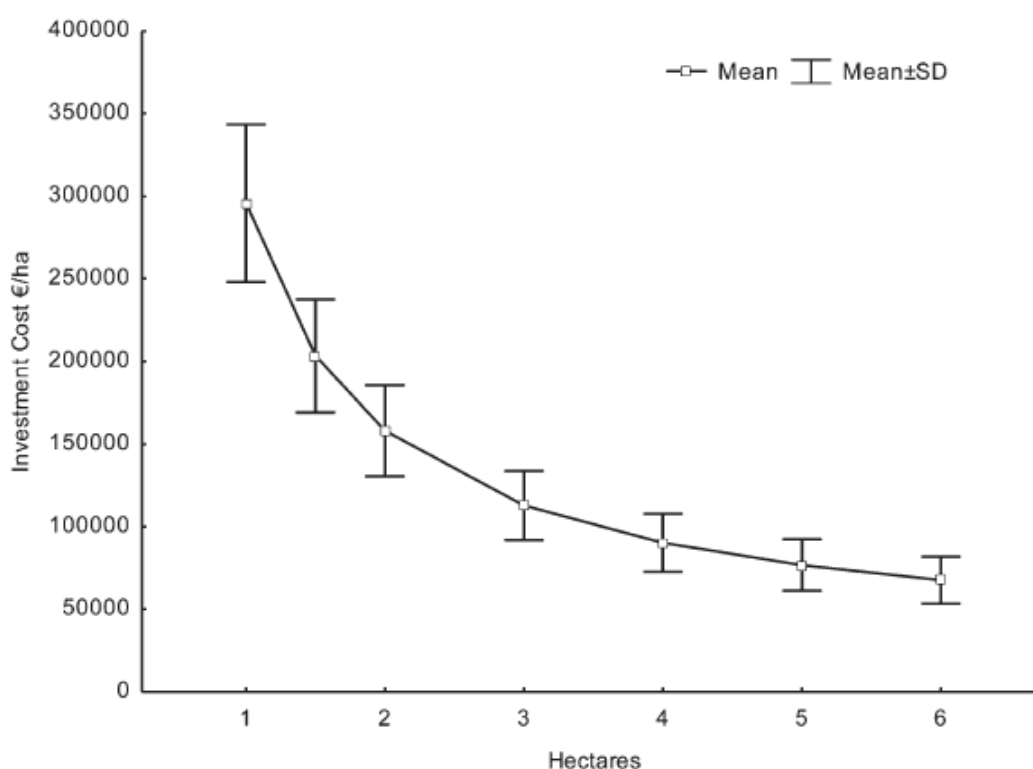


Figure 4.1. Total Investment Cost per hectare for a size range of mussel farms.

#### 4.3.6.2 Effects of changes in Farm Size

Figure 4.3 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 (Figure 4.4). Total

investment cost per hectare was very high for the 1–2-ha farms (Figure 4.1), 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. 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 (Figure 4.2). 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) (Figure 4.5) across product types.

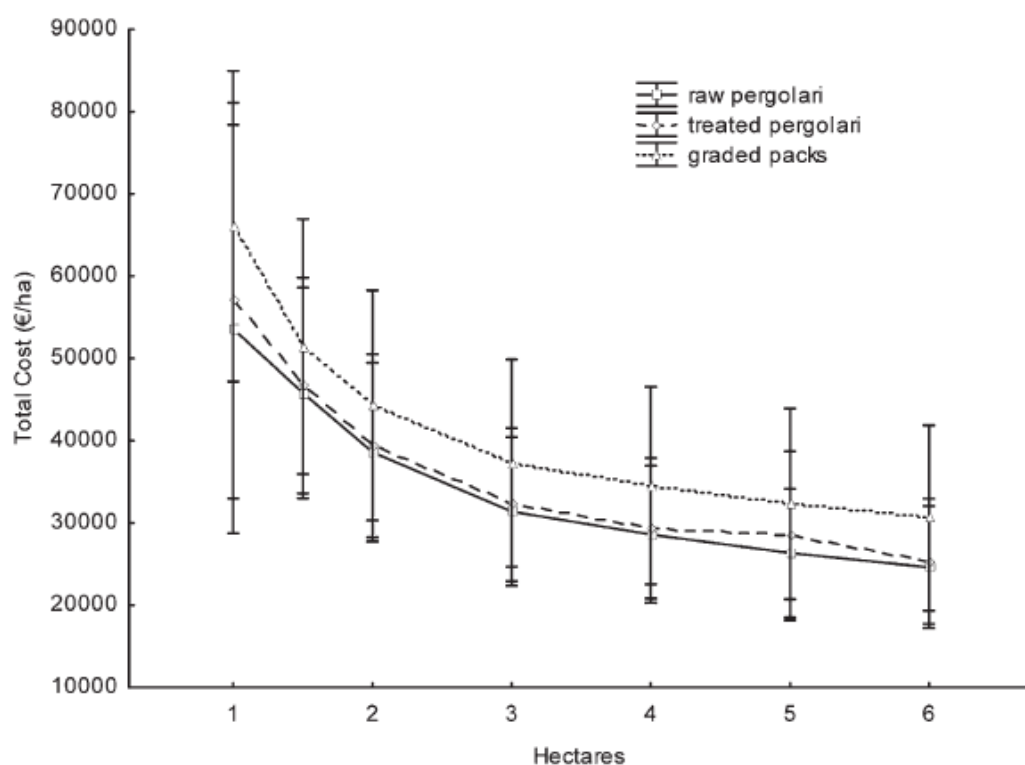


Figure 4.2. Effect of farm size on the total cost for different forms of the final product (raw or treated pergolari vs. graded packs).

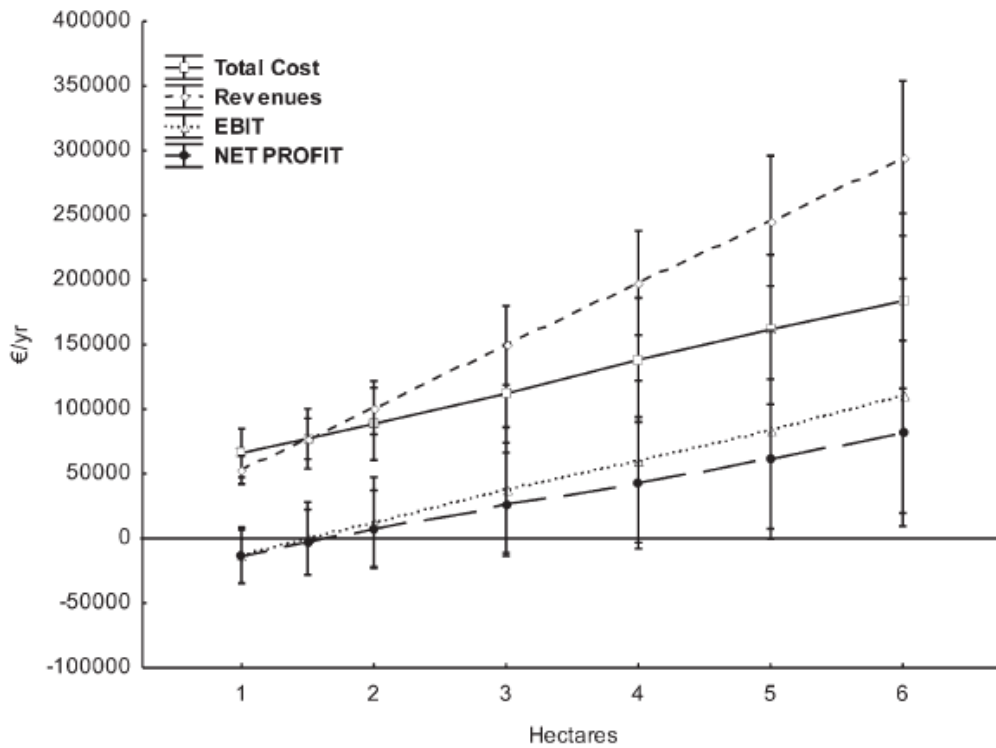


Figure 4.3. Annual revenues (Total Value Product, [TVP]) of the graded packed mussels in relation with the total cost (TC), the pre-tax *Profit* ( $\pi$ ) (earnings before income tax [EBIT]) and the net profit of a range of farms (1-6 ha).

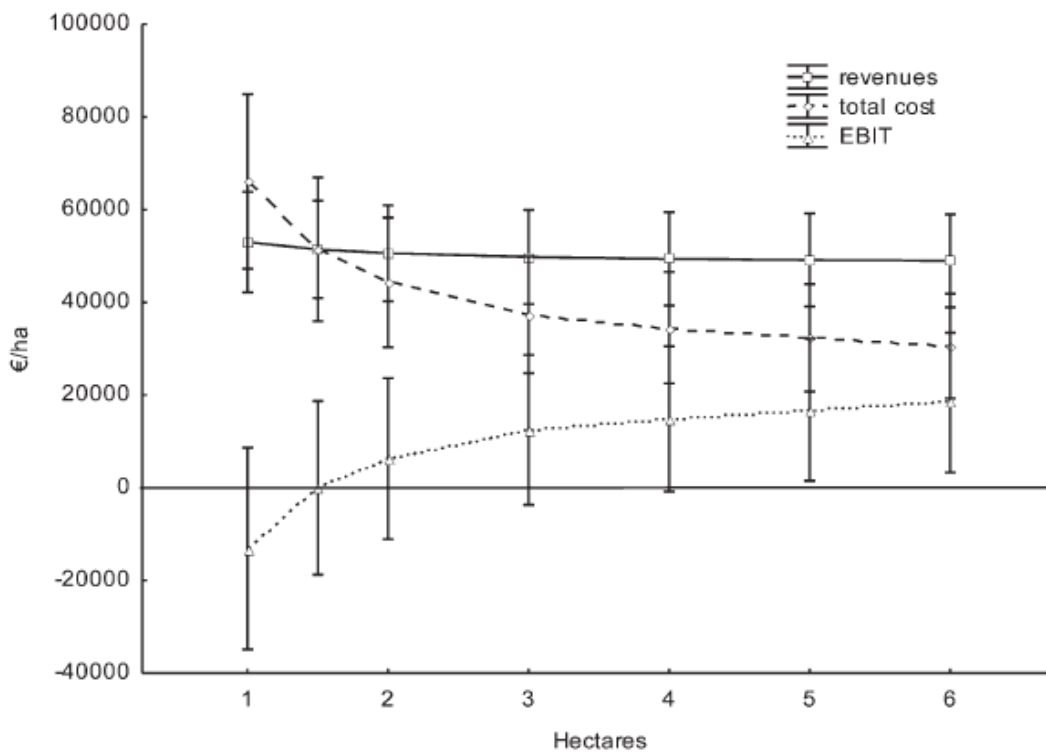


Figure 4.4. The revenues (total value product, [TVP]) per hectare of a range of mussel farms (1-6 ha) in relation with the total cost (TC) and the pre-tax *Profit* ( $\pi$ ) (EBIT).

#### **4.3.6.3 Effects of changes in Labour Units**

The mussel farming is a seasonal and labour intensive activity. Labor is a major component of the production cost (Theodorou et al., 2011a). The variation of the level of wages might be an important risk factor as in other industries; however in the present study it was not significant due to a very low range occurring in the Greek agricultural sector at the time of the study. Nevertheless, labour management had a significant impact on the total labour cost in relation to the farm size. MANOVA analysis demonstrated that the total cost per tonne of harvested product decreased with increasing working-labour units (from 2 to 7 individuals), with of the size of the farms playing a smaller role (Figure 4.6A). The Pre-tax *profits* ( $\pi$ ) showed an increase with larger crew size of the working vessel (15m) at any farm size (Figure 4.6B). Furthermore, as the labour intensive period is actually seasonally restricted to about 4 months overall, the full-time employment could be replaced by seasonal employment or by outsourcing this activity to a professional working-crew servicing multiple farms in the area. However, legal obstacles would need to be removed in order for seasonal employment to be utilized as is done in the terrestrial farming.

#### **4.3.6.4 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 & 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).

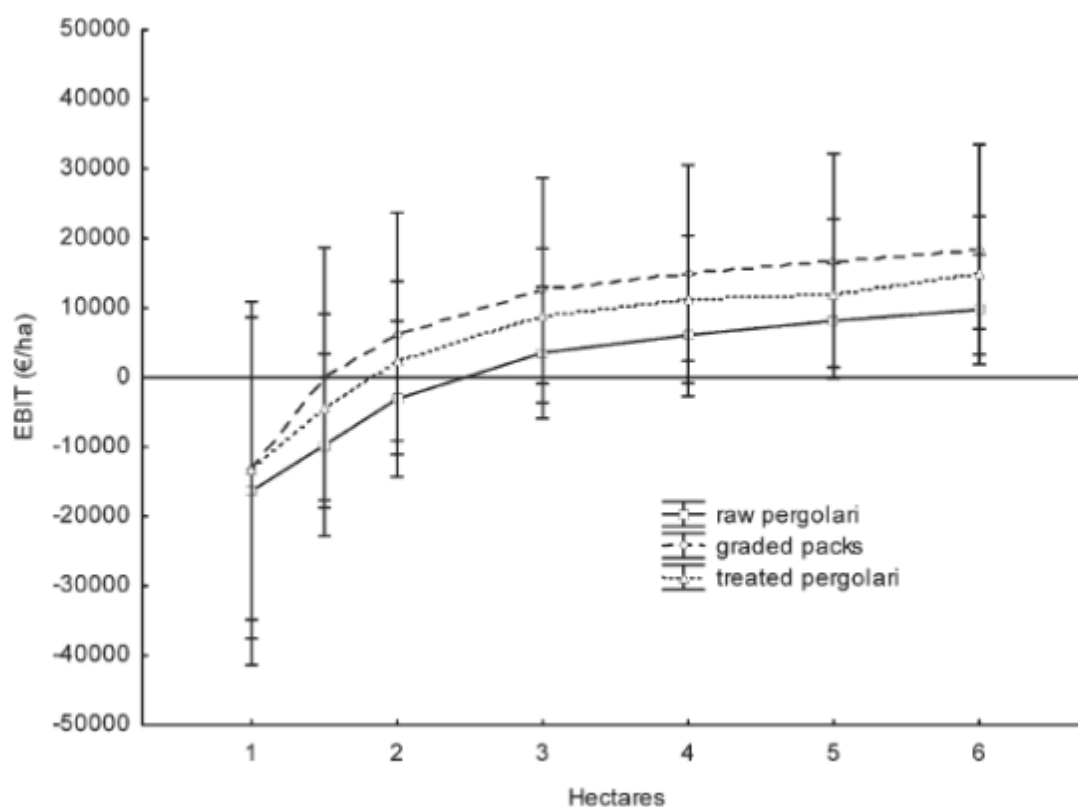


Figure 4.5. The effect of farm size on the unit pre-tax *Profit* ( $\pi$ ) (EBIT per hectare) for different forms of the final product (raw or treated pergolari vs. graded packs).

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., 2011a) 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 (Gouilletquer & Le Moine, 2002; Mongrue & 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 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/yr on poles whereas, later, a floating longline was assumed to produce 100 t/ha/yr. 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., 2011a) 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).

#### **4.3.7 Greek Mussel Farming Profitability**

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, there by 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.



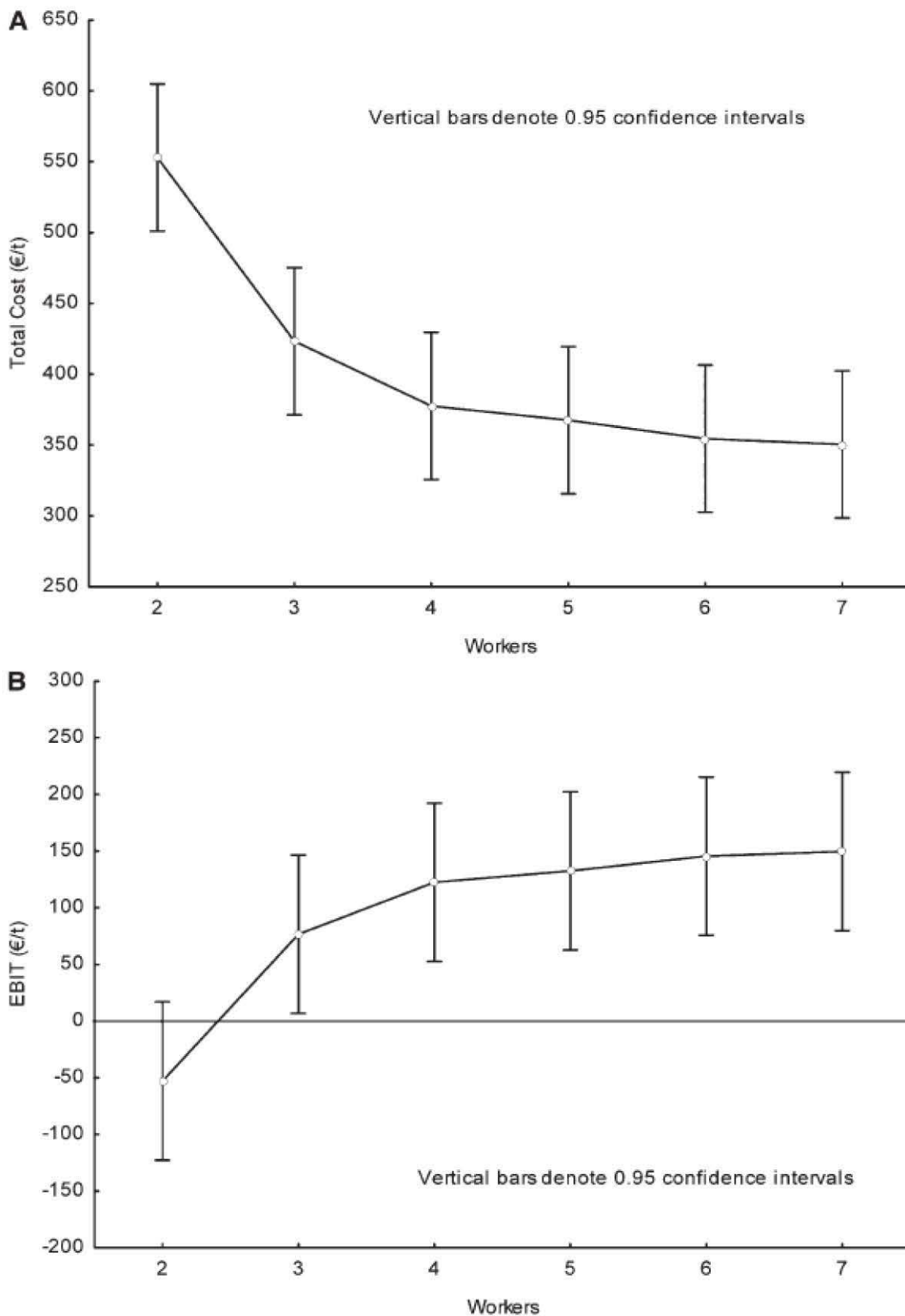


Figure 4.6 (A,B). Effect of the working crew size on the total cost (TC)(A) and on the pre-tax profit (earning before income [EBIT]) (B) after MANOVA analysis. Confidence intervals reflect variation also caused by different farm size.

#### 4.4 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.

Chapter 4 successfully represents a secondary process of the AS/NZS ISO 31000 Risk Management Standard (Figure 2.2). Through extensive sensitivity analysis, it provides efficient explanation of the research question retrieved by the primary process (Chapter 3): “Why farmers consider ex-farm prices as a major source of risk?” The answers given (marginal ex-farm prices, in relation with the limited operated production capacities as a consequence of the small farm sizes (<3ha) that dictated by the licencing system effects seriously the profitability) provided the relative management solutions (ie scaling up the activity through producers collaboration in order to minimize the costs and benefits from the economies of scale) as inputs of the secondary to the primary process of the

Standard. It meets also the risk management efficiency the criteria of the Standard (Chapter 2) as: i) the risk factors affecting profitability are identified and measured; ii) extensive sensitivity analysis provides the break-even points on the production volume, price and farm size, indicating profitable strategies. This explain why this study meets the Ostroms theory (2011) for a multi-tiered governance as a socio ecological system approach and explains the legalization of the piracy (North 1993) presented in Chapter 3. Even if farm sizes less than 3ha are not viable still are working with success even under the Greek economic crisis situation, as they are out of the mainstream legal culture. As a consequence, it amplifies the farmers' opinion about the EU rules that they seem to them to be "destructive"; iii & iv) the optimal operational policies in terms of labour costs (crew size) is determined; v) risk communication is provided through farmers' responses in personal interviews during the planning and feasibility of the present effort and the public dissemination of the relative results (Theodorou et al., 2010b; 2011a; 2014).



# **CHAPTER 5**

**SEMI - QUANTITATIVE RISK ASSESSMENT OF  
FARMED MEDITERRANEAN MUSSEL (*MYTILUS  
GALLOPROVINCIALIS L.*) HARVEST BANS DUE  
TO HARMFUL ALGAL BLOOMS (HABS)  
INCIDENTS IN GREECE**

## 5.1 INTRODUCTION

Empirical studies of the Greek mussel farmers' perceptions of risks demonstrate that the monitoring system and the public administration management of Harmful Algal Blooms (HABs) rank among the most sensitive–critical “institutional” risks that directly affect the industry (Theodorou et al., 2010b,c; Theodorou et al., 2011a,b). Since HABs are poorly understood (Shumway, 1990; Glibert et al., 2005; Berdalet et al., 2014), the shellfish harvesting site closures due to “halo” effects (toxic algal species densities close to the critical limits in the seawater), including those that might be precipitated by public policies or pronouncements, greatly increase the operating difficulties of mussel farming (Hoagland & Scatasta, 2006; Chadsey et al., 2012; Pérez Agúndez et al., 2013). For government officers, a ‘HAB risk’ is associated with the authority’s (agency’s/ department’s) performance of the objectives set under the relevant legislation (Theodorou, 2001; Fletcher et al., 2004). In contrast, for an aquaculturist, the term ‘HAB risk’ generally relates to the impact on profitability due to site closures, and their consequences (Conte, 1984; Kahn & Rockel, 1988; Shumway, 1990; Anderson et al., 2000; Karageorgis et al., 2005; Jin et al., 2008; Hoagland & Jin, 2008; Dyson & Huppert, 2010; Theodorou et al., 2012; Pérez Agúndez et al., 2013), and for society, ‘HAB risks’ possibly impact human health (Todd, 1993; Hoagland et al., 2002, J.C.J.M. van den Bergh et al., 2002; Batzios et al., 2004, Fleming et al., 2006;2014, Maso’ & Garce’, 2006; Economou et al., 2007; Kuhar et al., 2009; Picot et al., 2011; Kirkpatrick et al., 2004;2006;2014) as well as their pleasure in the marine/coastal environment (i.e. tourism, leisure) (Anderson et al., 2000; Scatasta et al., 2003; Whitehead et al., 2003; Morgan & Larkin, 2006; Hoagland & Scatasta, 2006; Larkin & Adams, 2007; Larkin & Adams, 2008; Backer, 2009; Morgan et al., 2008; 2010; 2011).

The aim of all parties should be to ensure that impacts be kept to an acceptable level. Rodríguez et al. (2011), examining the effects on the Galician mussel industry of the length of HAB-related site closures in days, suggested that HAB-related site closures cause losses because of the impossibility of placing products in the market. In the present study, we try to identify the impact on the Greek mussel farming sector, and propose suitable risk management strategies in order to ensure the impacts of HAB-related site closures are kept to an acceptable level. For this purpose, we followed similar systematic processes in other long-existing industries (e.g. constructions) that routinely assess and verify safety issues (Forbes et al., 2008; Hua, 2008).

Assessing the effects of HAB-related site closures on shellfish farming requires integrating methods and knowledge from multiple fields, such as aquatic animal health (MacDiarmid, 2001; Brun et al., 2003; Peeler et al., 2007), epidemiology (Groenendaal et al., 2002; De Vos, 2003), environmental biosafety (Kapuscinski, 2005; Kapuscinski et al., 2007; Lovell & Drake, 2009), algal physiology and ecology (Dolapsakis et al., 2008; Tzovenis et al., 2009), conservation (Harwood, 1999; 2000; Regan et al., 2002; 2005), shellfish biology and culture (Theodorou et al., 2007a,b; Adams et al., 2011), shellfish production economics and management (Adams & Pomeroy, 1992; Adams & Van Blokland, 1998; Adams et al., 2001; Kam & Leung, 2008; Pérez Agúndez et al., 2013; Theodorou et al., 2010b,d; 2011a; 2012; 2014), integrated coastal zone management (Goulletquer & Le Moine, 2002; Karageorgis et al., 2005; 2006; Mongruel & Thebaud, 2006; Caroppo et al., 2012; Latinopoulos et al., 2012; Davidson et al., 2014), system safety science (Ayyub, 2003), and environmental policy and legislation (Frey, 1992; Morgan & Henrion, 1990; Theodorou, 2001; Pollard et al., 2004; Konstantinou et al., 2012). Theodorou et al. (2006; 2010a), in an effort to conceptualize risk analysis in the Mediterranean marine aquaculture, demonstrated the suitability of a framework

application based on the principles of the Australian and New Zealand AS/NZS 4360:2004;1999 Risk Management Standard. These processes were recently incorporated into the new international version “Joint Australian and New Zealand ISO 31000:2009 Risk Management Standard” (Standards Australia, 2009), rendering the AS/NZS 4360 redundant.

The advantage of the model process of this standard for managing risks of undesired events is that its generic function applies to a wide variety of fields. It specifies the elements of the risk management process in any situation where an undesired or unexpected outcome could be significant. Crawford (2003) verified its use in aquaculture by conducting a qualitative risk assessment of the effects of shellfish farming on the Tasmanian (Australian) marine environment. As the standard is flexible, it is easily adapted, even in cases where available data is minimal (Cooper et al., 2005). The system has been successfully used to identify and assess the risks associated with the management of the aquaculture developmental plans (Fletcher et al., 2004) and qualitatively prioritize fisheries’ management issues (Fletcher, 2005). In addition, Fletcher et al. (2005) demonstrated a flexible and practical framework for reporting on ecologically sustainable development of wild capture fisheries based on the principles of this standard. A similar methodological approach (numerical risk ranking-numerical risk matrix of likelihood and consequence) has also been used by Wells & Jernakoff (2006) to study the major potential environmental and ecological risks arising from the various activities carried out by the pearl oyster *Pinctada maxima* industry.

As the key element for any valid risk analysis is to have procedures for determining appropriate consequence and likelihood levels (Fletcher et al., 2005), we have modified and adapted to our case (consequences of HAB-related Greek mussel farming site closures) the formal risk assessment process of the Australian & New Zealand Standard



Risk Management AS/NZS 4360:1999 (Standards Australia, and Standards New Zealand, 1999). The companion paper on Environmental Risk Management – Principles and Process (HB 203:2000) following the guidelines developed by Fletcher et al., (2004) to support an Ecologically Sustainable Development (ESD) reporting framework for aquaculture in Australia was also taken in account.

The process involves the examination of the sources of risk (issue identification), the potential consequences (impacts) associated with each issue, and the likelihood (probability) of a particular level of consequence actually occurring. The combination produces an estimated level of comparative risk that can then be used to assist in determining the level of management response required (Fletcher et al., 2005).

## **5.2 MATERIALS & METHODS**

### **5.2.1 Research Background**

#### **5.2.1.1 HAB's Profile in Greek waters**

Ignatiades & Gotsis-Skretas (2010), updating the earlier work of Nikolaidis et al., (2005) by reviewing the HABs incidents in the Greek coast waters, categorized the presence of 61 identified algal species (16 of them responsible for HABs) as follows:

i) *toxic*: species-generated blooms with toxic symptoms such as fish/shellfish mass mortalities and human poisoning through contaminated seafood consumption. In the latter, dinoflagellates *Dinophysis* spp., okadaic acid producers, have been responsible for diarrhetic shellfish poisoning (DSP), usually observed late winter and spring. This is characterized as the most potent threat of the mussel industry as it has caused economic losses in the past (Koukaras & Nikolaidis, 2004; Nikolaidis et al., 2005). Less extensive,

but more dangerous, agents have been detected in the diatoms *Pseudonitzschia spp.*; domoic acid producers, they could be the cause of amnesic shellfish poisoning (ASP).

ii) *potentially toxic*: toxigenic potential species such as the toxic dinoflagellate *Alexandrium minutum*, which does not generate toxic blooms as the nutritional status of the Greek waters is too poor to support the exponential population growth of this species.

iii) *high biomass*: non-toxic species such as the dinoflagellates *Noctiluca scintillans*, *Chatonella globosa* and *Prorocentrum spp.* that, when in season, massively explode (late winter/early spring, spring and autumn, respectively), generate anoxic conditions, and cause undesirable visual pollution through the discoloration of the seawater (Nikolaidis et al., 2005). Economic losses in the fishing and tourist industries are the result.

### **5.2.1.2 Public Health & Mussel Harvesting Management**

The most harmful marine biotoxins more frequently reported for extended periods in Greek coastal waters in the last decade and a half are the lipophilic toxins, responsible for diarrhetic shellfish poisoning (DSP) (Mouratidou et al. 2004, Prassopoulou et al. 2009, Louppis et al. 2010; Vlamis & Katikou 2014). The first report of a DSP outbreak in early 2000 (01/2000) caused the hospitalization of more than 120 consumers of contaminated mussels harvested in the Thermaikos Gulf (Economou et al., 2007). This event destroyed the public image of the product and, consequently, the local and national market. To avoid a future public health crisis and industry collapse, stakeholders (producers, administrators, scientists) established proactive measures, such as a monitoring program, that were scientifically supported by newly established, at that time, governmental infrastructures such as the National Reference Laboratory for Marine Biotoxins (Institute of Food Hygiene of Thessaloniki).

The present study aims to assess only the mussel industry risks that could possibly lead to financial or production losses due to HAB harvesting bans.

### **5.2.1.3 HAB Monitoring & Management**

Mediterranean mussel culture in Greece mainly (more than 90%) takes place within 7 gulfs (Thermaikos, Maliakos, Saronicos, Amvrakikos, Strymonikos, Kavala, Vistonikos), most of them (Figure 5.1) with rich freshwater inputs through river delta effluents and consequently a suitable high productivity environment (Theodorou et al., 2011a). The rest of the mussel farms are located at isolated and limited production capacity sites (i.e. Sagiada). Bivalve shellfish farming areas nationwide have been divided into production zones (from 1 up to more than 10 sampling areas/bands, as in the case of Thermaikos). A national biotoxin monitoring program has been operating since 1999 in order to promote seafood safety and protect the public from shellfish poisoning according to EU legislation (91/ 492/EEC; 853/2004/EC). On a weekly basis, stratified samples from seawater column are collected from each farm site located within a dedicated zone by the closest veterinary or fisheries authority responsible for sampling, following the recommended guidelines provided by EU Regulation 854/2004. Samples are preserved with Lugol's solution then directed within the same day for qualitative and quantitative identification of possible toxic microalgal species at the Laboratory of Marine Toxic Microalgae in the Biology Department of Aristotle University (Thessaloniki). Furthermore, between 1 to 4kg (depending on the season and the relevant condition index) of farmed live mussels from the same sampling sites/points are directed within a day to the National Reference Laboratory for Marine Biotoxins to investigate for possible biotoxin contamination. The biotoxin detection is carried out through the mouse bioassay test (Yasumoto et al., 1978) following the toxicity criteria (such as the death of two-thirds of the mice injected with

25g whole mussel flesh tissue extract after 24h) of EU Regulation 2074/2005 (2005). The whole process is in accordance with the EU legislation guidelines (EU Directive 86/609/EEC (1986); EU Recommendation 2007/526/EC (2007)) for the handling of the experimental animal welfare (Vlamiš et al., 2010; 2012; Vlamiš & Katikou, 2014).

#### **5.2.1.4 Mussel Harvesting Ban Management Options**

Results from both laboratories (toxic algal cell densities and mouse bioassay) are given within 3 days from the sampling day as feedback to the prefecture veterinary authorities responsible for the regulatory monitoring of the shellfish harvesting management.

The detected abundance of microalgal species characterises the weekly harvesting status of each mussel production zone. For instance, when *Dinophysis spp.* concentrations (the major threat in Greece, which could possibly produce lipophilic toxins) are below 199 cells/l, the area is free for shellfish harvesting; when it exceeds 200 cells/l, surveillance is required. Microalgal cell counts equal or higher than 1,000 cells/l lead directly to a harvesting prohibition. Microalgal abundance may also be cross-checked with the mouse bioassay, and the harvesting ban decision can be based on the results of each analysis independently or in combination. In order for the restriction to be lifted, at least three consecutive negative samples must be taken within at least 8 days.



Figure 5.1. Major mussel farming areas (usually Gulfs) in Greece: 1) Saronikos 2) Kavala 3) Amvrakikos, 4) Maliakos 5) Saronikos 6) Sagiada 7) Strimonikos 8) Vistonikos 9) Chalkidiki.

### 5.2.2 Methodology

A preliminary but essential step before beginning this effort was to identify whether HABs are perceived as a severe risk by the mussel farmers. For this purpose, personal interviews (n=48) (represented 68% of the total production) collected previously (Chapter 3) were carried out during farm visits in the main production areas and a questionnaire aimed at obtaining “fuzzy” (unreported and underdocumented) information on general production and marketing losses, including those due to HABs incidents, were distributed to all registered farms during the period October–December 2008 (see Chapter 3, Annex II: Risk Sources–no 13 & Open-ended Questions). As HABs were identified as the fourth most severe risk out of thirty-three potential risk sources (Theodorou et al., 2010a; Chapter 3) and the major risk recommended to be covered by the public/government support (Table 3.9), a second step followed, keeping in mind the suggestions of Hoagland

et al., (2002) that the duration of HAB effects must also be considered. For this purpose, the secondary model process of the working framework (Figure 2.2) is used. The critical questions to be answered at this stage are the duration of the HAB effects and the season that closures led to losses not encountered by the farmers under normal operation.

Detailed information and data regarding the effects of the HAB-related site closures on mussel farm management were obtained from open-ended questions during personal interviews of eight mussel farmers with more than 10 years of experience and located in different mussel farming areas in Greece.

The final step of the assignment of likelihood and consequence scores is carried out, following the risk management standard principles demonstrated in most cases in order to accommodate the effect of individual subjectivity (Fletcher et al., 2004; Carey et al., 2005). Fletcher et al. (2004) suggested that determining the levels of consequence and the likelihood of the examined risk should involve an assessment of the factors that may affect these criteria, but this should be done in the context of whatever existing control measures-management arrangements are already in place. For this purpose, a time series of HAB-related site closures in the past decade (2003-2008) was collected by the National Reference Laboratory of Marine Biotoxins, examined for their frequency and duration in Greece (Vlamiis et al., 2010; 2012), and then used as background information.

The calculation of a HAB-related risk in the context of the bivalve shellfish industry is done within a specific time frame such as the annual mussel production farming management plan and the life cycle (generation time) of the cultured species; i.e. *Mytilus galloprovincialis*. It provides a useful conceptual mind-map that assists in conveying the range and the types of pathways in a simple and transparent manner for qualitative assessments. The graphical description (Figure 1.5) of the annual production cycle of the Mediterranean mussel *Mytilus galloprovincialis* in relation to farming husbandry

practices in Greece is given by Theodorou & Tzovenis (2007) and Theodorou et al. (2011a). Risk assessment for HAB issues requires the determination of two factors each time – the potential consequence arising from the duration of the HABs closures (weeks), and the likelihood that this consequence will occur in a certain period of year (months). The combination of the level of consequence and the likelihood of this consequence is

Table 5.1. Qualitative evaluation of the impacts of HABs related harvesting bans imposed on mussel farms.

<b>Level</b>	<b>Weeks</b>	<b>Descriptor</b>	<b>Description</b>
0	0 to 1	<i>Negligible</i>	Insignificant impacts to the mussel farming - probably not measurable levels of impacts. The impact of the site closure is unlikely to be measurable against background variability
1	1 to 2	<i>Minor</i>	Measurable impacts. Possibly detectable but minimal impact on structure/function or dynamics of the mussel farming activity
2	2 to 3	<i>Moderate</i>	There are likely to be more widespread impacts on the mussel farming activity but the levels are still considered acceptable as there is recovery capacity. Levels of impact are at the maximum acceptable level
3	3 to 4	<i>Severe</i>	The level of impact on mussel farming may be larger than is sensible to ensure that the activity will be able to recover adequately, or it will cause strong downstream effects from loss of function. This level will result in wider and longer term impacts
4	4 to 6	<i>Major</i>	Very serious impacts now occurring with relatively long time frame probably needed, to restore to an acceptable level
5	6<	<i>Catastrophic</i>	Widespread and permanent/irreversible damage or loss will occur – unlikely to ever be fixed (e.g. causing extinctions)

used to produce an estimated level of risk associated with the site closures due to HABS (particular hazardous event/issue in question). A general consequence table has six ordinal levels of impact ranging from negligible (virtually no impact on a scale of 0) to catastrophic (irreversible on a scale of 5), with a moderate (on a scale of 2) defined as the highest acceptable level of consequence (Table5.1). The qualitative likelihood table (Table5.2) also has six ordinal levels ranging from remote (unknown, but not impossible on a scale of 1); to likely (expected to happen; with a scale of 6) (Fletcher, 2005).

Table 5.2. Qualitative measures of likelihood of the mussel harvesting bans due HABS closures based on the severity of the season.

<b><i>Level</i></b>	<b><i>Season</i></b>	<b><i>Descriptor</i></b>	<b><i>Description</i></b>
1	Nov-Dec	<i>Remote</i>	Never heard of damages, but not impossible
2	Jan-Feb	<i>Rare</i>	Losses may occur in exceptional circumstances
3	Sep-Oct	<i>Unlikely</i>	Uncommon, but losses have been known to occur elsewhere.
4	Mar-Apr	<i>Possible</i>	Evidence exists to suggest this will possibly cause losses.
5	May-June	<i>Occasional</i>	Damage may occur.
6	July-Aug	<i>Likely</i>	Expected to bring catastrophe-damage.

The likelihood estimation in the present study is given, according to Fletcher et al., (2004), on a gradual scale considering the likelihood of the ‘hazardous’ *event* (i.e. the consequence) actually occurring, *not* the likelihood of the activity occurring. In the present study, estimated likelihood is given on a gradual scale based on the



“sensitivities” of each bi-monthly period of the annual production cycle, as presented in Figure 1.5. The decision to use only six levels was a compromise between potentially increasing the precision of the outcomes against the increased confusion/complexity associated with the use of a greater number of levels (Fletcher, 2005). The overall risk level is calculated from the multiplication of the scores for consequence and likelihood (Risk = Consequence x Likelihood). Total scores vary from 0–30, which are divided into five risk categories: negligible, low, moderate, high, and extreme (Table 5.3). From this product, which is termed the *Risk Value*, each issue can be assigned a *Risk Ranking*, depending upon whether a risk value falls within one of the predetermined categories (Fletcher et al., 2005).

Table 5.3. Risk Ranking and likely management response to Harvesting Bans due to HABs.

<b><i>Risk Rankings</i></b>	<b><i>Risk Values</i></b>	<b><i>Likely Management Response</i></b>
<i>Negligible</i>	0	Nil
<i>Low</i>	1 to 6	No specific action needed to achieve acceptable performance
<i>Moderate</i>	7 to 12	Specific management needed to maintain acceptable performance
<i>High</i>	13-18	Possible increased management activities
<i>Extreme</i>	> 19	Additional management activities likely

Table 5.4. On-farm financial risk severity rating of the mussel harvesting bans due to HABs.

<b>Level</b>	<b>Descriptor</b>	<b>Description</b>
0	<i>Negligible</i>	Insignificant impact on the mussel farming – probably not measurable levels. The impact of the site closure is unlikely to be measurable against background variability
1	<i>Minor</i>	Measurable impacts. Possibly detectable but minimal impact on structure/function or dynamics of the mussel farming activity
2	<i>Moderate</i>	There are likely to be more widespread impacts on the mussel farming activity but the levels are still considered acceptable as there is recovery capacity. Levels of impact are at the maximum acceptable level
3	<i>Severe</i>	The level of impact on mussel farming may be larger than is sensible to ensure that the activity will be able to recover adequately, or it will cause strong downstream effects from loss of function. This level will result in wider and longer term impacts
4	<i>Major</i>	Very serious impacts now occurring with relatively long time-frame needed, to restore to an acceptable level
5	<i>Catastrophic</i>	Widespread and permanent/irreversible damage or loss will occur – unlikely to ever be fixed (e.g. causing extinctions)

The cut-off values between the risk rating levels and the management actions that flow from the different rankings are “*based on operational, technical, financial, legal, social, humanitarian or other criteria*” (Standards Australia and New Zealand, 2004).

It is logical that only issues of sufficient risk or priority (i.e. ‘moderate’, ‘high’ or ‘extreme’ risk) or those that require management actions to achieve a low risk score, require specific management actions (Fletcher et al., 2004). Financial risk characterization at the firm/farm

level is also demonstrated, semi-quantitatively in order to evaluate the relative impact of HAB-related site closures, or in order to determine which situations require management actions to achieve a low risk score or specific operating costs in comparison to a baseline – ideal situation – where no hazard exists.

The consequence severity rating of the mussel harvesting bans due to HABs is presented in Table 5.4, giving a range between negligible (0) insignificant impacts to catastrophic (5) results. In Table 5.5 the likelihood rating ranged between that of remote (0) or never heard of damages, and likely (5) if it is expected to bring catastrophes. Table 5.6 presents the operational risk ranking of the mussel farm harvesting bans due to HABs.

Table 5.5. Likely Severity Rating of the mussel harvesting bans due to HABs.

<b><i>Level</i></b>	<b><i>Descriptor</i></b>	<b><i>Description</i></b>
0	<i>Remote</i>	Never heard of damages, but not impossible
1	<i>Rare</i>	Losses may occur in exceptional circumstances
2	<i>Unlikely</i>	Uncommon, but has been known to occur losses elsewhere
3	<i>Possible</i>	Evidence exist to suggest this is possible to cause losses
4	<i>Occasional</i>	Damages may occur
5	<i>Likely</i>	Expected to bring catastrophes –damages

### 5.3 RESULTS

In this study we tried to evaluate the consequences of HAB-related mussel farming site closures, especially the losses suffered in different seasons. There are certain consequences as well as risk management strategies applicable at the farm level.

The annual production management cycle of the Mediterranean mussel *Mytilus galloprovincialis* farmed in Greece is graphically described in Figure 1.5 and used as a ‘mind map’ to identify pathways and variables as well as information requirements in order to assess the risks of site closures. The duration of HAB site closures has a gradually cumulative effect, expanding from 1 week (negligible) to more than 6 weeks (catastrophic), as shown in Table 5.1.

However, the site closures do not have the same effect during the year as the biological cycle and the operating management vary from month to month. Table 5.7 portrays the “sensitivity” of each season.

During the period of December–March, spat collectors are placed into the water (Theodorou et al., 2006; Fasoulas & Fantidou, 2008) and seed is collected when it is ready for harvesting (easily detached from the ropes manually) from the end of May until July. The seed is then used to fill up new pergolari (plastic cylindrical nets). During the period of August-October, the first batch of seed is graded again and placed into pergolari nets with a larger mesh size. In some cases, for example, if the pergolari are too heavy or the mussels de-clump easily and drop due to being overweight, a third grading is carried out from December up to March. Mussels longer than 6 cm are ready for the market usually from mid- to late-spring until early summer.

Table 5.6. On-farm operational risk rankings due to mussel farm harvesting bans.

<b>Risk Rankings</b>	<b>Risk Values</b>
<i>Negligible</i>	0
<i>Low</i>	1 to 6
<i>Moderate</i>	7 to 12
<i>High</i>	13-18
<i>Extreme</i>	> 19

Table 5.7. On-farm risk matrix for mussel harvesting bans due to HABs. Numbers indicate risk value as in Table 5.3. Shades indicate risk rankings (shade deeper with risk increase).

<i>Concequences</i>			<i>Negligible</i>	<i>Minor</i>	<i>Moderate</i>	<i>Severe</i>	<i>Major</i>	<i>Catastrophic</i>
			<i>0-1 wks</i>	<i>1-2 wks</i>	<i>2-3 wks</i>	<i>3-4 wks</i>	<i>4-6 wks</i>	<i>6&lt; wks</i>
<i>Likelihood</i>		<i>Levels</i>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<i>Remote</i>	<b>Nov-Dec</b>	<b>1</b>	0	1	2	3	4	5
<i>Rare</i>	<b>Jan-Feb</b>	<b>2</b>	0	2	4	6	8	10
<i>Unlikely</i>	<b>Sep-Oct</b>	<b>3</b>	0	3	6	9	12	15
<i>Possible</i>	<b>Mar-Apr</b>	<b>4</b>	0	4	8	12	16	20
<i>Occasional</i>	<b>May-Jun</b>	<b>5</b>	0	5	10	15	20	25
<i>Likely</i>	<b>July-Aug</b>	<b>6</b>	0	6	12	18	24	30

As the temperature rises, mussels gradually increase their condition index (flesh weight) and they become ready for the market. At the same time, adult mussels are spawning so spat collection for the new seed stock must take place (Theodorou & Tzovenis, 2007; Theodorou et al., 2010a,b).

Therefore, from late spring to late summer (July-August), restrictions of sales over 6 weeks might be catastrophic. There is a space limitation in the long-line farm during this

period and if harvesting delays are imposed due to HABs or any other reason, there is no room for the new seed stock.

The seed remaining in the collectors grows faster in high temperatures and eventually drops to the bottom if not harvested. Further losses are expected due to prices going down after the site reopens, as all the producers rush to sell their stock as soon as possible. Further losses occur if the mussels are not harvested when they should be, especially during the summer when heat waves and damage to the pergolari by the late July-August high winds lead to increased mortality.

Table 5.8. Risk register of risk ranking according to consequence levels on the operational cost of mussel farms due to HAB-related harvesting bans.

<i><b>Risk</b></i>	<i><b>Consequence (C)</b></i>	<i><b>Likelihood (L)</b></i>	<i><b>Risk Level</b></i>	<i><b>Description</b></i>
	Rating (0-5)	Rating (0-5)	(C x L)	
Price reduction	5	5	25	Extreme
Yield losses	4	5	20	Extreme
Seed losses	4	4	16	High
Extra energy	2	4	8	Moderate
Extra consumables	2	3	6	Low
Extra labour cost	3	5	15	High
Maintenance & service	3	4	12	Moderate

HAB-related site closures of a shorter period of time (3 to 4 weeks) during the same season (May-August) necessitate a special management plan, including harvesting/grading and packing of the product into plastic net bags, which are stored in the water as

stock, ready for the market when the toxic bloom disappears. This measure could be effectively extended to September-October if longer than 6 weeks is required. Such a management action could also be applied pre-emptively during the period of March-April for the early growing mussels if a site closure reaches 4 to 6 weeks.

Similar management actions but less intensive (smaller quantity) are required when site closures last between 2 to 3 weeks from May to August. However, longer periods of site closure (up to 4 weeks) in early spring (March-April), autumn (2 to 6 weeks in September–October) or winter (more than 4 weeks in January-February) may require the same management approach, mainly proactive or when absolutely needed.

Site closures of up to 2 weeks in any case are affordable year-round for the farmers (Table 5.7). Similarly, site closures of up to 4 weeks in January-February or for more than 6 weeks in November-December have no adverse effects since production activity is restricted to spat collections or grading of the stock during these periods.

Table 5.8 shows the financial impacts of the site closures at the farm level in the cases of the catastrophic risk rating (20-30). The semi-quantitative estimation of the major risk factors affecting the operational cost at the farm/firm level is based on the risk ranking of the financial operating risks of Table 5.6. In this case, the registered risk rankings from the mussel harvesting bans ranged between negligible (0) to extreme (>19) on a five-scale rating. Price reduction and mussel yield losses are the most severe threats to the profitability of a farm. Seed losses also affect profitability since seed represents the “livestock capital” of the firm and requires extra labour cost to manage the crisis. Energy consumption increases, equipment requires service and maintenance, and extra consumables are needed to manage the effects of the site closure. However, the cost of these extra expenses is moderate.

## 5.4 DISCUSSION

The risk assessment methodology is being used in the present study as a preliminary filtering process that separates the minor or acceptable risks of the mussel harvesting bans at certain days from the major or unacceptable risks occurring the rest of the year. It uses a semi-quantitative approach, where a descriptive qualitative scale is given in values, to describe the magnitude of the potential consequences of farming site closures due to HABs. This technique has several advantages according to Vose et al. (2001) as it can set the threshold for unacceptable risk after a careful and systematic comparison of probable risks generated by the seasonal duration of HABs incidents and the severity of their consequences. Risk characterisation and consequent risk evaluation carried out in the present study were thus based on extensive documentation and earlier justification studies (Theodorou et al., 2010a,b,c; 2011a,b; 2014a,b). A range of risk management policies could then be developed using these findings to efficiently address all possible outcomes (Vose et al., 2001).

The values assigned here to describe the consequences of a certain site closure due to HABs may not reflect with great accuracy the magnitude of the events but the causal description of why these values were assigned risk assessment scores is much more important than the actual values, according to Fletcher et al., (2004; 2005). Numbers can be reassessed with time and evolve to more accurate scoring but the important thing is to approach and deal with risks of high levels of complexity and uncertainty, such as HAB-generated mussel harvesting bans. This would enable management to understand the risk, not easily done with qualitative reasoning (Vose et al., 2001).

The proposed risk management actions on the farm level are based on the assumption that the farms are well equipped with a large boat (>15 m long) and a modern grading



“French type” machine with brushes, providing the holding capacity of 8-10 tonnes per day, depending on the quality of the raw material. Such a scheme is financial feasible and available only to the larger farms (>2 ha) (Theodorou et al., 2010c; 2014a). Smaller farms have to outsource for grading services to bigger producers, resulting in a delay and consequently extra loss. This management approach was introduced after the 1999 disaster resulting from extensive (6 months) site closures, the first time this phenomenon appeared, and was then added to the producers’ management agenda (Batzios et al., 2004). As a response, farmers turned to novel technology from France (French-type grading machines), capable of extending the period of stay of the mussels in water and adding some value to the final product before it is sent to the processors and distributors, thus balancing out some of the losses (Theodorou et al., 2010a,b; 2011a, 2012).

Theodorou et al., (2010c; 2014a,b), in an effort to analyse the financial risks of the mussel farming in Greece, demonstrated that a farm size smaller than 3 ha is not viable economically. Furthermore, seed loss due to the lack of space creates additional pressure on the financial efficiency of the following year. As a risk management measure, authorities could extraordinary license additional space to farms where they could place the extra-long lines needed to load the newly collected spat in fresh pergolari during the critical season. This way, mussel seed stock loss would decrease and farmers could re-allocate the seed after the crisis as there would be enough space available in the originally licenced boundaries of the farm. However, such a risk management action has to be accepted officially and be taken into account in future environmental spatial planning, and new alternative relocation sites need to be found; with neither option being yet considered by the administrators (Papoutsoglou, 2000; Theodorou et al., 2011a).

Despite several efforts to develop technologies for the partial protection of the bivalves from toxic algae (Pérez Agúndez et al., 2013; Soledad Fuentes & Wikfors, 2013; Taylor et

al., 2013), there are no widely applicable practical solutions to reduce the impact of a HAB (Shumway, 1990). An early warning system can certainly soften the impact (Kite-Powell, 2009; Moore et al., 2009; Shimada et al., 2012; Zhang et al., 2013), by hastening the marketing of the mussels when a potential bloom is detected. In the event of regular annual outbreaks, mussel growers can simply plan their market time around possible periods of closure.

Our results are in agreement with Rodrigues et al., (2011) who concluded that the economic losses in the Galician (Spain) mussel farming due to HAB-related harvesting bans depend on the period of time they occur and the intensity (duration) of the episode. Occurrences of short duration during the highest season could be dealt with a time shift in harvesting if possible, thus minimising the losses. In the case of Greece, summer is the most sensitive season for catastrophic losses providing the closure period exceeds 6 weeks.

An effort to evaluate the risk of HAB-related closures inevitably brings up the subject of insurance policies as a risk-sharing strategy. However, actuaries propose an insurance policy only in cases where the specific causes of a loss can be well-defined and the actual loss can be accurately measured. In aquaculture especially, the probability of loss and its statistical distribution should be calculable with reasonable confidence while the insured producer's management behaviour should be able to be monitored (Beach & Viator, 2008). Therefore, to realistically fulfil the requirements of actuaries and insurers, assessment of impacts should be based on the farm level in the context of its local ecosystem, taking into account the point of time the incident occurred (Hoagland et al., 2002). Losses should be able to be exactly calculated after optimal risk management has been applied for the specific hazard. For the mussel farming area of Chalastra, Northern Greece, Konstantinou et al. (2012) estimated that profit losses in scenarios corresponding

to harvesting bans from 45 to 165 days (6 to 22 weeks) year round ranged from 4% to 38%. However, these calculations did not reflect the importance of the period of the closure per event or the season in which such episodes occurred, and are problematic from an actuary's point of view.

Rodriguez et al. (2011) reported that it was not possible to calculate accurately the profit loss from a specific HAB-related harvesting ban in the mussel farming industry of Northern Spain, as part of the production was harvested before or after the site closure was imposed. They suggested that beyond the sanitary and technological measures applied to deal with HAB incidents, one should also take into account organisational measures incorporated in the farming management practice.

The findings from the present study on the Greek mussel industry showed that HAB-related risks due to farming site closures cannot be interpreted strictly by the presence or absence of an economic impact but also by the consideration that an effect is only produced under specific circumstances. In essence, harvesting bans lasting more than 6 weeks during the sales season in Greece could have catastrophic results. A proposed strategy to share the risk through insurance policies requires an accurate way to calculate losses based on a trusted record of HAB-related losses during certain periods within a specific ecosystem or wider bioregion. In this context, the present qualitative (semi-quantitative) method has to be supplemented with a quantitative risk assessment in order to precisely estimate the size of the economic risk (e.g. following the methodology by Kam & Leung (2008) that applies to monetary loss from the HAB-related farming site closures). Such a quantitative risk assessment would also serve as a basis for the development of a mechanism for extraordinary expanding of the affected farms' boundaries (e.g. 10 %) to alleviate fairly the threat imposed by space limitation.

## 5.5 CONCLUSION

Chapter 5 represents a secondary process of the AS/NZS ISO 31000 Risk Management Standard (Figure 2.2) that is also methodologically based on the same principles of the Standard. It meets the criteria for the risk management efficiency of the Standard as it provides: i) efficient semi-quantified answers to the question: “When is a HAB-harvesting ban a risk for mussel farming?”, retrieved by the primary process of the Chapter 3 (empirical study of the mussels farmers’ risk perceptions); ii) risk limits were clearly defined as it showed that HAB-harvesting bans are potential economic risks for the industry only when longer than 6 weeks during the harvesting season; iii & iv ) Chapter 5 focused only on the financial risks due to HABs, and for this reason it is proposed that managerial strategies that mitigate the risks at farm level is a possible public compensation as other “acts of God” could be proactively planned for; v) risk communication between stakeholders through responses in personal interviews during the planning and feasibility of the present effort and the public dissemination of the relative results (Theodorou et al., 2012).

# **CHAPTER 6**

CONCLUSIONS

&

PERSPECTIVES

Mussel farming, as an aquaculture activity based on the natural primary productivity, faces risks similar to those of the terrestrial agriculture sector. Consequently, much theoretical risk research has been applied to aquaculture as in agriculture, livestock, forestry, conservation management. Mussel farming, as a niche and vulnerable primary production sector, seems to be a high risk activity so it does not appear very promising for bank financing. Because of this fact, the 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 engage 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 back-up to compensate for losses, rendering the business vulnerable to operational risks. The lack of data losses and insurance policies in the Greek mussel farming direct to an alternative pathway to identify and analyze the risks of the sector needs to be found in order to develop and support an appropriate risk management scheme. An effort has been taken in the present study to cover this knowledge gap with a testing trial to use as a tool of a Risk Analysis Framework based on the principles of the Joint Australian and New Zealand Standard AS/NZS ISO 31000:2009 Risk management—Principles and guidelines (Standards Australia, 2009).

### **Framework outcomes**

The framework tool for Mediterranean mussel farming risk analysis consists of a primary process giving the generic points of the management process, the option definitions of a quantitative analysis of the risks and the management options, followed by an audit process.

The context of this effort has been established by Theodorou et al., (2011a) giving the profile of the industry (in Chapter 1) which is concentrated in northern Greece, covering 375.5 ha of sea surface and consisting of about 523 mussel farms (registered and unregistered), most of them less than 3 ha in size. The farming production capacity is approximately 100 t/ha. The total annual production (gross pergolari-socks weight) has increased to 36,000-40,000 tonnes, most of which is exported, at an annual value of over 10 million euros.

### **Primary process**

The primary process of the risk analysis was carried out by evaluating 33 identified risk sources proposed through a Likert-type questionnaire by the producers. Highly ranked sources of risk were ex-farm prices, disability and the health of the farmer and farmer's family, vessel availability, and harvesting bans due to HABs. The most preferred risk-management strategies were the development of financial and credit reserves, followed by off-farm employment (in agribusiness, commerce and other services providing an income certainty), producing the least possible costs, and the horizontal collaboration between farmers (i.e. by sharing equipment, supplies, labour, etc.). Moreover, mussel farmers prefer to take risks in areas that are familiar to them, such as production, and they try to avoid areas in which they have less knowledge and experience, such as finance. However, it seems that the risks are remediated with a high education level and experience, and dependent on the legal status of the company.

Most of them agree that a public policy must be established for compensating for disasters, mainly harvesting bans due to harmful algal blooms, predator attacks, extreme weather events, illegal actions and diseases.

The above results of the primary process of the risk assessment can be further boosted by a secondary process. The same methodological procedures were used to answer questions that come from risk communication of the primary results, such as a) which factors affect the profitability of the farms why ex-farm prices perceived as the major source of risk; and b) when the harvesting bans due to HABs lead to losses. The answers to these questions were re-input to the primary process (Figure 2.2).

*a. Risk factors affecting profitability*

In order to analyse the financial risks of mussel farming in Greece, the risk factors affecting profitability at the farm level were examined under the present market status following modern production practices. Theodorou et al. (2010b, 2014a) showed that mussel farms using the widely accepted long-line technique for less than 3 ha were not viable economically. Moreover, building new establishments and modernising the existing ones was affordable only if larger enterprise structures were adopted. Consequently, EU and/or public support (up to 45% of the total cost of the fixed assets) was critical for the development of the industry. The proposed risk-management process, taking into account that the majority of the Greek mussel farms are rather small (1-3 ha), concluded that in order to be financially sustainable, the sector needs to be restructured and organised into larger schemes, such as those of producers' organisations or cooperatives, in order to benefit from scale economics and attract better funding.

*b. Effects of mussel harvesting bans due to Habs*

A similar supporting process was followed to analyse the risks from the increasing number of HAB incidents during last decade. A semi-quantitative approach at the farm level was used, as demonstrated by Fletcher et al. (2004; 2005), where again the main principles of the methodology had their roots in the AS/NZ 4360 Risk Management Standard (1999; 2004). It was concluded that harvesting bans due to HABs were



catastrophic for mussel production only when the phenomenon occurred at the time the product was ready for the market (late spring to early autumn) and for site closures longer than 6 weeks. Harm resulted from yield losses, price reduction due to the market oversupply after harvesting restrictions lifted, and from imposed farm-space limits to deploy the new coming seed for the next season's production. Actions to mitigate the losses, such as differential handling of the marketable mussels and the expansion of the farm installations, were also suggested in the risk management strategies (Theodorou et al., 2012; 2015b).

### **Framework Evaluation & Perspectives**

The effectiveness of conceptual frameworks as a tool has been demonstrated by several researchers of different backgrounds (Baccarini, 1999; Mc Dermott et al., 2000; Chilonda & van Huylbroeck, 2001; De Vos et al., 2003; Fletcher et al., 2005; van Winsen et al., 2013; van Winsen 2014). This study was an attempt to define a conceptual working framework with which to assess and manage the major risks affecting Mediterranean mussel farming in Greece. The principles of the Joint Australian and New Zealand AS/NZS ISO 31000:2009 Risk Management Standard was useful as a framework - road map to approach the problem. The advantage of this model was the generic and flexible formulas that provides you with the opportunity to use part of its guided recommendations to meet your target. The criteria were set forth in order to evaluate the steps taken towards risk assessment's successful completion and were used as such to verify this approach in Chapter 2. The proposed framework was used as an interactive risk management tool of the sector rather than a risk report. It described the mission statement of this effort, how to approach it (methodologies), how to evaluate the results and provide adequate answers, and what to do in the case new questions come to surface during the process

(i.e. profitability, harvesting bans). The communication and consultation between stakeholders that carried out during the whole process of the risk analysis by the sharing of the outcomes through conference presentation and scientific publications, was a driver for continuous implementation and upgrade of the existing results.

In this effort the principles of the Joint Australian and New Zealand Risk Management Standard AS/NZS ISO 31000:2009 were adapted to the industry profile. Despite modern shellfish aquaculture being a relatively new activity in the primary sector, the mussel farming profile is more or less similar with land-based agribusiness. For this reason, the economic/risk behaviour of the mussel farmer was taken into account in the primary process of risk assessment (Cooper et al., 2005) by investigating risk perceptions and risk attitudes through structured questionnaires and interviews, all based on the principles suggested by Van Raaij's descriptive model (1981).

The risk model was developed using the best data on mussel farming in Greece (Theodorou et al., 2011a) available at the time. During the work process, information gaps were identified as well as discrepancies between different data sets as various measuring systems were used, constituting a major difficulty in the effort to produce unbiased and reliable statistics. As data quality is an important component of risk assessment (Bartholomew et al., 2005), the precision and sensitivity of the methods used to collect data were checked, allowing the estimation, and consequently, the elimination of the uncertainties in the process. The problem stems from the inefficient systems commonly used to collect fisheries statistics in the European Union (EU) (Protopappas & Theodorou, 1995; Theodorou, 1995; Hough et al., 2000; Kalaitzi et al., 2007; The Economist, 2008; Tsikliras et al., 2013; Moutopoulos & Koutsikopoulos, 2014). Production data, including import and exports values, were collected from the Greek National Statistic Service (NSS) and FAO, and cross-checked with data from structured

questionnaires and guided interviews with industry stakeholders such as mussel farmers, cooperative members, mussel processors and administrators. At this stage during the communication process, special attention was given to a clear understanding of the classification and terminology of risk assessment by the stakeholders (MacDiarmid & Pharo, 2003). For this purpose, preliminary in-depth interviews with several experienced industry and academic experts were carried out in order to draft a tailor-made risk assessment questionnaire with specification needs that could be easily understood by the respondents. In addition, a lot of emphasis was given to the extensive pre-testing of the questionnaire before commencing the survey, targeting the elimination of any misunderstandings during communication (Theodorou et al., 2010a). As the actual study progressed and answers were given to the questions, the quality of the risk assessment improved and, as a result of improved analysis, the conclusions were supported and modified (as in Bartholomew et al., 2005).

Principal Component Analysis (PCA) was used successfully in several other trials (Meuwissen et al., 1999; Le Grel & Le Bihan, 2009; Le Bihan et al., 2010; Theodorou et al., 2010a; Ahsan & Roth 2010; Le & Cheong, 2010; Ahsan, 2011) to identify risks and rank their severity according to the risk perceptions and attitudes of the farmers. It was also a suitable technique to sum up risk-management priorities despite the sample size in these studies being relatively small. The examined industries were structured with small numbers-members of companies (Ahsan & Roth, 2010; Le Bihan et al., 2013), compared to the usual application of the techniques in larger groups; e.g. consumer marketing research (Malhotra, 2004).

The socioeconomic profile and the structure of the farm play a critical role in determining how farmers perceive and manage risk. Mussel farmers seem to take risks in sectors familiar to them, such as in production and marketing rather than on financial issues

where they have less experience. A consequence of this preservative economic behaviour, is that mussel farming sector during the present economic crisis period, is less exposed to financial debt than the rest of aquaculture in Greece (Theodorou et al., 2014b).

As the primary process was carried out by a continuous monitoring and review, several new research questions came up, the answers to which were necessary to boost the analysis of the primary process. New areas where more knowledge was needed were identified, and the relevant gaps had to be filled in order to eliminate and control the risks.

For this purpose, a secondary supporting process was carried out based on the same general principles of the Joint Australian and New Zealand Risk Management Standard AS/NZS ISO 31000:2009, but the analytical tools were adapted to effectively answer the questions. The selection of analytical techniques was based on data availability and the best-suited system process. The principles of basic economic theory were used to analyse the risk factors affecting the profitability of the mussel farms, and it was concluded that the small scale of the activity in Greece affects the financial profitability of mussel farming. Furthermore, as farm size is dictated by the licensing system, the related public policy acts as an institutional risk. These findings were in accordance with Ashan & Roth (2010), who, from an empirical point of view, showed that larger mussel production and larger farms improve economic sustainability and decrease the risk of loss. In addition, they suggested that this implies a public administration failure to supply licences of a suitable size, in agreement with economic rationale, due to several reasons not fully understood scientifically.

Furthermore, assessment of the HAB-inflicted mussel harvesting bans as a cause of loss for the producers was carried out as a secondary supporting process using a semi-quantitative risk approach based on the same principles of the Joint AS/NZS ISO

31000:2009 standard. The synthesis of both primary (overall analysis and models) and secondary supporting processes (detailed analyses and models) gave an ample overview and finalised the risk analysis of the mussel farming sector in Greece.

This working framework is very important as a mind-map for a continuous update in the future, as risk assessment and management is not a static process and potential new risks may have to be taken into account. As it was based on generic principles, with its platform modified and specially adapted to the current risk analysis needs of the Mediterranean mussel farming industry, it could easily be updated to give answers and competent risk-management solutions in the future.

The working framework developed for the Greek mussel farming sector complies with the 11 effectiveness principles of the Joint AS/NZS ISO 31000 Standard as:

1. It creates value with the identification and evaluation of the major risk sources of the Greek mussel industry and concludes with risk management strategies and insurance policies that eliminate losses;
2. Its multi-layer approach makes it an integral part of the organisational sector process;
3. It was developed as an interactive tool for the industry decision making;
4. It can detect the uncertainties that lead to losses; i.e. profitability and harvesting bans due to HABs;
5. It was structured following the basic principles of the standard, giving a systematic function to the risk management of the mussel farming sector (Chapter 2);
6. It used the best available information (Chapter 1), with cross-checking of various sources in combination (Chapter 2) with mussel farmers' questionnaire survey (Chapter 3);
7. The framework was tailor-made for use in Mediterranean mussel aquaculture, incorporating different methodological methods to answer each individual research

question separately (Chapter 3, 4 & 5), concluding at the end on a synthesis of the required risk management priorities (Chapter 6);

8. It takes into account all the socioeconomic factors, including the risk perceptions and risk attitudes of the Greek mussel farmers;

9. The transparency of the process was secured by the publishing of the research outcomes (Theodorou et al., 2010 a, b; 2011; 2012; 2014a,b);

10. It is a dynamic system that could be repeatedly used with new data inputs (i.e. by adding new risks, and partial or in-depth analysis of the existing ones by a secondary supplementary process);

11. It can be used for a continuous improvement of the industry by providing policies for effective risk management especially under the recent financial Greek crisis environment. The proposed conceptual framework for the risk assessment of the Greek bivalve aquaculture also meets the main characteristics for advanced risk management (Purdy, 2010), following the annex of AS/NZS ISO 31000; that is:

i) It sets up accountable values (measurements) and industry performance goals for each level of the activity such as on the primary (Chapter 3) and secondary (Chapters 4 & 5) models, giving the opportunity for a continuous upgrade and improvement on each level of decision making (Theodorou et al., 2012; 2014) .

ii) It is comprehensive, and the risks are clearly defined and measured at each level of the process (Chapters 3, 4 & 5), giving accountable ranges of acceptability and treatment (Theodorou et al., 2010a,b;2012).

iii) Management strategies for risk mitigation are involved in all levels of the multi-layer decision making within the industry structure (Theodorou et al., 2011; 2014a,b).

iv) It is focused on the continuous boosting of the risk-management process of mussel farming in Greece, giving emphasis on its development as a major risk-

management tool for the industry stakeholders and the policy makers. This is given as a secondary process in Chapter 4 & 5 in order to provide answers on the new questions about the profitability and HABs losses that came up to the surface in Chapter 3 .

v) In practice, all the above-mentioned characteristics were achieved through able and continuous communication between internal (producers, fisheries administrators, etc) and external (scientists, legislators, actuaries, consumers, etc.) stakeholders as demonstrated in Chapter 2 and analytical presented in Annex I of this effort.

### **Aqua/Agri-culture Risk Analysis Perspectives**

Given that the working methodology to identify mussel farmers risk perceptions and risk management in Chapter 3 benchmarked from agriculture (Meuwissen et al., 2001) a comparative evaluation of the present outcomes with the rather extensive agriculture risk literature contribute to the understanding better the farmers risk behaviour.

The way that mussel producers responds to the risks, seems to be independent from the perception of the risk priorities that previously identified by themselves. This was common also in agricultural studies as the risk perceptions are not significant related to the intended risk behaviour as both investigated risk sources, attitude and managements strategies are generic, rather than explicit (Meuwissen et al., 2001; van Winsen et al. 2014). Furthermore, the absence of the direct links of the risk sources with the relative management strategies amplify this gap. In addition, the operationalisation of perceived risk when it occurs is disputed as humans have difficulties to think in probabilities following recent findings of the cognitive neuro-science (van Winsen, 2014).

The overall stance regarding the risk attitude of the Greek mussel farmers was over average coinciding with their eagerness to take more risks than the others in the same business (Theodorou et al., 2010a). In agri-farming, the overall risk attitude is wide

diverse and can be varied in different areas with different production domains (Boggess et al., 1985; Bard & Barry, 2000; Hansson & Lagerkvist, 2012). This is not a surprise for the complex personal nature of risk perception and the preference of risk management strategies, as the risk attitude is an individual socio-psychological expression rather than a typological characteristic of each activity (Wilson et al., 1993; Wauters et al., 2014).

However, Greek mussels farmers as well as the agrifarmers in Flanders (Wauters et al., 2014) and livestock producers in the Netherlands (Meuwissen et al., 2001) preferred to take risks on farm internal management activities that are familiar with rather than areas that have less knowledge and experience.

As the primary sector (land and aquatic) is very diverse, studies in both domains test each one separate sector independently in order to identify the most preferred risk management strategies. For instance, Greek mussel producers and the Belgian agrifarmers have similar preferences to the financial credit reserves as the best option for a successful risk management strategy, while the Dutch dairy farmers preferred “income certainty” rather than the “diversification” proposed by pig producers in the Netherlands (Meuwissen et al., 2001). However, van Winsen (2014) recently demonstrated that more than the industry specifications and farm features, the socio-psychological characteristics of the producers seem to have equal or even more crucial impact on the complex choice of risk management policies. This is also in accordance with the earlier observations of Meuwissen et al. (1999) showing that as more detailed and specific farmers features variables used as more critical are their role on the risk management decision making in livestock production.

Both producers such as the agrifarmers in Flanders (Wauters et al., 2014; van Winsen, 2014) the livestock producers in the Netherlands (Meuwissen et al., 2001) and the mussel farmers in Greece showed limited acceptance of price contracts and other



business insurance schemes. This may indicate that these products may be not cover by an efficient way the demands of the producers. In the other hand as these new tools comes from an area that producers are not familiar (financial), may be additional effort is needed to communicate of these opportunities that has to be tailored-made to the farmers needs in order to surpass trust difficulties (Meuwissen et al., 2001).

Flanders agrifarmers pay attention on the long term production cost and prices rather than in short term price volatilities that could be covered by futures or price contracts but are inefficient to meet the demand to cover long term price fluctuations. Similar the Greek mussel farmers preferences (third most important strategy) focused on how to produce at the lowest possible cost, in order to cope the constantly stable and long term marginal prices of the mussels.

Based on these outcomes, it seems to be a challenge even for the Greek mussel farming, the proposal of Wauters et al., (2014) to the agricultural policy makers, for the design of diversified policy measures in order to assist producers in managing on-farms risks. Given the priority on the internal risk management especially of the debt and the liquidity balance at farm level, it is proposed specific policy measures targeted on the credit risk reduction such as the provision of short term loans to overcome short term cash flow deficits or investment support instruments.

### **Farmers Perspectives**

The outcomes of the sensitivity analysis in Chapter 4 indicated that modern vessels (bigger than 15 m long) equipped with “French type” grading machines is profitable investment only if the production exceeds the 300 t. As most of the mussel farms in Greece are far below this production capacity, in order to be profitable may be have to collaborate between them by sharing equipments and also work with larger crews (4-7)

workers per vessel. Increasing the number of workers per trip increase the return per labor unit effort and minimize the operating cost of each trip.

It is proposed to consider a “cluster management” of small scale mussel farmers enabling the producers to work together and, improve production, develop sufficient economies of scale and knowledge to participate in modern chains, increase their ability to join certification schemes, improve their reliability of production and reduce risks.

### **Industry Perspectives**

The results from risk perception exploratory study of the Greek mussel farmers show that the ex-farm price of the mussels was perceived to be the major source of risk. We examine the price fluctuation during the last two decades and it is concluded that prices are relatively stable despite the increases of the production cost. So, the problem is the profitability rather than the price itself and, as an extensive system, it is related with the farming space availability. In contrast with the rather flexible land-based farming policies in Europe, the size of the marine aquaculture farms is dictated by national licensing systems and the lack of suitable space availability (eutrophic sea areas suitable for bivalve culture). As the farm size is related with the licensing system, it is demonstrated that this could be indirectly a major risk factor for the financial sustainability of the sector. In our case it is clear that for the majority of the Greek mussel farms that are less than 3ha each, there is a problem of survival, and act as an institutional risk directly related with restrictions of space due to the state licensing system that lacks any reasonable flexibility. The findings from this study also indicate the importance of EU governmental support for the viability and sustainability of the sector. The initial investment was a high risk opportunity as the variability of the production due to the

extensive nature of the business increased the financial risk and consequently there was a limited interest from the banking sector to support this type of operations.

The future of the industry, therefore, and the organization of the producers on larger schemes, hinges on the industrialization of the production methods and the scaling-up of production units in order to reduce average production costs and enhance the marketability of the product.

Risks such as the harvesting bans due to HABs closures have not always resulted in economic losses. A semi-quantitative risk assessment, based on the principles of the Joint Australian and New Zealand Risk Management Standard AS/NZS ISO 31000:2009 Standard, was carried out and showed that the economic losses are dependent on the season and the duration of the episodes. In our case in Greece, summer is the most sensitive risk season for catastrophic losses if the closure period is more than 6 weeks. However, this effort to evaluate the restrictions due to the risk of HABs closures could be taken up in insurance policies. Key issues for this risk sharing strategy, include covering only measurable losses from specific well defined causes of loss where the probability of loss and the distribution of losses can be calculated with some confidence and producer management behaviour can be monitored (Beach & Viator, 2008). To realistically assess the HABs closure impacts as stated above, the assessments must be completed on the farm level in the relevant local ecosystems within the local bioregion. However, the present qualitative (semi-quantitative) method has to be completed by a quantitative risk assessment in order to estimate the size of the economic risk (Kam & Leung, 2008) that implies monetary loss from the HABs closures.

Greek mussel farmers opted for financial reserves as best risk management strategy with farming excellence as second. Although previous work demonstrates the necessity for collaboration between producers to achieve the benefits of scale, Greek producers lack

this tradition and do not trust these practises. Greek producers do not consider the tackling of persisting bureaucracy problems as a risk management strategy, as they perceive it as a common daily action. Diversification (into other species) seems to be the last priority for Greek mussel farmers, as their traditional stance does not allow for easy adoption of new products let alone needs for new markets. Price contracts were not perceived also as important risk-management tools to mitigate marketing risks by the mussel farmers. Finally, limited preference for insurance products was expressed by the producers because it is usually expected that such “risky” products will receive state support or compensation during a disaster period as practiced in agri-farming.

It is concluded that the risk management priorities of the Greek mussel producers is based on their local experience (e.g. low prices). The risk sharing strategies were focused on the self-protective mechanisms such as capital reserves and farming optimisation. Other tools such as price contracts or insurance policies were considered too complicated and beyond their routine for most of them. Further research on improving the risk management tools would guarantee the recovery from possible future disasters.

As the present study shows the pre-financial crisis condition of the industry, it is interesting to investigate the mussel farmers risk perceptions and risk management strategies adaptations to the new business environment.

### **Policy Perspectives**

State policy should focus on more license issuing to help industry sustainability. Furthermore public services should collect accurate data on production and losses. State or private insurance underwriters should be encouraged to develop policies based on such accurate data bases. The present risk analysis demonstrates that mussel farm size (extensive system totally depended on local natural productivity) affects directly the

mussel production outcomes and consequently the industry function. As this has a direct effect on the wealth of the local society, the social factor can create relevant policies focused on the local sustainability and profitability. The research outcomes further partly explain what is needed to make mussel farming, in this case, and European Maritime Governance viable in Europe, despite the completely different local governance management adoptions of common EU policies (Jouanneau & Raakjær, 2014; Kraan et al., 2014). European and National Rules and Directives seem to be applied locally by a “modification” of the rules. It refers to the lack of control of their application (due to negligence or inadequacy or corruption) that after a while become the norm with people seemingly forgetting the original rule. In the case of the Greek mussel farming the application of rules created by the centralized authorities (EU, Greek State) such as for spatial planning, legitimate technology etc. it is locally applied with different criteria, sometimes illegal, driven by ignorance or deliberate negligence, but the production is going on... this is a competitive evolutionary advantage for the future as, when things are normalized then piracy becomes status. Piracy refers to the surging counteraction of the local stakeholders to rules imposed by the centralised authorities leading to a diversified behaviour that governs local business. This is not only Greek or mussel industry practice. As Jouanneau & Raakjær (2014) recently demonstrated, it is common in Mediterranean Sea governance and the structural difference between the common rules application in the countries of the Baltic Sea. As the institutional framework promotes and accepts “piracy”, then this scheme will emerge finally, following North (1993). This explain why this study meets the Ostroms theory (2011) for a multi-tiered governance as a socio ecological system approach and explains the legalization of the piracy (North 1993) (in Chapter 3). Even if mussel farm sizes are not viable (most of them <3ha) still are working with success even under economic crisis situation, as they are out of the mainstream legal culture. As a

consequence, it amplifies the farmers' opinion about the EU rules that they seem to them to be “destructive”.

### **Research Perspectives**

The outcomes of the present multi-lever risk analysis of the Greek mussel farming industry, seem to be suitable inputs to the multi-tiered diagnostic framework approach proposed by Ostrom (Ostrom et al., 2007; Ostrom 2007; 2009; 2010; 2011; Ostrom & Cox, 2010), and further developed by McGinnis (McGinnis, 2011a,b; McGinnis & Ostrom, 2014) for defining the role of the polycentric governance of complex economic systems. The mussel farming in this case, is a “simple” model (capture based coastal aquaculture generating a socio-ecologically driven local community mentality/culture) and a “perfect” socio-ecological system (mussel farming is an activity that exploits natural resources belonging to the local society and returns a lot of its revenues to it...) to verify her theory. In addition, it was demonstrated in practice, the advantage of a multi-method approach for risk-related research objectives, the way recommended and supported by Ostrom's work on complicated socio-economic systems.

This approach could be considered as a step, may be at the right time, to link the recently acquired aquaculture multi-level knowledge (from genetics to highly sophisticated mass production technology) and socio-ecological transitions experience (social process of aquaculture innovations; Bush & Marschke (2014)) with theoretical biology (of the “aquatic farmed species”) and evolutionary economics.

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# **SUMMARY**

## Summary

Modern Mediterranean mussel (*Mytilus galloprovincialis*) aquaculture developed considerably during the last 35 years passing from early pilot stages to maturation at the beginning of the new century. The production and marketing trends of the Mediterranean mussel farming in Greece are presented in **Chapter 1**. This aquaculture activity is based on the natural primary productivity and thus faces risks similar to those of the agriculture sector. Consequently, much theoretical risk research has been applied to aquaculture as in agriculture, livestock, forestry, conservation and its management. Nevertheless, limited studies have so far focused on risk perception strategies of the aquaculture sector.

Nonetheless, however successful the industry may have been in research and development issues, little or no attention has been paid yet to the risk assessment and moreover to the risk management of the activity. The structure of the present study, in order to fill up this “knowledge gap”, is given as a general introductory chapter, the **Chapter 2** dealing with the exploratory research on risks and their management options associated with the mussel farming business. In this context, the **Chapter 2** aims at developing a conceptual framework for the marine shellfish aquaculture industry of Greece to be used as a tool by the sector’s decision makers. The work is based on the Joint Australian and New Zealand Risk Management Standard AS/NZS ISO 31000:2009. As this is a generic risk management standard tool it has been successfully adapted to the specific national characteristics of all levels of the business activities and the industrial function of the sector under study.

The working steps have been to (1) establish the context; (2) identify the risks; (3) analyse the risks; (4) evaluate the risks; (5) treat the risks; (6) monitor and review the whole process; and (7) communicate and consult the outcomes.

The framework input included data sets regarding development, production, profits and losses, retrieved by surveys through distributed questionnaires or interviews during site-visits, as well as by collecting data from national and international authorities. Data input covered technology, farm size, farmer risk-attitude, risk-management strategies, risk-perceptions and socioeconomic profiles. Major risks and risk management options were identified and ranked by principal component analysis.

In **Chapter 3** a study was conducted in the context of Mediterranean mussel farming risk assessment in order to explore the farmers' perceptions of risk and risk management, to examine relationships between farm and farmer characteristics, and highlight the prevailing risk perceptions and strategies. The data were collected through a sampling survey of the Greek mussel farmers based on personal questionnaires and interviews. Results in **Chapter 3** show that the ex-farm price of the mussels were perceived to be the major source of risk while the financial/credit reserves were the most preferred risk management strategy. Farmers seem to resort to such practices as the activity is characterized by negligible banking support, due to the production unpredictability and the marginal profitability. Finally, the farmers' attitudes and comments on loss compensations bring up the need to develop a more effective and versatile insurance system.

The profitability of the Mediterranean mussel farming depends on a combination of factors including natural productivity, technical practices, production costs and product pricing. In an effort to analyse the financial risks of the mussel farming in Greece (**Chapter 4**), we examined the profitability of the different farm sizes (1 to 6 ha) under the present situation of the local market and the modern production practices. Assuming that the farms use the widely accepted long-line technique, it was demonstrated that small farm sizes, of less than 3 ha, are not viable economically. Moreover, the cost of new

installations and the modernization of the existing ones is affordable only if larger enterprising structures are adopted. Consequently, the past EU and/or public support (up to 45% of the total cost of the fixed assets) has been critical for the development of the industry. Taking in account that the majority of the Greek mussel farms are rather small (1-3 ha), we concluded that for financial sustainability the sector needs to be restructured and be organised in larger schemes, such as those of producer organisations or co-operatives, in order to benefit from scale economics and attract better funding.

The severity and consequences of site closures to shellfish commercial harvesting, a protection measure for public health against toxicity inflicted by harmful algal blooms, has been estimated for the Mediterranean mussel farming in Greece in **Chapter 5**. Estimations were carried out in a semi-quantitative manner at the farm level. Results showed that financial losses depended on the season and the duration of the harvest ban. Since the product becomes marketable from late spring to early autumn, site-closures longer than 6 weeks within that period could be catastrophic for a farm. Consequences include yield losses due to extended stocking of ready to harvest mussels in the farm and ex-farm price reduction due to oversupply after the harvest ban. Moreover, mussel seed collection and placement within the farm is delayed due to lack of space as the bulk of mussels remain un-harvested putting in danger next season's production. Proposed strategies to minimise losses consisting of differential handling of the marketable mussels and of spatial extension of farm facilities due to harvest bans caused by HABs are discussed.

The conclusions of this study are presented in **Chapter 6**. For the time being, no insurance policy exists for this sector. Recently (2012) limited compensation was available through the European Fisheries Fund only in cases of mussel harvesting losses to ensure human health protection. The situation seems to be further improve as the

article 57 of the EU Regulation 508/2014 through the European Maritime & Fisheries Fund takes into account the insurance compensation of the animal stock losses due to natural disasters, weather impacts, water quality problems and diseases. The present exploratory attempt was carried out in order to delineate the major indicative 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.

Finally, the multi-level risk analysis of the mussel aquaculture in the present study could be used as a case model to verify the multi-tiered diagnostic approach to explore the polycentric governance of complex economic systems proposed and fully supported by Ostrom's (Nobel Prize winner in Economics, 2009) work.



# **SAMENVATTING**

## Samenvatting

De hedendaagse productie van de mediterrane mossel (*Mytilus galloprovincialis*) is de afgelopen 35 jaar aanzienlijk geëvolueerd van een vroeg pilootstadium tot een mature sector bij het begin van de 21<sup>ste</sup> eeuw. De trends in productie en marketing van de mediterrane mosselkweek in Griekenland worden voorgesteld in **Hoofdstuk 1**. Deze aquacultuuractiviteit is gebaseerd op natuurlijke primaire productie en is dus onderhevig aan dezelfde risico's als de landbouwsector. Bijgevolg is reeds veel theoretisch risico-onderzoek gedaan in de aquacultuursector, zoals in de landbouw, veeteelt, bosbeheer, en natuurbehoud. Desalniettemin hebben slechts weinig studies dermate gefocust op risicoperceptiestrategieën in de aquacultuursector.

Ondanks het succes van de industrie wat onderzoek en ontwikkeling betreft, is er geen tot weinig aandacht besteed aan risicoanalyse en meerbepaald aan het risicobeheer van de ondernemingen. De structuur van dit onderzoek, wat als doel heeft deze kennislacune te dichten, wordt weergegeven in **Hoofdstuk 2**. Het behandelt een verkennend onderzoek over risico's en hun potentieel beheer in de mosselkweekindustrie.

In deze context schept **Hoofdstuk 2** een conceptueel kader voor de mariene schelpdierproducerende industrie in Griekenland dat gebruikt kan worden door beleidsmakers uit de sector. De studie is gebaseerd op de 'Joint Australian and New-Zealand Risk Management Standard AS / NZS ISO 31000: 2009'. Aangezien dit een algemene standaard is voor risicobeheer is hij reeds succesvol aangepast aan de specifieke nationale eigenschappen op alle niveau's van de ondernemingsactiviteiten en het industrieel functioneren van de hier bestudeerde sector.

De verschillende stappen in dit onderzoek waren (1) de context scheppen; (2) de risico's identificeren; (3) de risico's analyseren; (4) de risico's evalueren; (5) de risico's



aanpakken; (6) het hele proces bijhouden en herzien; en (7) het communiceren en consulteren van de resultaten.

De input bestaat uit datasets aangaande ontwikkeling, productie, winst en verlies, bekomen door rondgestuurde enquêtes of afgenomen interviews bij bedrijfsbezoeken. Andere data zijn verkregen van nationale en internationale autoriteiten. Data input had betrekking op technische aspecten, omvang van het bedrijf, risicoattitude van de kweker, risicobeheerstrategieën, risicoperceptie en socio-economische profielen. De voornaamste risico's en opties voor risicobeheer werden geïdentificeerd en gerangschikt volgens de hoofdcomponentanalyse.

**Hoofdstuk 3** bestudeert de risicoanalyse van de mediterrane mosselkweek om de kwekers' perceptie over risico's en risicobeheer te achterhalen. Zodoende worden relaties tussen het bedrijf en de bedrijfskenmerken onderzocht, en worden de huidige risicopercepties en strategieën in de verf gezet. De gegevens werden verzameld door een steekproef bij Griekse mosselkwekers gebaseerd op een persoonlijke enquête en interviews. De resultaten in **Hoofdstuk 3** tonen aan dat de ex-farmprijs van de mosselen als de grootste risicobron wordt aanzien, terwijl financiële en kredietreserves als managementstrategie de voorkeur genieten. Mosselkwekers lijken daartoe hun toevlucht te nemen wanneer hun banksteun onderhandelingsmarge heeft, door onvoorspelbaarheid van productie en marginale rentabiliteit. Tenslotte noodzaken het gedrag van de kwekers en hun commentaren op verliescompensatie het ontwikkelen van een doeltreffend en veelzijdig verzekeringssysteem.

De rentabiliteit van de mediterrane mosselkweek hangt af van een combinatie van factoren zoals natuurlijke productie, technische aspecten, productiekost en productprijs. In een poging de financiële risico's van de mosselkweek in Griekenland te analyseren,

onderzoeken we in **Hoofdstuk 4** de winstgevendheid van kwekerijen van verschillende oppervlaktes (1 tot 6 ha) bij de huidige lokale marktsituatie en de hedendaagse productietechnieken. In de veronderstelling dat de kwekerijen gebruik maken van de longlinetechniek, wordt aangetoond dat kleine bedrijven (minder dan 3 ha) niet economisch rendabel zijn. Daarnaast is de kost van nieuwe installaties of het moderniseren van bestaande enkel haalbaar in grotere ondernemingen. Bijgevolg is de EU- of publieke steun (tot 45% van de totale kost van vaste activa) steeds noodzakelijk geweest voor de ontwikkeling van de industrie. Rekening houdend met het feit dat het merendeel van de Griekse mosselkwekerijen kleine bedrijven zijn (1 tot 3 ha), concluderen we dat de sector moet geherstructureerd worden om financiële duurzaamheid te bereiken. Ook moet de sector georganiseerd worden in ruimere structuren, zoals productie-organisaties of coöperatieven om te kunnen genieten van schaalvoordeel en om betere financiering aan te trekken.

De ernst en de gevolgen van het afsluiten van commerciële oogstgronden, een beschermingsmaatregel voor de volksgezondheid tegen toxische algenbloei, worden geraamd voor de mediterrane mosselkweek in Griekenland in **Hoofdstuk 5**. De schattingen werden uitgevoerd op een semi-kwantitatieve wijze op bedrijfsniveau. De resultaten tonen aan dat de financiële verliezen afhankelijk zijn van het seizoen en de duur van het oogstverbod. Aangezien mosselen verhandelbaar zijn van de late lente tot de vroege herfst, kunnen sluitingen die langer dan 6 weken duren binnen die periode katastrofaal zijn voor een mosselkwekerij. De gevolgen zijn opbrengstverliezen als gevolg van verlengde stockage van oogstklare mosselen in de boerderij en ex-farmprijsverlaging na het oogstverbod door overaanbod op de markt. Bovendien worden mosselzaadinzameling en zaaien vertraagd door gebrek aan ruimte wanneer een groot deel van de mosselen ongeogst blijft. Dit brengt de productie van het volgend seizoen in

gevaar. Er volgt een discussie over voorgestelde strategieën ter minimalisatie van de verliezen door gedifferentieerde behandeling van de marktklare mosselen en door uitstel van bedrijfsactiviteiten door de toxische algenbloeien.

In **Hoofdstuk 6** worden de conclusies van dit onderzoek gepresenteerd. Vooralsnog bestaat er geen verzekeringsbeleid voor deze sector. Recent (2012) werd een beperkte vergoeding mogelijk via het Europees Visserijfonds, enkel in gevallen van mosseloogstverliezen om de volksgezondheid te verzekeren. De situatie blijkt verder te verbeteren wanneer het artikel 57 van de EU-verordening 508/2014 door het Europees Fonds voor Maritieme & Visserij de verliezen als gevolg van natuurrampen, weersinvloeden, waterkwaliteit en ziekten gaat verzekeren. Het huidige verkennend onderzoek werd uitgevoerd om de belangrijkste indicatieve aspecten die nodig zijn voor particuliere bedrijven, banken of de overheid uit te stippelen. Dit is nodig om een werkbaar plan te formuleren voor risicobeheer van de sector. Ondertussen kunnen gespecialiseerde programma's, die opleiding aanbieden in arbeid en milieuveiligheidsprocedures, het risicobeheer van de bedrijven verbeteren en dus verliezen verminderen.

Tot slot kan de multi-level risicoanalyse van de mosselkweek uit deze studie gebruikt worden als casusmodel om de meerlagige diagnostische aanpak te verifiëren. Zo kan een voorgesteld polycentrisch beheer van complexe economische systemen onderzocht worden dat volledig wordt ondersteund door het werk van Prof. E. Ostrom (Nobelprijswinnaar voor Economie, 2009).



# **CURRICULUM VITAE**

**Ioannis (John) Theodorou** was born in Athens, Greece in 1966. He has a B.Sc. in Biology from School of Natural Sciences, University of Patras, Greece (1989) and an MSc. in Shellfish Biology and Culture, School of Ocean Sciences, Menai Bridge, University College of North Wales at Bangor, University of Wales, U.K. (1990). He has also specialised in Fisheries Product Quality Management & Marketing (Certificate), Hull International Fisheries Institute (HIFI) Hull University, UK, (1995).

He has 25 years of industrial experience in Mediterranean Marine Aquaculture (seabass/seabream and mussel farming) in various tasks in production, management, quality control systems, marketing and consulting. He supported as a scientific advisor the Federation of Greek Maricultures (FGM) for 7 years (1995-2002) providing technical service and support on aspects related with the European national policy administration and running as a national operator the Pan-European Data Base FEAP (CFP funded Project).

He has participated in 26 research (EU and national) and industrial projects with emphasis on innovation, training and technology transfer in aquaculture. He was invited by the EU (DG-XIV) as an external expert evaluator of CRAFT projects in aquaculture (1997). He was a member of the Board of AquaTT UETP Ltd, Ireland, (Aquaculture Technology Transfer & Training Organisation) & National Representative in Greece (1996-1999).

Since 2001, he is Lecturer (on industrial applications) in the purification technology, quality control and marketing of shellfish products in the Dept. of Fisheries & Aquaculture in the Technological Educational Institution (TEI) of Epirus, Greece, recently jointed with the Dept. of Fisheries & Aquaculture Technology of the TEI W. Greece, at Messolonghi.

## **Publications**

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#### **1. Peer-reviewed journal publications**

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