The sustainable development of Mediterranean aquaculture: Problems and perspectives

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SUMMARY – This text looks at the sustainable development of Mediterranean aquaculture. After reviewing the validity of the concept for aquaculture and existing tools, it outlines the conclusions of the Guidelines provided by IUCN and FEAP on Interactions between aquaculture and the environment, as well as the initial conclusions of the ongoing IUCN/FEAP Guidelines on site selection. It also touches upon other aspects of sustainable development, such as the diversification of aquaculture production and the issue of certification.

Keywords: Aquaculture, sustainable development, ecosystemic approach, Mediterranean.

RESUME – *"Le développement durable de l'aquaculture méditerranéenne : Problèmes et perspectives". Ce texte concerne le développement durable de l'aquaculture méditerranéenne. Après un rappel sur la validité des concepts du développement durable pour l'aquaculture, il présente les conclusions des Guides élaborés par l'UICN et la FEAP sur les Interactions entre Aquaculture et Environnement ainsi que les premières conclusions des travaux de ce groupe sur la Sélection des sites. Il touche aussi d'autres sujets concernant le développement durable tels que la diversification des productions aquacoles et la question de la certification.*

Mots-clés : *Aquaculture, développement durable, approche écosystème, Méditerranée.*

Introduction – Meaning of sustainable development for Mediterranean aquaculture

According to the definition of sustainable development, a sustainable aquaculture should be environmentally acceptable, economically viable, and socially equitable. However, even if these principles are clear, their application is not so straightforward.

Environmental acceptability is the most difficult component of the definition. The main question is "acceptable by whom?" From the very beginning, aquaculture as a human activity has to take into consideration other human activities occurring in the same area; in other words, acceptability is linked to the participation of all stakeholders. Furthermore, in order to understand what would be environmentally acceptable, the ecosystem where the activity takes place has to be identified and understood to the greatest extent possible.

Economic viability is the most obvious element of the definition, but this concept is deeply linked with the economic system of the country where the development takes place. For example, the concept of economic viability would not be the same in European countries as in North African countries, due to the different systems and stages of economic development. A common misunderstanding of economic development is its confusion with economic growth. The former is the process by which an economic activity obtains all the tools and knowledge necessary to operate successfully and reach an adequate level of maturity; the latter is the process of growing linked with the capitalist economies which, by definition, is not sustainable, as no growth can be indefinite in a finite world.

Social equity or fairness is the most variable aspect of the definition. It depends greatly on the social parameters of the society where the activity takes place. It is the most difficult to use because of its intrinsic variability.

A number of tools are available for the implementation of sustainable development:

The Ecosystem Approach

The Ecosystem Approach is a management approach for taking into account the broader ecosystem, including the human activities which take place; According to the *Convention on Biological Diversity* (Secretariat of the Convention on Biological Diversity, 2004): "*The Ecosystem Approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way*".

The existing planning processes for aquaculture, in Andalusia for example, are close to the ecosystem approach since they integrate all human activities. The Integrated Coastal Zone Management is also relevant to the ecosystem approach, especially in the way it takes into consideration all stakeholders. However, in these strategies the "missing part" are the conservation objectives which are at the base of the ecosystem approach. Applying the ecosystem approach in aquaculture implies looking at the ecosystem goods and services that aquaculture is using, how they are linked to the ecosystem functioning and finally what ecosystem component is to be conserved while developing the activity. This is to be done in the framework of the stakeholders forum, and at different time scales (adaptive management) and spatial scales (local, regional, national, etc.).

The Precautionary Principle

The Precautionary Principle is a basic principle allowing the taking of decisions even though not all scientific data are available: "*Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*". (Principle 15 of the Rio Declaration on Environment and Development - 1992). It is a strong principle that can be useful when used within the framework of the Ecosystem Approach, during participative and adaptive processes, and within the framework of good governance.

Tuna farming is a typical example of non application of the Precautionary Principle. This activity has not been developed taking into consideration the uncertainties related to sustainable use of the resources and the stocks. In the case of seabream / seabass cage culture, most of the planning processes are using a precautionary approach.

Good Governance

The principles of Good Governance were established during the 1990s and promoted in more recent years. They are applicable to all activities. Governance looks at how decisions are made, who decides, who has influence and who the players are. Governance does not look at objectives, which is the role of management, but rather at the way decisions are taken.

The principles of Good Governance are basically those of democracy. According to UNDP (Governance for sustainable human development, January 1997), *"Good Governance is a process of executing a coherent governing plan for the nation based on the interests and priorities of people. It purports to create a just society based on the principles of human essence, such as inclusiveness, liberty, equality and cooperation*". According to IUCN, Good Governance relies on five principles which are mutually inclusive and reinforcing: (i) legitimacy and voice (participation and consensus orientation); (ii) direction (strategic vision, including human development and historical, cultural and social complexities); (iii) performance (responsiveness of institutions and processes to stakeholders, effectiveness and efficiency); (iv) accountability (to the public and to the institutional stakeholders, transparency); and (v) fairness (equity and rule of law) (Graham, J., B.Amos, T.Plumptre, 2003).

"Governance" opens a new intellectual space. It provides a concept that allows discussion of the role of government in coping with public issues and the contribution that other players can make. It opens one’s mind to the possibility that groups in society other than government (e.g. "communities" or the "voluntary sector") may have to play a stronger role in addressing problems; Good Governance brings the framework and the tools for decision making according to all components of the society.

Aquaculture (marine fish) being a young activity, it still faces difficulties for implementing open processes to involve local stakeholders in its decision making processes. The main issues are to set up bases for transparent communication and ground for discussion. Great efforts have been made recently by the sector. In this sense, marine fish aquaculture is moving from a "pioneer stage" to a "farmer stage" in integrating into the local societies.

Interaction between aquaculture and the environment

The development and intensification of aquaculture has revealed a broad spectrum of associated environmental issues. The interaction between aquaculture and the environment is a varied and complex topic, in relation to sustainable development. A working group including scientists and aquaculture producers, as well as representatives of governmental and environmental organisations, under the coordination of the IUCN Centre for Mediterranean Cooperation and the Federation of European Aquaculture producers is working on Guidelines for the sustainable development of Mediterranean Aquaculture, with the support of the *Secretaria de Pesca Maritima* of the Ministry of Agriculture, Fisheries and Food of Spain. The first topic that this group is addressing is interaction between aquaculture and the environment (IUCN, 2007). The main conclusions of these Guidelines are as follows.

Domestication

Domestication in aquaculture is the acclimatisation to captive conditions, the total control of the life cycle and the manipulation of breeding in captivity of aquatic organisms (Hassin *et al.*, 1997). The advantages of domesticating organisms are: (i) to secure seed supply and improve production efficiency through the mastering of breeding and feeding to select organisms that can grow faster; (ii) to achieve better feed efficiency; and therefore (iii) to alleviate the pressure on fishes used as feed. It will also minimise the potential negative impacts on wild stocks by attempting to make cultured organisms unable to live in wild ecosystems.

However, domesticated animals become significantly different over time from their wild counterparts, both genetically and physically. The escape or release of strongly domesticated organisms into the environment can lead to unpredictable effects on the ecosystems, both on wild populations of the same species and/or other organisms. In the case of aquaculture, the risk posed by the escape of domesticated organisms is far greater than that of terrestrial animals or plants in similar circumstances, because of their ability to disperse and the difficulty of recapture.

As a principle for the sustainable development of aquaculture, it can be said that as the domestication of species for aquaculture is necessary, the interaction of these domesticated organisms with their wild counterparts should not have negative effects.

Therefore: (i) domestication of aquacultured organisms should be encouraged; (ii) selective breeding of aquacultured organisms should be designed to reduce their capacity to survive or reproduce in the wild; and (iii) research for domestication should be encouraged and supported, and the creation of gene banks of wild species should be promoted as a reservoir of genetic resources.

Accordingly, about escapement management: (i) aquaculture systems should be designed to effectively contain organisms and minimise the possibility of escape; (ii) contingency plans should be set up for the eventuality of escapes (additional preventative measures should be incorporated for high risk activities such as organisms transfer, grading and harvesting); and (iii) research on surveillance of escaped organisms should be encouraged.

Introduced marine species

In aquaculture, the risks posed by the introduction of species, whether for their rearing (intentional) or as associated with aquaculture species (accidental), are important. The consequences of the releasing of those species may be major impacts on biodiversity and ecosystems (McNeely and Schutyser, 2003), such as alterations in the genetic pattern of wild populations. Such organisms may compete with native species for food and space, such as a number of algae brought from Japan when introducing the Japanese oysters, and might also transfer diseases and parasites, such as the case of sea lice for salmon culture in North Atlantic; in the Mediterranean no such case has been observed yet, but it is a potential threat.

The use of introduced species in aquaculture, is highly risky, and therefore, as a principle, the precautionary approach should be implemented. Introduction of species should be carried out only in special cases and taking all required precautions.

Native species should be cultured whenever feasible. The recommendations developed in the ICES *Code of Practices on the Introductions and Transfers of Marine Organisms* (2005) as well as the considerations and suggestions of the report on *Alien Species in Aquaculture* by Hewitt *et al*. (2006) should be followed. Regional and international collaboration should be supported to address trans-boundary biodiversity impacts of introduced species as stated in UNEP/MAP (2005).

Capture of wild stocks for aquaculture needs

One of the most important issues for the sustainable development of aquaculture is the sustainability of the source of cultivated fish or shellfish. As worldwide fisheries stocks and their supporting ecosystems are in a fragile state, the growing importance of aquaculture production should not increase the pressure already exercised by capture fisheries on wild stocks. Rather the opposite, aquaculture should be a way to relieve this pressure on wild stocks and foster the maintenance of biodiversity, whilst satisfying the growing market demand for aquatic products. The main objective is to produce parent fish and larvae in an integrated way with control of the whole life cycle. However, according to species, and under scientific control, taking part of the wild stock may be a sustainable alternative (Ottolenghi *et al.*, 2004).

Therefore, as a principle, the stocking of aquaculture farms should not affect the natural status or viability of wild populations, their ecosystems or biodiversity in general. It is preferable that organisms that are to be raised in aquaculture farms should have been produced in hatcheries. For this purpose: (i) research on closing the life cycles of cultured species should be encouraged in order to be able to produce hatchery organisms; and (ii) research on the fish life cycle and functioning of the ecosystem should be promoted. In the case of taking from wild stocks, (i) the sourcing of individuals for stocking the aquaculture farms done through their capture from wild stocks should be exercised in a sustainable manner; (ii) the capture of specimens to be used as broodstock in hatcheries should not distort wild populations; and (iii) wild stocks from endangered species should not be used, except for rehabilitation or recovery plans, in order to maintain biodiversity.

As described by FAO (2005b), the farming of Atlantic bluefin tuna (BFT) in the Mediterranean Sea should be considered as an activity clearly overlapping between capture fisheries and aquaculture. In this case, and in the context of a sustained increase in fishing and farming overcapacity, all attempts to achieve a real regional management of this key Mediterranean fish resource have resulted in failure (WWF, 2006). The potential sustainability of BFT farming is linked also to research advances in the successful "domestication" of the species. Although considerable progress has been made in this regard, the economically feasible "closed cycle" production of BFT has not yet been achieved. The expansion of tuna farming activities in the Mediterranean has generated a growing demand for wild fish specimens. Hence, one of the main concerns about this demand is the current and potential pressure to increase fishing. An important step towards responsible and sustainable fishing is to enforce the conservation and management measures of the regional fisheries management organisations, particularly ICCAT and GFCM.

However, the problem of tuna fattening is not only that we do not know how to produce tuna larvae and juveniles in quantity, but also that the fattening activity is by definition based on wild stocks. Fattening is a special aquaculture case that involves only a short period of the life span of the fishes. The basic concept is to keep live fishery products in captivity for a while in order to give them an added value. In terms of feed consumption, it is a much better solution than the aquaculture on the complete cycle. In the case of tuna, most of the animals that fatten in the cages are adults that have spawned several times and are part of a fisheries quota. Therefore knowing how to artificially produce tuna seed might create a new production (aquacultured tuna) in the future, but would not automatically replace the tuna fattening which is something different. In any case, this activity has to be sustainable from the point of view of tuna stocks (quotas, etc.) and feed fish stocks, as well as economically (to be based on one market on the other side of the world is questionable for sustainability) and socially, e.g. resources being utilised by one type of dominant fishery (seines) to the detriment of other smaller fishing methods such as the traditional fixed trap net (*almadraba*).

Ongoing tuna fattening in the Mediterranean is raising a number of issues regarding sustainability: (i) the lack of available data to assess the status of the stock; (ii) the difficulty of management organisations setting strong management measures; (iii) the use of feed fish from all around the world; (iv) the equitable use of resources; (v) the impact on the local environment; and (vi) compliance with regional regulations. A clear and drastic recuperation plan, and a clear management plan, will need to be enforced quickly if the collapse of the resources is to be avoided. The management plan might set up a kind of secondary quota, part of the fisheries quota, for the tuna that can be put into the fattening process.

Feed ingredients

Aquaculture organisms reared in captivity must be fed in order to enhance their productivity. Some filter feeder species, such as mussels, clams or oysters, take their food directly from the surrounding water column. However, in most cases (all finfish and crustaceans) feed must be supplied by the farmer. Feed is the main exogenous input into the aquaculture system, and the quantity of feed required is, in general, two or three times the volume of the output produced. For the manufacturing of these feeds, large volumes of natural raw materials are needed. This is the most difficult issue regarding sustainability. As for capture of the wild fishes for aquaculture purposes, the growing importance of aquaculture production should not increase the pressure already exercised by capture fisheries on wild stocks in using wild fishes for producing feeds for aquaculture.

The future development of aquaculture is strongly linked to the possibility of providing sustainable aquafeed ingredients. The current marked increase in aquaculture production has to take into account that fish meal and fish oil are worldwide limited resources (Tacon, 2004). If the aquaculture of carnivorous species wishes to continue further growth, improvements must be achieved in the feeding of these animals, and alternative raw ingredients for aquafeeds must be found. As a principle, the production of aquafeeds should be a sustainable activity. The sourcing of these raw materials should be environmentally acceptable, and should not have negative impacts on the ecosystems from which these ingredients are harvested. This is probably the strongest limiting factor to the development of aquaculture in the future.

However, some recommendations can be made: (i) in relation to the use of feeds and technology: the use of formulated feeds should be recommended and feed management, as well as feed production technologies and feed quality, should be improved; (ii) regarding alternative sources for feed ingredients, the use of alternative ingredients, as well as the use of other existing sources of marine proteins and oils, should be encouraged; and (iii) concerning the optimisation of nutrients, (a) the farming of low-trophic level species, as well as (b) the integration of aquaculture with other agricultural farming activities should be promoted.

"Turning carnivorous fish species into vegetarians" (Powell, 2003) has recently been suggested as a more sustainable solution. It has its own issues, but in the face of the increasing costs of carnivorous fish production and the ecological implications of the decline in wild stocks, this seems to be one possible way forward. However, the conversion of finfish from carnivorous to vegetarian is concerning. At present, partial replacement of fish meal and fish oil in the diets of aquacultured fish by vegetable proteins and oils is taking place without compromising the fish and flesh quality as well as the health benefits of a ω3 diet (Izquierdo *et al.*, 2003). Over time, the percentage of this substitution will probably increase for the sake of sustainability.

There is an apparent collision of ethical concepts between what is believed to be "natural" and what is considered to be "sustainable". Food safety concerns exist in relation to the inclusion of processed terrestrial animal proteins into the feeds of aquacultured fish. The use of blood meal, generally porcine, in feeds for carnivorous fish has existed worldwide for decades because of its high quality. After the Bovine Spongiform Encephalopathy (BSE) crisis started in 1986, the use of these proteins was forbidden in the European Union as a precaution. In 2003, after the scientific committees of the European Commission demonstrated the complete safety of these ingredients, the use of non ruminant blood meal in fish feeds was authorised. Nevertheless, the use of these proteins in fish feeds in Europe today is small, because of worries within the aquaculture sector about its image. At the same time, they are widely used in Asia and America. Similarly, the use of genetically modified organisms (GMOs) as ingredients could be a solution for aquaculture feeds. Genetically engineered plants producing oils with tailored composition profiles could be the ultimate solution to the fish oil shortage. Nevertheless, their application in Europe will require solid proof of food and environmental safety, and a major change in the attitude of consumers and legislators towards GMOs, and will remain a major concern for biodiversity conservation.

Organic matter in the effluents and waste management (nutrients, pathogen transfer, therapeutic and other products, antifouling products)

Effluents of aquaculture facilities include uneaten feed, metabolic excretions, faeces and dead fish, and they consist of both organic solid wastes and dissolved organic and inorganic nutrients. If the flux of these compounds into the environment surpasses the natural assimilation capacity of the ecosystems, severe impacts, such as eutrophication, oxygen depletion and alteration of local biodiversity, can occur both in the water column and in the bottom substrate. Within the objectives of sustainable development, as a principle, the organic matter in the effluents from aquaculture farms should, be capable of assimilation by the ecosystem, in quantity and quality, thereby not producing negative effects on the local environment.

Aquaculture farms are generally open systems in which pathogens can flow in and out, and interact with wild populations. Recently, Diamant *et al.* (2007) have reported the transfer of pathogens in both directions with cage aquaculture in the Gulf of Eilat. Although cases of pathogen transfer between wild and aquacultured organisms, and vice-versa, are rare in Mediterranean aquaculture, the growing importance of aquaculture increases the risk of this happening in the future. Nevertheless, this risk is certainly high in the case of the introduction of alien species that might transfer diseases especially virulent for the local species. The possible transfer of pathogens between farmed organisms and wild stock populations should be minimised.

Veterinary medicines and therapeutic products are tools for animal health management. They are important for the welfare of the animals and must also be considered from the point of view of human food safety. Most aquaculture veterinary medicines, if properly used, have minimal adverse environmental impacts. However, excessive dosage and failure to provide for adequate neutralisation or dilution prior to discharge to the natural environment could make their use unsafe and harmful to wildlife near the aquaculture facility. The use of therapeutants should be managed correctly to minimise possible detrimental effects on the natural environment.

Antifouling products are needed in aquaculture to prevent or minimise biofouling, but they are effective precisely because of their toxic properties towards these organisms. This toxicity may harm non-targeted organisms and affect the surrounding ecosystems. As a principle for sustainable development, antifouling products used in aquaculture should have no perceivable toxic effects on non-targeted organisms of the surrounding ecosystems.

Although these effluents from aquaculture facilities are worrying in many cases, all these problems have simple solutions if the site is well selected and if the farm is well managed according to existing guidelines.

Effects on local flora and fauna

Many societal concerns come from the perceived environmental effects of finfish cages or land-based aquaculture production units on the local flora and fauna. The interaction of aquaculture with nearby wild flora and fauna is of concern in relation to its development. In some cases, aquaculture facilities, especially fish cages, have negative impacts on local fragile or sensitive species, such as seagrass meadows. On the other hand, farm operations might attract local fauna and even have positive effects on fish populations and productivity. The negative impacts of interaction between aquaculture and local flora and fauna should be avoided, whilst the positive effects should be exploited. Therefore: (i) Environmental Impact Assessments should be carried out to detect any possible effect on the wild ecosystem; (ii) decisions to develop or stop further deployment of aquaculture facilities should be managed case by case; (iii) hydrodynamic and ecological studies should be conducted as part of the process of site selection; (iv) areas which contain significant communities of seagrass meadows should be considered as incompatible with the establishment of aquaculture facilities; (v) the settlement of cages in exposed areas, located away from the coastal shore, should be encouraged; and (vi) the attraction of local fauna by the aquaculture structures should be part of the management of farms.

One of the main issues concerning marine protected areas is the role that they can play in sustaining local livelihoods and alleviating local poverty issues. Small scale fisheries, ecotourism and diving activities are often presented as sustainable activities that can take place inside, or close to, marine protected areas. Aquaculture can probably play a role in this case. Aquaculture requires good quality water and a healthy ecosystem. Sustainable aquaculture can only take place in a healthy environment. Although the overload of organic matter created by aquaculture operations would not usually be compatible with marine protected areas, low density aquaculture might be a good solution for sustaining the livelihoods of the local population around marine protected areas. Some types of aquaculture, such as mussel or oyster culture, have a long history, are traditional practices, and are heavily linked with the local ecosystems. In this case, some aquaculture areas would merit protection in the same way that some vineyards or olive trees fields are now protected in rural areas. Traditional aquaculture areas do have cultural values. For example, earthen pond fish farms ("*esteros*") along the Southeastern coast of Spain, which are the economic evolution of old salt pans, provide the centre of the conservation values of a local protected area ("*Parque Natural Bahía de Cádiz*"). Another example is *valli* culture in the Northern Adriatic sea, which is an important part of the local landscape. The recognition that traditional aquaculture is supporting local biodiversity, as well as landscape and seascape, is important and could help to conserve marine biodiversity. Areas where traditional aquaculture takes place could be designated as marine protected areas. In this case they would fall under IUCN category V (*Protected Landscape/Seascape: Protected area managed mainly for landscape/seascape conservation and recreation*).

The density of the reared fish stocks is a major factor in relation to the effects of aquaculture on the environment. The density is the number of fish per volume of water in one cage (or the quantity of shellfish in one structure), or the quantity of cages in a site; it is a matter of scale. In both cases, the strength of the effects is linked to the aquaculture density. Therefore, the density and the adequacy of the type of aquaculture activities have to be considered alongside the sensitivity of the local ecosystem. The optimisation of densities in cages and other rearing devices might avoid problems linked to ecosystem sensitivity. Extensive aquaculture might in many cases be a solution to avoid problems related to local flora and fauna. The concept of the carrying / holding capacity is key to this issue.

All these aspects should also be taken into account when considering the relation of aquaculture with other human activities in coastal areas. This is the case of the interaction between aquaculture and capture fisheries also in terms of environmental interaction within marine and coastal ecosystems. Most of the potential environmental impacts of aquaculture can be managed and minimised through the understanding of the processes, responsible management and the effective siting of farms. Therefore, sustainable management guides are essential tools for policy makers, administrators, aquaculture producers and other stakeholders.

Site selection

Based on the identification and understanding of the interaction between aquaculture and the environment, examining site selection processes is the next step for the sustainable development of aquaculture. However, it includes all social and economic development requirement as well. The IUCN-FEAP is currently working on Guidelines for site selection. The processes of site selection include scientific knowledge, tools and legal frameworks, as well as tools for decision making and management.

Scientific knowledge for site selection

The scientific base for site selection is the understanding of the capacity of a site to receive aquaculture production, i.e. the carrying capacity. However it is not an easy concept when applied to aquaculture. The definition of carrying capacity is *the maximum population size that a certain environment can support for an extended period of time, for a population of a particular species* (Karakassis and Angel pers. comm.). This concept can be easily applied to mussel farming where the farmed species depends on natural resources (phytoplankton), but in the case of finfish cage culture, the carrying capacity of the system depends less on the ecosystem properties and more on the technology used, the amount of (allochthonous) food supplied and the effects on the environment (externally defined). Defining a "standard" carrying capacity for fish farming sites is not, therefore, straightforward.

The term "holding capacity" might be preferred for use in relation to fish farms. This is *the biomass of farmed fish that a defined water body can sustain without undergoing unacceptable ecological change species* (Karakassis and Angel pers. comm.). This is linked to the assimilative capacity of the water body. It seems that producers, regulators and scientists have in mind different types of "capacities" and therefore there is a need to take into account different perceptions and interests while establishing a way to calculate the maximum allowable production at a given site: (i) *physical carrying capacity* –the total area of marine farms that can be accommodated in the available physical space; (ii) *production carrying capacity* –the stocking density of bivalves at which harvests are maximised; (iii) *ecological carrying capacity* –the stocking density or the farm density which causes unacceptable ecological impacts; and (iv) *social carrying capacity* –the level of farm development that causes unacceptable social impacts. This last capacity needs to be defined by policy makers rather than by scientists, so some lack of clarity is expected.

Nowadays there are several models suitable for particular cases and situations such as DEPOMOD – MERAMOD. The ECASA project Ecosystem Approach for Sustainable Aquaculture looks at available models as tools for the development of aquaculture and proposes a toolbox for their use.

The standards for site selection should not wait to encounter unacceptable ecological impacts but could be adopted to promote good practice by adapting farm size to the environmental characteristics of the receiving environment.

The main challenge for carrying capacity in the Mediterranean is the concept of social acceptability which is not measurable scientifically. However, ecologically acceptability, which is currently addressed within cause / effects relationship in a qualitative way (pathway of effects), contributes to inform on social acceptability.

Tools for site selection

Environmental Impact Assessment (EIA)

The Environmental Impact Assessment (EIA) aims to analyse the positive and negative impacts of the establishment of an aquaculture facility, and to develop measures to reduce and/or mitigate the latter. However, generally since the EIA is carried out after the site is selected, it is not actually a tool for site selection but rather for the monitoring of the environment in regard to aquaculture development. It answers precisely the need to know the potential impact of a farm (Fernandes *et al*., 2001). The EIA supports the decision making processes, communication with stakeholders and respects regulations. EIA is particularly useful when there are few land / coastal / sea use planning regulations.

Geographic Information System (GIS)

A Geographic Information System (GIS) is a computer system for capturing, storing, checking, integrating, manipulating, analysing and displaying data related to positions on the Earth's surface. Typically, a Geographical Information System (or Spatial Information System) is used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular kind of feature. Each feature is linked to a position on the graphical image of a map. In aquaculture, it has been used to assess the suitability of geographical sectors, and also to investigate the suitability of a species to an area (FAO, 2007).

Spatial analysis applied to aquaculture is well positioned to take on several kinds of ecosystem issues that include: (i) Environmental impacts of aquaculture; (ii) impacts of changes in the ecosystem on the sustainability of aquaculture; (iii) resolving competing and conflicting uses of space and resources; (vi) relating ecosystem boundaries to administrative and political jurisdictions and their management responsibilities; and (v) integrating information from all disciplines for decision-making and risk analysis. The real potential for GIS is in dealing with scales, and in defining boundaries of aquaculture systems within other systems and how they will interact.

An increasing number of experiences, case studies and applications gained in different areas of the world are there to demonstrate the potential of using GIS and remote sensing spatial analytical capabilities for data collection, management, analysis and dissemination in support of aquaculture and fisheries management strategies. However, for GIS to be effective in supporting the EAA it urgently needs the integration of socio-economic aspects to better integrate people in the ecosystem as key components and not simply extraneous. Also, the benefits of GIS will not be realized if: policies for planning and development are not in place, if there is lack of integrated development planning and overall if resources allocation is not confronted at the ecosystem level.

The role of GIS (that includes remote sensing and mapping) for the management and development of aquaculture and in strategic and operational decision-making is yet to be realized. However, it is clear that these tools could promote and strengthen collaboration between members from disciplines other than fisheries and aquaculture to: (i) better understand the ecosystem, (ii) generate scenarios illustrating the consequences of different management decisions on natural resources and economy, and (iii) to facilitating multistakeholder participation in the planning processes.

The availability of proper sites for aquaculture development is considered one of the major bottlenecks to aquaculture growth in the Mediterranean Sea. GIS and related models could be used to identify suitable sites for aquaculture development following the Ecosystem Approach principles and could provide a framework for monitoring aquaculture activities (Aguilar-Manjarrez, 2007).

Licensing

The licensing system is the process for the allocation of space on the maritime public domain. The main issues for licensing are: (i) where will aquaculture facilities be allowed?; (ii) on what basis and requirements will they be approved?; (iii) which agencies are involved and which of them have decision-making powers?; (iv) what annual fees will they expect to pay?; (v) what environmental protection measures will be required?; and (vi) before accepting a concession or authorisation that would permit the allocation of rights to exclusive use of land, coast space or maritime waters, the promoter will also need to be assured that existing rights are adequately protected, particularly over time (Chapela, pers. comm.).

All government bodies with responsibility for aquaculture wishing to consider aquaculture as a strategic activity should develop clear permit application guidelines (complete with all legal and institutional information). This guidance would be crucial in the design of aquaculture policies, not only for policy makers or agencies involved in the permit procedure, but also for aquaculture promoters and, in general, for society as a whole.

Clear legislation is key to protection of the environment and the sustainable development of aquaculture, but any such legislation must reflect social issues, for instance the strategic dimension of aquaculture in local economies, and participation tools. A lack of regulation can cause a rejection of aquaculture by society.

Licences are necessary for aquaculture activities. However, in the majority of countries, the procedures for applying for an aquaculture licence are complex and require the involvement of many agencies that have to provide reports or evaluations. Such complex application procedures are time-consuming and result in a lack of juridical security.

Social and political issues

Planning systems are diverse and complex, but they are critical to the sustainable development of aquaculture. Planning should look at suitable zones for aquaculture development as well as potential zones for the development of aquaculture. This is the zoning process.

Integrated Coastal Zone Management is a tool for decision-makers in the planning, zoning and licensing of all human activities and all stakeholder rights in relation to a defined coastal area. It is a time consuming method which implies consultation and participatory processes, and enhances good governance and information flows from local to national (supranational) level and vice versa, avoiding conflicts among different stakeholders.

The Ecosystem Approach, the target of which is *the conservation of ecosystem structure and functioning to maintain ecosystem services, through integration of conservation and use of biological diversity,* is based on 12 principles as defined by the Convention on Biological Diversity, 2004 (Table 1). The 12 main principles are shown as questions to be answered, in as much as this is the way in which they are to be utilised.

Table 1. The 12 principles of the Ecosystem Approach (Secretariat of the Convention on Biological Diversity, 2004)

1. Are the objectives of the management of land, water and living resources a matter of societal choice?
2. Is management decentralised to the lowest appropriate level?
3. Does such management consider the effects (actual or potential) of its activities on adjacent and other ecosystems?
4. Is the ecosystem understood and managed in an economic context? Are potential gains from management recognised?
   a. Have interventions been implemented that reduce market distortions that adversely affect biological diversity?
   b. Are incentives to promote biodiversity conservation and sustainable use aligned?
   c. Are costs and benefits in the given ecosystem internalised?
5. Is the conservation of ecosystem structure and functioning to maintain ecosystem services a priority target for management?
6. Are ecosystems managed within the limits of their functioning?
7. Is management undertaken on the appropriate spatial and temporal scale?
8. Are the objectives for ecosystem management set for the long term so that the varying temporal scales and lag-effects that characterise ecosystem processes recognised?
9. Is management flexible and adaptable to changes?
10. Does management reflect the appropriate balance between, and integration of, conservation and use of biological diversity?
11. Are all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices considered in the management?
12. Are all relevant sectors of society and scientific disciplines involved?

For the implementation of the Ecosystem Approach, the principles have been sequenced so that action can flow more simply from them (Shepherd, 2004). Public participation, participatory processes and later adaptive management over time and space are included in the ecosystem approach.

In all the above tools, approaches and methods, the central element is stakeholder participation. However, it is also the most difficult to put in place, since it requires a strong will from the aquaculture community to open itself to others, along with the involvement, from the very beginning of the process, of groups that are often diffuse and difficult to identify.

The aquaculture sector being relatively young, especially for finfish production, does not yet have a full size organisation. There is still a lack of representativeness at some levels, such as at the local level.

Steps forward and conclusion

The sustainable development of Mediterranean aquaculture is extremely complex and many issues have to be addressed. Following the work already undertaken, and still ongoing, on the interaction between aquaculture and the environment, and about site selection, many issues are remaining such as the diversity as a key factor of sustainability and the importance of the market as a driver.

Is the diversity of cultivated species a key point for the sustainable development of Mediterranean aquaculture? In the case of both fish and shellfish the number of cultivated species might be multiplied. Other organisms might also be used, such as sea weeds and other invertebrates. Products from the farming process could also be diversified. For example, where whole fish is the main product, fillets or cooked fish could be developed. Furthermore, non food products might be developed too (e.g. cosmetics). Another type of diversification relates to the size of the farm. Most fish farms produce 500 to 1000 tons annually. Compared to the structure of agricultural production, it seems that aquaculture misses a step of its development and therefore remains unstable from this point of view: the small-scale stage, a stage which exists for molluscs culture (oysters, mussels).

Aquaculture, as well as all food production, is driven by the market. Aquaculture products have to be identifiable for their intrinsic quality. How is the issue of traceability (data about the history of the product) key to sustainability? How are different kinds of labels important for such sustainability? Is the certification of sustainability a major achievement for the future?

Mediterranean aquaculture is still at an early stage of development although some productions (molluscs) have already a long tradition. Its sustainable development needs a better integration in the society and to take better into consideration basic principles. At the international / regional level there is a current effort to streamline the sector, its framework and its communication tools (European Federation of Aquaculture Producers, Committee on Aquaculture of the General Fisheries Commission for the Mediterranean). However, as in many other cases, the Mediterranean aquaculture is quite diverse in terms of stage of development and needs for scientific and technological support. The current efforts made by various international entities should be better coordinated and strengthened. However, the efforts are also to be made at the local levels where operational decisions are to be made and the development is to take place.

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