Integrated aquaculture (INTAQ) as a tool for an ecosystem approach to the marine farming sector in the Mediterranean Sea

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ABSTRACT

Aquaculture accounts for nearly 50 percent of worldwide fish landings (FAO, 2009). While aquaculture is an important source of fish stock, employment and profits, it also presents ecological, environmental and socio-economic challenges. *Integrated aquaculture* (INTAQ) has been proposed as one of a number of farming methods with the potential to mitigate some of the environmental problems associated with mono-specific aquaculture (monoculture) and to increase total production in a given site. INTAQ is the culture of two or more species of different trophic levels in a single farm or in close enough proximity that they interact in a way that mimics the energy flow pathways in natural ecosystems. Of particular interest is the combination of finfish culture with detritivores and algae both of which use finfish waste as food. Their presence reduces waste effluent into the environment as compared to a monoculture finfish installation with no waste treatment. It also produces added product that has a market value. The purpose of this report is to examine opportunities for INTAQ in the Mediterranean Sea basin for industry and local communities reliant on aquaculture and the commercial fisheries as well as its potential for lowering environmental impacts compared to capture fisheries, monoculture farming and other uses of coastal and marine resources. Thus, the main question guiding this study is whether and in what ways, INTAQ can significantly improve the productivity of selected areas in the Mediterranean Sea without increasing (and perhaps even decreasing) the negative externalities associated with monoculture. The study applies the ecosystem approach to analyze the potential of INTAQ and therefore considers a wide range of physical, ecological, social, political and business factors that determine the feasibility, social acceptability and ecological sustainability of INTAQ. The following four issues are addressed in order to assess the potential of INTAQ:

1. To what extent does INTAQ permits natural adjustments at the ecological level? As with any use of natural and environmental resources INTAQ will have impacts that may be positive, negative or neutral. An important issue in assessing INTAQ is the extent to which it alters the environment and this report attempts to describe and where possible quantify the potential effects.
2. With respect to their impacts, how does INTAQ compare with alternative uses of the same environment? The main comparison in this report is between monoculture and INTAQ, but in principle a wide range of alternative uses (e.g.: urban, industrial, tourism, recreation, capture fisheries, preservation) could also be considered as they coexist and often compete with aquaculture operations for the same coastal environment.
3. Given the fact that there is intense competition for coastal and marine resources, where does INTAQ fit in terms of regional priorities (e.g.: local development; economic viability; communities reliant on the fishery sector)?
4. What are the technical, engineering, production, investment, and regulatory challenges, opportunities and risks for business?

INTAQ is in its infancy and comes under several spheres of influence, including the aquaculture industry and fisheries sector, the coastal zones, a variety of ecosystems and several regulatory jurisdictions. This report therefore gives considerable attention to describing each of these in order to provide clear point of reference. Where needed, examples from experience outside of the Mediterranean Sea region have been used. Particular attention is given to:

- the ecology of the Mediterranean Sea basin and major environmental concerns;
- background to the aquaculture industry as a whole (including INTAQ);
- classification and description of INTAQ practices in the region;
- comparison between the impacts (known and potential) of monoculture and INTAQ;
- regulatory background;
- technical, production and financial issues; and

- potential of INTAQ for the growth and development of mariculture in the Mediterranean Sea.

The European Environmental Agency lists aquaculture as an important potential cause of environmental deterioration in the region if it is developed in unregulated and inappropriate modes. It identifies eleven potential negative impacts on the environment stemming from aquaculture (EEA, 2006). Since aquaculture has become such an important source of sea products, these concerns must be addressed if the industry is to be sustainable in the long run. Equally important for sustainability is the fact that aquaculture is also challenged by pollution, congestion and other environmental pressures from the surrounding ecosystem. Urban and industrial pollution and intense competition for space in many coastal areas are very real constraints on the potential for aquaculture in parts of the Mediterranean Sea region.

We have found that the main environmental advantage that distinguishes INTAQ from monoculture is its capacity to reduce farm effluent in the form of uneaten food, faeces and excretory wastes. Since this report is concerned with the potential advantages of INTAQ over more standard practices, effluent reduction and production enhancement are the focus of this study. This does not mean that other environmental impacts of concern to the EEA and others are less important, rather, they are shared by both INTAQ and other forms of aquaculture. Any discussion of sustainable mariculture must in fact include issues such as pathogen transfer between cultured and wild fish stocks, genetic contamination and visual distress associated with fish farms. But this needs to be done in a wider forum whose focus is mariculture in general.

Experience with INTAQ in the Mediterranean Sea is largely restricted to experimental and small scale pilot projects. These offer meaningful information on production possibilities and ecological impacts. For indications of potential business opportunities (e.g. investment, operating costs, market risks) we have relied on evidence from more advanced pilot and early commercial projects outside of the region, in particular in North America, Chile, and the United Kingdom. There are preliminary indications that there is potential for significant improvement in the return on investment mainly from increased production in the form of lower trophic taxa without the necessity of augmenting manufactured feed inputs. Moreover, INTAQ may have significant advantages in risk management at the business level because it offers diversification of products and access to multiple markets for finfish, shellfish, macroalgae and other seafood directly as well as derivative products.

In order to realize the potential of INTAQ more information is needed on most aspects of the practice. Research and commercial scale experience is required. Information on the potential risks and returns to investment will be especially important in order to facilitate entry at the enterprise levels. INTAQ as a business must be convincingly marketed to business operators as they will not engage in the practice unless they are well informed and confident of success. In addition, information on the environmental and broader social consequences must be disseminated efficiently and public education increased in order to counter prevailing skepticism and negative attitudes toward mariculture and INTAQ. A favorable and consistent regulatory climate with efficient policy design and implementation involving a wide stakeholder base will also facilitate acceptance and expansion.

Introduction

Of the three reviews included in this technical publication, the Mediterranean Sea has the smallest presence of integrated aquaculture (INTAQ). As a result, our assessment focuses on the reasons that the incidence is so low and on its potential and the requirements for expansion in the region. We have also relied on selected examples from outside the region in the belief that practitioners, the industry, regulators and the public at large in the Mediterranean Sea can benefit from experience from outside the region. The review of the history, current state, and major challenges and opportunities in the region is comprehensive in breadth. In order to gain the in-depth understanding needed, for the promotion of INTAQ, extensive fieldwork and further country and site specific research is required and this is beyond the scope of this desktop undertaking, however, we provide insights on a number of these requirements.

In its various freshwater and marine forms aquaculture has been practised alongside capture fisheries for centuries, and over the last half century has exhibited unprecedented growth worldwide. This accelerated growth is the result of a combination of technical advances in engineering, species' domestication and husbandry that have made aquaculture more cost-effective; increased demand for fish globally; and the depletion of wild fish stocks[1]. In many places increasing demand and rising prices have transformed aquaculture from a set of *backstop technologies*[2] to a viable and important substitute for capture fisheries. This is particularly true in temperate zones and the Mediterranean Sea region where modern production methods and advances in technology have driven expansion within the industry. In contrast, growth in tropical aquaculture has often (though not exclusively) been characterized by the proliferation of traditional methods (Troell, 2009. In 2006, aquaculture accounted for over 47 percent of worldwide fish landings (FAO, 2009). It may also prove to be a source of new food and non-food products and a spur for local development and food security in less developed countries. While aquaculture is an important source of fish protein, aquatic products, employment and profits, it also presents ecological socio-economic and political challenges.

The co-culture of several different trophic level taxa, with the specific objective of obtaining both environmental and production benefits goes by several names including, *integrated aquaculture* (INTAQ) and *integrated multitrophic aquaculture* (IMTA or IMT-aquaculture; Chopin, 2006; Barrington, Chopin and Robinson, 2009) and *polytrophic aquaculture*. We use the first to refer to a group of practices that includes the rearing of fed finfish, together with one or more species of bivalve, shellfish and macrophyte. It also can include other productive practices such capture fisheries in the vicinity of fish farms or artificial reefs. (Please refer to the section *Concepts and Definitions* for a more detailed description.) INTAQ is one of a number of farming

[1] According to the Fisheries and Aquaculture Department of the Food and Agricultural Organization of the UN, 80 percent of world fisheries are fully exploited or overexploited (FAO, 2009).

[2] The concept of *backstop technology* was introduced by Hotelling (1931). In the original conceptualization, it referred to alternative sources for the services from scarce exhaustible natural resources but is also applicable to cases in which the demand for renewable resource such as fish outstrips supply. In general, a *backstop technology is* an alternative source of supply for the scarce commodity and becomes economically viable when the cost of securing the commodity using conventional means rises to the point at which it equals (or exceeds) the cost of securing the same commodity using the backstop technology. In many cases, aquaculture conforms to this definition, as wild stock biomass falls, the cost of capture fisheries rises and demand outstrips supply forcing up the market price of fish. The higher price justifies investment in aquaculture and there is a proliferation as enterprises are attracted by potential profits.

methods that has the potential to mitigate some of the problems associated with monospecific aquaculture (monoculture) and to increase total production. Though very rare in the Mediterranean Sea, there are a number of examples of INTAQ internationally, the results of which point to the need for further examination of its technical feasibility, environmental and economic benefits and costs in the context of the Mediterranean Sea ecosystem. The basin is quite oligotrophic, especially in its western regions and this means that primary productivity and nutrients may be insufficient to support the co-cultivation of filter feeders and algae in many areas. This may be one of the reasons for the lack of INTAQ in the Mediterranean Sea compared to other areas of the world and attention needs to be paid to baseline primary productivity in different parts of the region in order to understand the potential for expanding INTAQ. INTAQ is also quite new and many farmers may be unaware of its potential in providing additional nutrients where they are scarce. Thus information may also be a factor in the absence of INTAQ.

OBJECTIVES AND APPROACH

The purpose of this report is to assess the opportunities and challenges for marine and brackish water INTAQ in the Mediterranean Sea basin for enterprises, industry and communities reliant or potentially reliant on aquaculture. We consider these opportunities with reference to an ecosystem approach taking into account the ecological and wider environmental interactions (i.e. physical, ecological, social, economic and political) associated with INTAQ and the potential benefits that INTAQ offers in comparison to monoculture, capture fisheries and other uses of the coastal and marine resources. The report synthesizes information from the field, including research and government reports, policy papers, regulatory reviews, scientific publications and industry information. It brings together several disciplines and gives an overview of the main positive descriptions and normative prescriptions.

The main motivating elements behind this report are:

1. ***Pressures on the fishing industry (rising demand/falling supply) and opportunities for aquaculture***: The decline in capture fisheries and increasing demand for fish in the Mediterranean Sea basin (and globally) has created unprecedented opportunities for aquaculture. The sector is proving to be a technologically and economically viable source of fish and on the ecological side has the potential to prevent further over-fishing that would lead to large scale collapse of existing wild stocks. A caution to this statement regards the potential pressure that aquaculture demand for fishmeal can exert on wild stocks. However concerning the situation of the Mediterranean Sea aquaculture offers an alternative to avoid further depletion of wild stocks and may even be a source of replenishment considering nutrient inputs to the ecosystem. Aquaculture also has the benefit of reliability in the sense that quantities and prices may be less variable than is currently the case in capture fisheries. From the standpoint of communities that rely on fishing, fish farms and related industries may also serve as an alternative source of employment and income. The rapid expansion of aquaculture has largely occurred in a policy vacuum. Though this report focuses on integrated forms of aquaculture, an important point of reference is directions within the industry as a whole. This is especially important in the Mediterranean Sea region, where INTAQ is rare and its potential will be heavily influenced by developments in policy, markets and public attitudes towards aquaculture in general.
2. ***Issues within the aquaculture sector (better management of environmental impacts, improving operations and profit)***: Preliminary evidence, mainly from pilot studies outside the Mediterranean Sea region, indicates that INTAQ can lower costs, diversify and increase production and improve profits while

solving a number of the environmental challenges posed by monoculture aquaculture. At the same time it requires a higher level of technological and engineering sophistication and up-front investment. If practised by means of different operators (e.g. independent fish farmers and mussel farmers) working in concert, it would require close collaboration and coordination of management and production activities. Presently, there is also a measure of uncertainty associated with INTAQ since it is so new in the Mediterranean Sea and this can be a deterrent for operators.

3. ***Issues in the management of multiple use marine and coastal resources (stakeholder competition and resource allocation)***: While aquaculture has the potential to release pressure on fish resources and INTAQ has specific potential benefits for the enterprises and the environment, fish farming competes with other users for the scarce coastal and marine habitats. Stakeholder conflicts are common and range from concerns about pollution and impacts on wild fish populations to site allocation and local priorities. The challenges for expanding INTAQ practice are therefore significant although it can offer a mitigation opportunity to those areas where mariculture has a poor public image and competes for space with other activities. Few countries in the Mediterranean Sea region have national aquaculture plans or well developed integrated management of coastal zones. This means that decisions on site selection, licensing and regulation are often ad hoc and highly subject to political pressures and local priorities. Moreover, as congestion in the coastal zone increases, many mariculture sites are threatened by urban and industrial pollution and accidental damage.

The main objectives of this report are:

1. to compile available information on integrated aquaculture in the Mediterranean Sea;
2. to determine the potential for integrated aquaculture considering major obstacles and opportunities in this ecosystem; and
3. to identify key issues and priorities in order to provide recommendations and a way forward to the implementation of INTAQ in the Mediterranean Sea.

To achieve these objectives, a broad range of stakeholders and information sources is considered. Factual background on INTAQ in the Mediterranean Sea, together with a synthesis of relevant research and key reports from academia, governmental organizations (national, regional and international), industrial and other organizations, are provided. Since the countries of the Mediterranean Sea region are varied in terms of their level of development and potential objectives associated with INTAQ, we attempt to consider, as much as possible, country specific scenarios and issues such as food security in the case of countries in the southern Mediterranean Sea and needs of different local communities and stakeholders over the region. Specific attention is given to gaps in current knowledge and research needs because INTAQ in marine areas is relatively new worldwide and experience in the Mediterranean Sea is scarce. In many places, mariculture is the subject of public and political concern, ranging from water quality and biodiversity to conflicts among different users of coastal and marine resources. The potential environmental improvements, that INTAQ offers over conventional monoculture, may improve public attitudes and those of decision-makers. Therefore, the issue of public perceptions and public education also receives attention.

In order to provide the reader with a clear frame of reference, the following two sections are devoted to defining the terms, INTAQ and ecosystem approach and providing the analytic framework used to evaluate the potential for INTAQ. This is followed by an introduction to the Mediterranean Sea ecosystem, a review of

mariculture in the region and key issues for expanding the practice of INTAQ. These sections provide background for understanding why there is less INTAQ practised in the Mediterranean Sea than in many other parts of the world and for considering its potential in the region. The main body of the report is a synthesis that describes different types of INTAQ practices and documents them on a country-by-country basis together with close-to-INTAQ practices. It also reviews relevant policy/governance provisions, technological requirements and environmental considerations; identifies places where INTAQ is likely to flourish, provides information requirements; and summarizes the main opportunities and constraints.

CONCEPTS AND DEFINITIONS

What is INTAQ?

As defined earlier in this review, *integrated aquaculture* (INTAQ) is the culture of aquatic species within or together with the undertaking of other productive activity including different types of aquaculture or capture fisheries. As in the case of IMTA, these activities may take place within a single farm or adjacent installations (e.g. mussel and finfish farms located close together, as found in Slovenia and in some parts of Croatia). Similarly, benefits can be achieved on a larger scale, involving a number of operators, locating farms growing seaweed, fed finfish and detritivores in close proximity to each other (ICES, 2005).

INTAQ also includes enhanced productive opportunities from combinations of fish farming with, for example artificial reefs that enhance local fish biomass around farms by providing refuge and additional food opportunity (from the fed aquaculture). Facilities may also be land based. INTAQ must meet two criteria; first that the co-cultivation or the coupled activities (e.g. fish farm plus artificial reefs) increase net production and second, that it has fewer associated negative environmental impacts in comparison to monoculture.

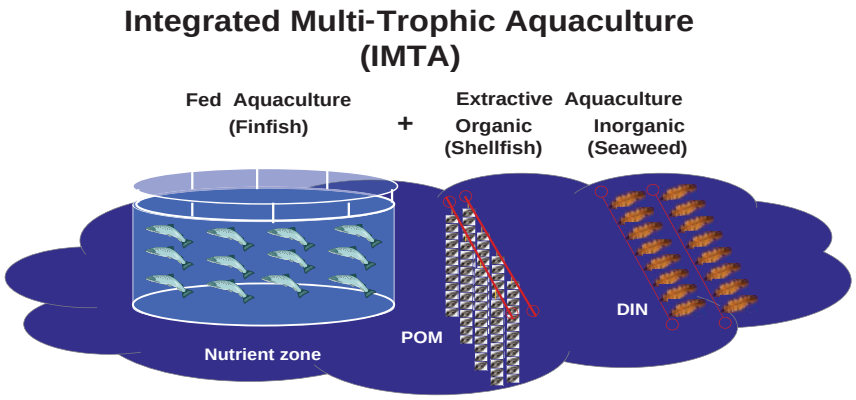
The discussion in this study focuses on combinations involving *intensive* marine net cage fish farms, and to a lesser extent, on-land man-made ponds or tanks. These are the main forms of mariculture in the Mediterranean Sea and stand to benefit the most from INTAQ approaches (Mathe *et al.*, 2006). *Intensive* aquaculture involves hand or mechanical feeding of the farmed stock, often using formulated feeds and rearing organisms at high stocking densities. Figure 1 illustrates an intensive salmon-mussel-macroalgae IMTA installation (Chopin, 2006; Barrington, Chopin and Robinson, 2009). The selection of species satisfies a variety of criteria, including environmental suitability, market value and compatibility with a variety of social and political objectives.

Environmental sustainability is one of the main considerations in INTAQ, thus, one of the criteria guiding species selection is the replication of natural ecosystem functions by balancing biological and chemical interactions between the cultivated organisms and surrounding ecosystem. INTAQ has been shown to generate less waste than its monoculture counterparts. It is also more sustainable than many other types of polyculture, the co-cultivation of different species without reference to their trophic level. Chopin (2006) provides the example of the joint culture of salmon-cod-halibut, stressing that while qualifying as polyculture, the system is not INTAQ because all three finfish species share the same basic biological and chemical processes that can lead to significant shifts in the ecosystem, mainly as a consequence of food waste, faeces and excretory discharges.

The production benefits of INTAQ stem from its potential to increase biomass per unit of artificial feed. Manufactured feed is one of the highest variable cost components of aquaculture. By exploiting the extractive capacities of co-cultured lower trophic-level taxa, and/or by enhancing use of excess feed and organic matter from the farm

FIGURE 1

Conceptual diagram of an integrated multi-trophic aquaculture (IMTA) operation combining fed aquaculture (finfish) with organic extractive aquaculture (shellfish), taking advantage of the enrichment in particulate organic matter (POM), and inorganic extractive aquaculture (seaweeds), taking advantage of the enrichment in dissolved inorganic nutrients (DIN)



Source: from Chopin (2006).

by wild species around site (e.g. in the artificial reefs case) the farm can obtain added products that can outweigh the added costs involved in constructing and operating an INTAQ farm. This is quite different from traditional forms of *extensive* polyculture, for example Italian *vallicultur*e observed in the Mediterranean Sea region. *Vallicultur*e involves the trapping of young finfish, during seasonal migrations into estuaries or lagoons and rearing them together with the natural fauna and flora in a brackish-water environment. The fish grow on naturally occurring plankton, or detritus, and are harvested when they have attained market size. While *vallicultur*e may be more environmentally sustainable than monoculture, it lacks the added value of joint, complementary production that characterizes INTAQ.

Ecosystem approach

Broadly defined, the ecosystem approach attempts to account for all the significant interactions stemming from human uses and other sources of change in the natural environment. The interdisciplinary perspective of the ecosystem approach can take advantage of using the collective strengths of each discipline but is challenged by the need to integrate across different methodological approaches and emphases that characterize individual disciplines (Falkenmark and Tropp, 2005; Adamowicz and Veeman, 1998). Given the importance of sustainability in resource management, the ecosystem approach is necessary because it recognizes a wide range of factors and interactions. In this report, the main underlying principle is that INTAQ shall be designed to be an integral part of the ecosystem. Aquaculture in general and INTAQ in particular is not examined in isolation as a source of external disturbance, nor as simply reactive in the face of surrounding change.

Like most human activities, INTAQ will impact the physical and human environment and these effects may be positive, negative or neutral (Choo, 2001). Similarly, it will be influenced by its surroundings and has the capacity to be proactive. Moreover, INTAQ is only one of many activities in coastal marine ecosystems and therefore any discussion of policies, management and decision-making must be in the general context of these other activities.

Over the last twenty years, systems approaches have been increasingly applied to the management of natural resources. The Appendix presents, in tabular form, a history of the evolution of the Ecosystem Approach to Fisheries (EAF). This is the point of departure for applying the ecosystem approach to aquaculture. Since 1980,