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SITE SELECTION AND CARRYING CAPACITY IN MEDITERRANEAN MARINE AQUACULTURE: KEY ISSUES (WGSC-SHoCMed)

(Version before editing)

***Available in English only**

PREPARATION OF THIS DOCUMENT

This document is a draft version of the report for the first year of the SHoCMed Project “Developing site selection and carrying capacity guidelines for Mediterranean aquaculture within aquaculture appropriate areas”, which is funded by the EU’s DG Mare, and implemented within the GFCM CAQ Working Group on Site Selection and Carrying Capacity. The report has two components: the first, covered by Chapter 1, deals with the SHoCMed Project rationale and outlines the activities carried out during the first year. Various experts have contributed to and/or attended the various meetings held as part of the SHoCMed Project. A list of participants of the meetings is presented in Appendix 1. The second component of the present report, covered by Chapters 2 - 8, comprises a series of reviews by Mediterranean experts that are aimed at providing a regional inventory of information and a source of reference which are useful for participants of the SHoCMed Project and for professionals involved in aquaculture in general. Chapter 2 covers various aspects of interactions between aquaculture and the environment, and also includes a list of international initiatives and projects on aquaculture-environment topics, and site selection and carrying capacity issues, and a bibliographical list (as an appendix) of published works that are relevant to the theme. Chapter 3 comprises a review of aspects of environmental monitoring of aquaculture activities and includes a guide on useful variables and parameters that can be used to monitor aquaculture activities. Chapter 4 covers thresholds for environmental change that may be applied in monitoring of aquaculture activities. Various aspects of environmental criteria and other important considerations, including bottlenecks, in relation to site selection for aquaculture, are reviewed in Chapter 5. Aspects of interactions between aquaculture and other uses of the coastal zone, and economic bottlenecks are respectively covered in Chapters 6 and 7. Finally, Chapter 7 comprises a review of procedures for site selection, regulatory schemes and EIA procedures that are used in the various Mediterranean countries. This last chapter also presents the results of surveys, carried out as part of the SHoCMed project, that were aimed at establishing the guidelines, laws and other relevant procedures (including the EIA) and administrative procedures that are used by various countries in the Mediterranean.

The document was edited by J. A. Borg, D. Crosetti and F. Massa.

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1. Introduction and background to the SHoCMed project

By Fabio Massa, Donatella Crosetti and Joseph A. Borg

1.1 Sustainable development of aquaculture in the Mediterranean: site selection for aquaculture

Aquaculture in the Mediterranean, as in the rest of the world, plays an important role in enhancing the regional fish production, and in meeting rising demand for fishery product, and will continue to be a very important activity in the foreseeable future. The General Fishery Commission for the Mediterranean (GFCM) has, on many occasions, stressed the increasing importance of the Aquaculture sector. Accordingly, in 1995, the GFCM established a Committee on Aquaculture (CAQ) to promote the sustainable development and responsible management of marine and brackish-water aquaculture in the region.

During the last few decades, aquaculture production in the Mediterranean and Black Sea, in particular production of finfish, has shown a trend of increase, mainly resulting from technological developments for the two finfish species European sea bass (*Dicentrarchus labrax*) and gilthead sea bream (*Sparus aurata*).

The expansion of aquaculture in the Mediterranean has, however, brought with it several environmental and socio-economic issues, which influence the sustainability of the sector and risk compromising its further development. Aquaculture in the Mediterranean is already facing difficulties that concern, among other aspects, its introduction and integration in coastal areas.

Several past projects, also undertaken in the Mediterranean Sea, have focussed on a technical approach to aquaculture sustainability, in particular a biological approach to understanding environment-aquaculture interactions that comprise issues related to carrying capacity and the development of environmental impact assessment (EIA) procedures. However it is widely recognised that this knowledge needs to be reintegrated into the wider context of viability and sustainability of aquaculture within integrated coastal zone management schemes (ICZM). This is of utmost importance in the Mediterranean region where the coastal zone is highly populated and supports multiple uses, which in places are also conflicting. Moreover increasing pressure on the coastal zone implies difficult societal choices and development of specific decision-making schemes related to territorial management of activities and competing uses.

In particular, there is a great opportunity to enhance fish cage farming and aquaculture development in the Mediterranean region, where the activity represents the sector with the fastest growth. However, some of the most relevant bottlenecks are the siting of fish farms and the conflicts that are appearing in several countries where other sectors, such as tourism, are displacing cage farming out of some areas or resulting in translocation of the activity further offshore or, where not yet established, are simply not accepted for lack of availability of proper criteria to identify suitable areas.

Criteria are needed for enhancing the integration of aquaculture into coastal zone management, by improving site selection and holding capacity benchmarks and reference points. Criteria are also needed for the harmonisation of standards, aquaculture policies and legal frameworks across the Mediterranean region to ensure equal terms of competition and minimal environmental impact.

1.2 Background

In the GFCM region, increased interest has been shown on aquaculture sustainability in its four dimensions; governance, economics, social and environmental. In 2005, an expert meeting on the re-establishment of the Network on Environment and Aquaculture in the Mediterranean (EAM) was held in the framework of the GFCM Committee on Aquaculture (CAQ). This expert meeting was focussed on environment-aquaculture interactions and highlighted the related crucial issues that should be addressed, such as the necessity of better integration of aquaculture within integrated coastal zone management, and of an improved public image of aquaculture with respect to both consumer and social acceptability of the activity. Thus, the expert meeting identified a list of priority issues to be tackled in the short- and medium-term: i) harmonisation of aquaculture environmental legislation; ii) integrated environmental impact assessment (EIA), monitoring and management; iii) integrated coastal zone management; iv) improved aquaculture public image.

Consequently, the CAQ reorganised its subsidiary bodies in 2007 to face the new challenges of Mediterranean aquaculture and to address the identified priority issues. Three working groups were created: one on site selection and carrying capacity (WGSC), one on sustainability (WGSA) and one on marketing (WGMA). These three groups are liaising closely with each other to address the identified fundamental issues of Mediterranean aquaculture.

1.3 The SHoCMed project framework

SHoCMed "*Developing site selection and carrying capacity for the Mediterranean aquaculture within aquaculture appropriate areas*" was designed and developed within the Working Group on Site selection and Carrying Capacity (WGSC). The project proposes to explore the potential for using Allocated Zones for Aquaculture (AZA) as a means for improving sustainable growth of the sector and to assess the consequences of site selection and of holding capacity under increasing aquaculture production scenarios, as well as to identify bottlenecks for production related to site selection.

The first brief of SHoCMed was prepared in November 2006 during the first meeting of the GFCM-CAQ WGSC and represents the follow-up of the request made by the CAQ during its fifth session (held in June 2006). The project attempts to support the CAQ in its effort to address some of the identified priority issues, as endorsed by the GFCM at its 31st session (held in January 2007). During the 32nd session of the GFCM (held in Rome, in February 2008) the work plan presented by the CAQ was approved by the Commission. On this occasion, the European Commission (EC) delegate confirmed interest in supporting the Working groups of the CAQ by financing the Project "SHoCMed". The SHoCMed project, which has been operative since October 2008 and is funded by a contribution of the EC's DG Mare, has a duration of 40 months.

1.3.1 Project objective

The SHoCMed Project, among other, aims to produce criteria for enhancing the integration of aquaculture in coastal areas by improving site selection and holding capacity benchmarks and reference points. This will also provide a base for harmonisation of standards and for the formulation of appropriate aquaculture policies and legal frameworks for sustainable development of the activity across the Mediterranean, hence ensuring equal terms of competition and minimal environmental impact. Furthermore, the project is aimed at designing a strategy for a consensus on site selection in the region, also at establishing standards, agreed and harmonised methodology adapted to the GFCM region at different levels.

1.3.2 Strategy and methodology

It appears that the required strategy is to develop criteria (including guidelines and standards) for improved site selection and carrying capacity of aquaculture in the perspective of ICZM. It is expected that this would enhance the integration of aquaculture within coastal management; this would be partly possible through the provision of a favourable framework for the selection of aquaculture sites and establishment of suitable carrying capacity for the various types of fish farms in the Mediterranean.

Such an objective implies the use of a multi-disciplinary and participatory approach and methodology, which should be based on extensive reviews of existing knowledge and information on biological aspects (e.g. aquaculture-environment interactions), socio-economic and territorial aspects (e.g. interactions and conflicts with other uses), and regulatory aspects (e.g. existing procedures and regulatory schemes for site selection and carrying capacity assessment). Case studies should be developed across the Mediterranean to test proposed tools and criteria. The relevance and applicability of new procedures and standards for site selection and establishment of carrying capacity should be secured through the participation of stakeholders (producers, regulators, policy makers) at all stages of the project duration.

Although various studies have been carried out and different tools for the management of the coastal zone have been defined, selection of sites for aquaculture is still a critical and unresolved issue in most Mediterranean countries. Several programs, which are related to site selection and establishment of carrying capacity of aquaculture sites in the Mediterranean or to other specific issues addressed within SHoCMed, have been undertaken or are being performed. SHoCMed may, where relevant, build on the most recent programs or establish links with other current initiatives, and latch onto more recent technical outputs and guidelines, such as the ones by IUCN[1]. In particular, SHoCMed may build on the guidelines on interactions of aquaculture with the environment, and on site selection and site management which IUCN formulated together with the Federation of European Aquaculture Producers (FEAP) and with the support of the Spanish Minister of Agriculture, Fisheries and Food**.** The collaboration between the GFCM and the IUCN on sustainable aquaculture was also recalled during the 32nd session (Rome, 25 - 29 February 2008) in which a specific agreement was signed by the two parties. For the activities related to Environmental Impact Assessment (EIA), a valid contribution has also been incorporated in the FAO[2] review on EIA and monitoring in aquaculture. In addition SHoCMed has also utilised outputs from some relevant and recent projects and initiatives from a larger area than the GFCM region, and hence not only focused on the Mediterranean.

Particular links have been established with the other Subsidiary bodies of the CAQ; between SHoCMed and InDAM[3] for aspects related to the identification of indicators on aquaculture for the environmental dimension, as well as between SHoCMed and SIPAM[4] for the aspects related to data banks.

Links with other regional projects and initiatives related to aquaculture sustainability and ICZM will also be established to follow linkage between the sustainability of aquaculture and that of Mediterranean fisheries, in particular coastal fisheries.

The integration of the SHoCMed project in the GFCM framework will be beneficial as the latter will provide regular fora for discussion on progress and follow-up, as well as access to donor for ad-hoc actions that will be determined during the program.

1.3.3 Expected outputs

The work program integrates the outputs outlined below. Output 1 covers activities carried out during the first year of the program; it integrates a number of studies and data gathering exercises on site selection and carrying capacity in order to help refine the SHoCMed strategy, and to confirm the methodology and guide the choice for case studies that will be considered in year 2 and 3 of the program. Criteria and related guidelines for aquaculture site selection will be developed on the basis of the results of output 1 and specific activities (reviews, multi-stakeholder workshops, case studies). Standards and guidelines to be adopted will be detailed at the end of year 1, taking into account the preliminary results of outputs 1 and 2. Understanding of holding capacity issues will be enhanced on the basis of extensive reviews and focussed case studies. Outputs 2 and 3 are yet to be produced.

OUTPUT 1 - *Preliminary study to design the best strategy for a consensus on site selection and establishment of Mediterranean standards for carrying/holding capacity of aquaculture farms has been completed.*

OUTPUT 2 - *Production of criteria and related guidelines (including standards) for aquaculture site selection in the GFCM region.*

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[1] *Interaction between Aquaculture and the Environment* (2007). IUCN, Gland, Switzerland and Malaga, Spain. 107 pages; and *Aquaculture Site Selection and Site Management* (2009) IUCN, Gland, Switzerland and Malaga, Spain. 303 pages

[2] *Environmental Impact Assessment and monitoring in aquaculture. FAO Fisheries and Aquaculture Technical Paper. No. 527. Rome, FAO 2009. 57p. (full text CD – 648 pages)*

[3] InDAM *" Indicators for Sustainable Development of Aquaculture and Guidelines for their use in the Mediterranean (InDAM) GFCM/CAQ"* is a project in support to the activities of the GFCM Committee on Aquaculture (CAQ) which is cofunded by European Commission DG-MARE.

[4] SIPAM . Information System for the Promotion on Aquaculture on Mediterranean www.faosipam.org

OUTPUT 3 - *Assessment and development of issues on carrying capacity of aquaculture sites, and of standards for carrying capacity with a main aim of harmonisation within the GFCM region.*

The project work plan is an annual-based one and strategic revision can be done every year on the basis of the priorities gaps that will be identified.

1.4 SHoCMed activities

The SHoCMed project has been operative since October 2008. The present report refers to the first year of activities, during which the actions listed below were carried out. Reviews of stakeholder's meetings have been prepared, based on the available information relevant to SHoCMed's objectives and taking into consideration the recent outputs of other projects. In particular, the following reviews have been finalised:

- Review of aquaculture-environment interactions in the Mediterranean, including: effects of different types of aquaculture on the marine environment; effects on biodiversity, including effects on habitats and species and on protected areas and other sensitive sites; effects on the water column; organic enrichment of the seabed.
- Review of ecological monitoring of aquaculture activities, including: monitoring change; use of chemical and physical attributes to assess sediment quality; use of physical, chemical and biological variables to assess water quality.
- Review of thresholds for environmental change, including: thresholds for oxygen, benthic fauna, nutrients and Chlorophyll *a*, and seagrass *Posidonia oceanica.*
- Review of interactions between aquaculture and other users of the coastal zone, including: stakeholder issues; stakeholder interaction scales and locations; stakeholder interaction scales and their management.
- Review of site selection criteria, including: challenges for aquaculture in relation to site selection and carrying capacity; environmental considerations for site selection; good management practices for site selection; global change and aquaculture; socio-economic considerations for site selection; infrastructural requirements; risk analysis and site selection.
- Review of environmental and economic bottlenecks for aquaculture production
- Review on existing procedures for site selection in the Mediterranean and evaluation of the effectivity of regulatory schemes and EIA procedures including: aquaculture policies and legal frameworks; licensing procedures; planning; recommendations.

Furthermore, work was initiated to produce a database of published articles dealing with aspects of aquaculture-environment interactions. To this effect, a preliminary list of 281 references to such works has already been compiled and is appended to the present report (see Appendix 1).

As part of the SHoCMed project, the CAQ – WGSC organised a series of meetings and events. These were:

a) ***The first meeting of the Working Group on Site selection and Carrying Capacity (WGSC)*** held at the Institute of Marine Biology of Crete (Greece) from 21 to 23 October 2008.

The full report of this meeting is available on the SIPAM web site (ww.faosipam.org), while the main conclusions and specific recommendations were presented at the 7th session of the CAQ held in Tirana, Albania (17 - 19 December 2008) and are summarised as follows:

Conclusions

- The WGSC confirmed the need for proper site selection protocols for marine finfish aquaculture in the Mediterranean region and emphasised that these should be given priority. This action should be implemented following the coordination of the numerous initiatives present at the Mediterranean-wide level, taking advantage of the scientific achievements made within the different dimensions of the aquaculture sector (governance, economic, social, and environmental) and in an interdisciplinary manner.

- The development of aquaculture in the coastal zone should be considered within the context of Integrated Coastal Zone Management and in an ecosystem perspective, using as far as possible the development of aquaculture zoning and a participatory and integrated approach.
- Monitoring of marine finfish aquaculture is essential to evaluate the effects and impacts of aquaculture on the environment and on aquaculture activities. A minimum list of variables to be monitored, that may have an impact on the water column and on the seabed, should include: sediment sampling, redox potential, organic and inorganic nutrients, sediment organic matter, total phosphorus in sediment, sediment grain size, benthic community attributes, and general water quality attributes.
- Monitoring of capture fisheries (i.e. fisheries landings and surveys of fisheries resources) in aquaculture areas could contribute to a better identification, evaluation, and assessment of the potential positive interaction between aquaculture activities and local fishing communities.
- For the purposes of the WGSC it is necessary to take more advantage of the outputs and achievement of different experiences, pilot projects, studies and research programs carried out in the Mediterranean, with respect to site selection, and with particular emphasis on aspects concerning aquaculture-environment interactions and carrying capacity.

<u>Recommendations</u>

- An environmental monitoring program for finfish marine aquaculture should be established at local and national levels. It is necessary to monitor the physical environment, including both the water column and sediments in the vicinity of fish farms (in particular, at sites that support maerl and *Posidonia oceanica* habitats) in order to ensure that environmental quality standards that have been established for the relevant water body are not exceeded. A limited list of variables to be measured at Mediterranean fish farms has been established to serve as a basis for pan-Mediterranean environmental impact assessment (EIA) and monitoring protocols. The establishment of robust monitoring programs at aquaculture sites will enable the Working Group to further toward addressing environmental carrying and holding capacities for relevant Mediterranean sites.
- In Mediterranean countries, the establishment of new aquaculture sites in the vicinity of *Posidonia oceanica* beds should be avoided. In any case, a monitoring protocol to assess the impact of fish farms on seagrass beds should be introduced. Compensatory and/or mitigation plans should be introduced for aquaculture sites (minimum water depth, minimum distance from the shore and from other relevant features, current regime, and translocation/rotational plans for the farm).
- For site selection and site management of Mediterranean aquaculture, the procedures of Environmental Impact Assessment (EIA) as well as Environmental Monitoring Programs should be mandatory; these should be harmonised and implemented in all Mediterranean countries.

b) ***Workshop on National legislation on site selection, Monitoring programs and Environmental Impact Assessment for finfish marine aquaculture (SHoCMed)*** held in Vigo (Spain), from 13 to 14 July 2009, and organized with the cooperation of the Centro Tecnológico del Mar-Fundación (CETMAR) of Vigo (Spain).

The full report of this meeting is available on the SIPAM web site (www.faosipam.org).

The workshop took the form of ‘planning meetings’ and ‘working groups’, attended by the various experts, and in which priorities were identified. During the workshop, the discussion focused on the current situation of aquaculture licensing procedures that are currently in place in different Mediterranean countries. Particular attention was given to environmental aspects, to site selection criteria and related regulations, to local aquaculture planning and to environmental monitoring plans.

Presentations were given by experts (scientists, farmers and staff from national fisheries directorates) from Albania, Croatia, Greece, Italy, Morocco, Spain and Turkey.

Experts from Centro Tecnológico del Mar - Fundación CETMAR presented preliminary results of the SHoCMed questionnaire on the different legal and administrative national frameworks that had been previously sent to Mediterranean experts. The presentation was followed by a discussion on some national case studies on aquaculture zoning and space allocation of aquaculture activities in the coastal zone, including aspects related to interactions between aquaculture and other coastal zone users.

The main topics highlighted during the discussion, as well as the main aspects related to the workshop (planning, monitoring and legal aspects) that were recommended for further action within the SHoCMed Project and the WGSC program, are summarised as follows:

Planning zones:

- The case studies of Galicia and Andalusia (Spain), Sicily and Veneto (Italy), Bodrum (Turkey), Mali Stone and Velebiti Channel Areas (Croatia), as well as the general presentations from Greece, Turkey and Albania, provided a heterogeneous picture of the experience on aquaculture zoning and planning approach in the Mediterranean region.
- All the presentations highlighted the evident need to integrate aquaculture activities into the coastal zone. The experience on allocated zones for aquaculture is still limited and, as stated in all the cases studies presented, there is still no consideration of this issue at national level.
- Participants agreed that appropriate sectoral planning should be based on sound knowledge of the sector, level of development, growth potential and market capacity. It is necessary to achieve a balance between aquaculture operations and all other activities operating in the public domain in order to achieve effective and sustainable development of the sector. The sector’s growth potential in each geographic area should also be considered as essential for site selection. Planning activities can be based on regulatory and/or consultative and participatory approaches and/or a combination of these, and made within the context of coastal zone management and ecosystem-approach perspectives.
- A wide consensus was evident concerning space being a limiting factor for further development of Mediterranean aquaculture in many areas, and that good sectoral planning should be based on: availability of human and financial resources; knowledge of the sector and its potential; knowledge of potential sites; availability of strategic development plans; presence of appropriate administrative systems and useful regulations. GIS applications were considered as one of the main tools in supporting sectoral planning to perform an appropriate time and space analysis.
- Economic, social, spatial and environmental analyses, together with participatory and integrated approaches, remain the main aspects to be considered when planning aquaculture zoning.

In the Mediterranean region, experiences with aquaculture activities in the framework of Integrated Coastal Zone Management - or more generally within coastal zone management - are still limited or not well known. An integration process between this knowledge and its legal aspects is still challenging; a more detailed analysis on the required steps to perform in order to solve this issue should also be investigated in depth.

The preliminary analyses made during the discussion and on the basis of the results of the ten questionnaires from different Mediterranean countries analysed by CETMAR showed considerable variation and differences between current procedures and regulatory schemes for site selection assessment, in particular, with respect to norms, rules and regulations on legal aspects of aquaculture, and the concepts and terms used. Such variation is considered to render large difficulties when attempting to harmonise aquaculture legal aspects within the GFCM region.

c) ***Multistakeholder Workshop on Site selection and Carrying Capacity*** **(SHoCMed)** held in Malabata – Tangier (Morocco) on 29^{th} - 30^{th} October 2009 and hosted by the Centre Regional de l’Institut National de Recherche Halieutique (INRH).

Participants at this meeting discussed and presented the main achievements of the WGSC with respect to the SHoCMed activities. The full report of the meeting is available on the SIPAM web site (www.faosipam.org). The conclusions and recommendations of the meeting and a summary of the work plan proposal for the second year of activities of SHoCMed are summarized hereunder:

- Space availability, space allocation and license procedures for farms allocation still remain the main constrains and issues to be addressed for any further development of Mediterranean sustainable aquaculture.

With respect to space allocation and monitoring:

- Site selection should be considered for sustainable marine and coastal aquaculture development by assessing environmental conditions, economic feasibility and social acceptability.
- The multidisciplinary and multistakeholder approach is essential for a better integration of marine aquaculture within coastal zone management and in adopting an ecosystem approach for aquaculture management. If such an approach is used for aquaculture, it could be also considered as a model of sustainability within coastal areas.
- Aquaculture procedures for Environmental Impact Assessment should be mandatory for site selection in the Mediterranean. However, the EIA is not sufficient and should be supported by a risk analysis, as well as by an environmental monitoring program for aquaculture activities.
- Aquaculture growth potential and monitoring should be assessed using tools such as Geographic Information System (GIS) applications. GIS will enable the preparation of a zoning and planning approach for decision makers and other interested parties, while for areas suitable for aquaculture activities, attention should be paid to planning Allocated Zones for Aquaculture. GIS may also be used at appropriate levels (local, national, regional) as a tool to transfer information and for communication between decision makers and different stakeholders in a transparent way. Public administration bodies should also be involved in the collection of data for site selection, or in the process of making them available.
- Particular attention should be paid to monitoring marine aquaculture and capture fisheries for the evaluation of positive (environmental and socio economic) interactions between these activities, when they the two operate in the same areas. Those near-shore areas in which traditional extensive aquaculture practices exist should be censed and assessed. This could be performed by underlining the more evident case studies, by highlighting their socio-economic contribution to the local communities and through their impacts on biodiversity.
- Monitoring of the physical environment surrounding aquaculture installations still remains a priority for evaluation of the effects/interactions/impacts of aquaculture on the environment and on the activity itself. Major attention should be paid to monitoring of the sediments rather than of the water column. To this extent, the list of variables identified by the WGSC (sediment sampling, redox potential, organic & inorganic nutrients, sediment organic matter, total phosphorus in sediment, sediment grain size, benthic community, water quality) has been established.
- There remains difficulty in defining environmental quality standards (EQS) for carrying and holding capacity for aquaculture through the use of common values for benthic attributes; this results from the numerous physical variables (current, water depth, sediment type) and complex interactions thereof. However, harmonization of collection of data on environmental variables at the Mediterranean level will facilitate monitoring since it will enable establishment of reference levels for aquaculture sites.

- Establishment of new aquaculture sites should be avoided or limited in or around sites that support sensitive habitats; if already in existence, the aquaculture installations should adopt strict monitoring and mitigation plans.

With respect to license procedures and legislation for site selection:

The main gaps identified through analysis of the aquaculture legislative framework within the Mediterranean region, using the data obtained from the SHoCMed survey, can be summarized as follows:

- the survey results show considerable heterogeneity in the legal frameworks that regulate aquaculture, such as concepts, definitions, competences, rights, institutions, etc.. The absence of specific regulations tends to serve as a constraint for the development of aquaculture;
- the definition of aquaculture legal frameworks does not include a comprehensive concept which should consider not only the activity itself but also different types of aquaculture, production systems and other relevant criteria;
- there is a predominance of cumbersome institutional procedures, excessive burocracy and lack of coordination between different regulatory/administrative agencies; hence it is desirable to simplify regulations and administrative procedures and enhance coordination tools for use by entities involved in aquaculture planning;
- aquaculture planning in some countries is limited to technical studies or recommendations; aquaculture site selection is generally focused on administrative or environmental criteria; social and economic assessments are not usually included as tools for aquaculture planning; integrated coastal zone management is limited to specific regions or local lack of common criteria and standards with respect to environmental monitoring and EIAs.
- There is a general lack of mechanisms for stakeholder participation which ensure proactive input and accountability of the actors involved; it is desirable that this be resolved at the Mediterranean level.
- the implementation of specific regulations for aquaculture is essential to promote and facilitate aquaculture development;
- regulatory frameworks should also take into consideration aquaculture related laws, including ones dealing with land, water and the environment; the legislative framework should also include all the conditions for its practice as well as guarantees for the rights and obligations of aquaculture license holders;
- there should be coordination among the agencies involved in aquaculture planning; tools need to be in place to ensure coordination of administrative procedures for the granting of the various endorsements; the creation of simple 'one-stop shop' should be promoted; this should centralize license-granting procedures, thus reducing lengthy steps for the granting of various authorizations;
- improvement of governance should be pursued by including aquaculture in strategic policies, and by ensuring that stakeholders have proactive participation in the decision making process, while ensuring stakeholder's accountability. Utilization of indicators should be promoted to assess the impact of aquaculture planning on the activity itself (production, value, employment); the main steps for the inclusion of aquaculture activities on coastal zone management should be identified;
- the building of a national capacity at the institution level for monitoring activities, for legal issues and which uses GIS applications for site selection and site monitoring, should be improved through the implementation of collaborative training programmes;

- there is a need to take stock of the positive experience on planning and integration of marine aquaculture into coastal zone planning within Mediterranean countries; for this it is useful to prepare detailed guidelines for the development and establishment of aquaculture coastal planning procedures;
- there is a need to identify reliable indicators in relation to governance of sustainable aquaculture and to evaluate the impacts of aquaculture, including indicators to measure the results from policies and plans in the medium and short term.

1.5 Main activities to be implemented by the WGSC during the second year of SHoCMed

The following activities are proposed for implementation during the second year of SHoCMed (2010 – 2011):

- *Glossary of terms:* a glossary of the different terms used for site selection and carrying capacity for aquaculture activities will be produced. The glossary will also include aspects related to legal issues and monitoring of marine aquaculture.
- *Environmental Quality Standards (EQS)*: it is planned to prepare a technical review on EQSs for Mediterranean aquaculture on the basis of the main environmental parameters, including physical ones (current regime, water depth, distance from the shore etc) identified by the WGSC. The EQSs should be indicated in relation to the size and allocation of the aquaculture activities. A panel of experts will be established to determine reference values of EQS, through a Delphi approach or another method. Examples will be also taken from case studies and research programmes carried out in the Mediterranean.
- *Harmonised technical protocol for monitoring marine aquaculture activities:* a protocol on procedures for monitoring aquaculture activities based on the identified environmental parameters will be produced. The protocol will take into consideration current regulations and procedures applied at different levels in Mediterranean countries.
- *Updating information on legal aspects on site selection and carrying capacity*: such information collected as part of the SHoCMed Project during its first year of activities will be updated. Particular attention will be given to gaps on reporting and on dissemination of information on monitoring programs and on the legal procedures implemented for improving governance and the participation of the different stakeholders.
- *Improvement of the SHoCMed data bank hosted* on the SIPAM website: the SHoCMed data bank, which includes metadata on unpublished and published environmental data concerning aquaculture-environment interactions, will be finalised. Cooperation will be established with national research institutions in order to improve/update data content and utilisation.
- *Meeting on the Allocated Zones for Aquaculture activities and integration of aquaculture into coastal zone management*: it is planned to hold a meeting which will be aimed at identifying the main aspects, steps to be taken and guidelines needed for the integration of aquaculture activities into coastal zone planning.
- *Review on the Allocated Zones for Aquaculture (AZA) activities and integration of aquaculture into coastal zone management and guidelines (legal aspects, methodologies, and procedures):* A review on experiences on Allocated Zones for Aquaculture in the Mediterranean, and on the integration of aquaculture activities at the different levels of application, including use of GIS tools, will be produced. The review will be based on the currently available information and guidelines.

2. Aquaculture-environment interactions in the Mediterranean Sea

by Ioannis Karakassis and Angel Dror

2.1 Effects of aquaculture activities on the Mediterranean marine environment

Aquaculture, in particular fish farming, releases a variety of wastes into the aquatic environment including nutrients such as nitrogen and phosphorus, organic material, and a number of associated by-products such as medication and pesticides, which can have undesirable impacts on the environment (Fernandes et al. 2001). Furthermore, aquaculture influences directly and indirectly, various biogeochemical processes in the marine environment (Karakassis 1998), the activity is made in the coastal zone where biodiversity is high and human pressures are complex and on the increase, and it involves impacts at varying spatial and temporal scales (Silvert 1992). An extensive list of the potential impacts of aquaculture on various biotic communities has been compiled by Milewski (2001); this includes effects (Table 1) related to the physical presence of floating structures and nets, to management issues such as the use of anti-predator practices, to the use of chemicals for various purposes, and to normally discharged particulate and dissolved wastes.

Some of the impacts shown in Table 1 have been extensively studied and are well documented in the scientific literature, whereas others are inadequately or poorly documented (as a result of technical problems or reporting from a single study in which information on the spatial extent of the problem is limited and/or the environmental conditions are highly variable). The spatial scales affected are also variable depending on the topographic and hydrographic characteristics of the site, the response of the environment, the dispersion processes for the associated pollutants and the mobility of the affected marine biological communities. Recovery of marine communities in general, and particularly in relation to aquaculture effects, is poorly studied. Most of the impacts are expected to be negative although the severity of the impact can vary between sites and individual farms.

Some of these impacts are related to inefficient management, and can be avoided or reduced considerably by adopting alternative management options, improved technologies or other mitigation measures (e.g. use of more efficient containment methods to avoid the escape of fish, use of vaccines to replace antibiotics, minimisation of food wastage etc). On the other hand, some impacts such as those resulting from nutrients released from uneaten fish feed and from faeces, are difficult to avoid as they form an intrinsic part of the fish farming process.

The severity of some of the above environmental effects are related to site-specific environmental attributes, such as depth, hydrographic conditions, water quality, sediment characteristics, and the presence of other activities and pressures in the area, Glasson et al. (1999) have used different types of classification of impacts for the various types of projects. It is important to place the environmental effects of aquaculture within the context of this classification scheme:

Physical and socioeconomic: this category refers to biological and geochemical impacts (usually negative) and socioeconomic effects, some of which are likely to be positive (e.g. increase in employment). Some of the biological effects, however, are likely to have secondary effects on the local economy e.g. through changes in fisheries production (if any) or through changes in water quality.

Reversible and irreversible impacts: most of the environmental effects of aquaculture are reversible, although the temporal scale of recovery is not sufficiently known. Likely exceptions include genetic effects, particularly if they involve extinction of local populations and/or genotypes.

Adverse and beneficial: Most effects of aquaculture are adverse, as is the case with most anthropogenic activities. However, there are cases where beneficial effects could arise with respect to particular use of the environment (e.g. fisheries).

2.2 Effects of different types of aquaculture

Fish farming in cages affects the marine environment through several pathways, particularly through the release of nutrients, particulate material and chemicals. Aquaculture practiced using land-based closed systems is more likely to avoid most of these adverse problems by using treatment methods to control the quality of effluents, although this will increase the production costs to potential unsustainable levels.

The effects of molluscan farming on the environment are usually simpler and in most cases they go towards the opposite direction of finfish farming, at least in terms of effects on the water column. In particular, mussel farming results in intense filtration of seawater and removal of particulate material from the water column. In this context, it has been suggested that coupling fish with mussel farming is likely to reduce the overall effect of aquaculture. Along these lines there have also been suggestions for polyculture systems of various types. However, there is still the need for information on the economic viability of such systems, as well as on their efficiency in improving the environmental conditions in areas of deployment. For example, mussels are likely to take up considerable amounts of small-size particles from the water column but they cannot remove large-size food or faecal pellets which are the very ones causing anoxic conditions on the seabed below fish cages. Furthermore, mussels produce large amounts of pseudofaeces (filtered and rejected particles) settling on the seabed, thereby inducing benthic effects similar to those caused by fish cages.

Tuna farming has been introduced recently in the Mediterranean but up to 2007 there were more than 60 farms registered in the Mediterranean, particularly in Croatia, Cyprus, Greece, Italy, Malta, Spain, Tunisia and Turkey (CIESM 2007). There are serious reservations regarding the sustainability of this industry and the direct effects it has on wild tuna stocks, as well as the indirect effects on other fish species used to feed the tuna in captivity, and the potential for causing mass mortalities through translocation of pathogens when using imported fish feed (see review in CIESM 2007). However, from the local environmental point of view it would be expected that the fact that these farms are located in offshore waters with considerable depth, and their potential to use state-of-the-art equipment, could minimize their direct impact on the surrounding environment. Furthermore, as the farming/fattening season is approximately 6 months, there is a period during which the environment is allowed to recover, and this is expected to result in better environmental performance for these farms. Despite the above, the information available to date on interactions of tuna-farming with the environment is not very encouraging.

Table 1 - Effects of aquaculture on marine biotic communities (modified from Milowski, 2001); int = intermediate, loc = local, lar = large, unid = unidentified.

Source of pressure	Potential effect on biota	Level of scientific documentation	Communities affected	Relevant/expected spatial scale	type of impact	Estimated recovery of the community
physical structure	Direct mortality through entanglement	poor	Vertebrates	local	neg	medium
	Behavioural changes in coastal pelagic fish	medium	Vertebrates (Fish)	local	unid	unidentified
	Behavioural changes in coastal birds and marine mammals (e.g., avoidance)	poor	Vertebrates	loc/int	neg	unidentified
predator control systems	Direct mortality	poor	Vertebrates	loc/int	neg	unidentified
	Behavioural changes of wild fauna	medium	Vertebrates	loc/int	neg	unidentified
fish escapement	Disease transmission to other species	poor	various (probably fish)	int/lar	neg	unidentified
	Genetic interactions with wild fish	High	Vertebrates (Fish)	int/lar	neg	slow
	Displacement of wild fish from natural habitat (e.g., through competition, predation)	poor	Vertebrates (Fish)	int/lar	neg	unidentified
release of uneaten food and faeces	Suffocation and displacement of benthic organisms	High	Macrofauna	local	neg	slow
	Loss of foraging, spawning and/or nursery habitat for wild species	High	various	local	neg	slow
	Loss of biodiversity	High	Macrofauna	local	neg	slow
	Fragmentation of benthic habitat	poor	various	loc/int	neg	slow
release of nutrients	Change in water quality	poor	various	loc/int	nrg/pos	rapid
	Mortality of plankton (including fish and invertebrate egg and larvae)	poor	various	local	neg	rapid
	Increased primary productivity	poor	various	loc/int	nrg/pos	rapid
	Shift in plankton community composition	poor	Phytoplankton	loc/int	unid	rapid
	Increase in harmful algal blooms	poor	various	loc/int	neg	rapid
	Decline of seagrass meadows	poor-medium	marine plants & various indirectly	loc/int	neg	slow
antibiotics	Tainting of wild species	poor	various	local	neg	rapid
	Changes in benthic bacterial community	poor	microbes	local	neg	unidentified
	Resistant microbial strains	poor	various indirectly	unknown	neg	unidentified
pesticides	Direct mortality and sublethal effects	poor	invertebrates	local	neg	unidentified
	Tainting of wild species	poor	various	local	neg	unidentified
disinfectants and anti-foulants	Direct mortality and sublethal effects	poor	invertebrates	local	neg	unidentified
	Tainting of wild species	poor	invertebrates	loc/int	neg	unidentified
	Changes in physiology	poor	invertebrates	loc/int	neg	unidentified

2.3 Effects on ecosystems, habitats and species

The European Environmental Agency (EEA) has defined (http://glossary.eea.europa.eu/); different types of sensitive areas such as:

- **Environmentally sensitive areas**: *areas of a country where special measures may be given to protect the natural habitats which present a high level of vulnerability*;
- **Ecologically sensitive area**: *an area where it is likely that a change in some parts of the system will produce a recognizable response*, and
- **Sensitive natural area**: *Terrestrial or aquatic area or other fragile natural setting with unique or highly-valued environmental features*.

These terms characterize various geographical sites, habitat types and ecosystems which may be subject to a wide range of anthropogenic pressures and could also be protected by various specific international conventions and agreements or by general management measures that promote sustainable management of natural resources.

Huntington et al. (2006) have reviewed the potential effects of aquaculture on nature conservation, focusing on a series of designations, i.e. Biogenetic reserves, Biosphere reserves, Marine Protected Areas, Ramsar Sites, World /Heritage Sites, Natura 2000 sites (Special Protected Areas (SPA) and Special Areas of Conservation (SAC), and Specially Protected Areas of Mediterranean Importance (SPAMI). Based on an initial screening, habitats included under the EU habitat Directive that are likely to be affected by aquaculture were selected and assessed for sensitivity. A modified version of the Huntington et al. (2006) analysis of the sensitivity of key habitats and species to various pressures from aquaculture operations, but which is only focussed on ones that are of relevance to the Mediterranean region are given in Table 2.

Of the habitats and species listed in Table 2, there is adequate documentation on the effects of fish farming on seagrass meadows (*Posidonia oceanica*) and maerl beds in the Mediterranean.

Seagrass habitat

Posidonia oceanica is a slow-growing endemic seagrass species in the Mediterranean that thrives in clear oligotrophic waters with high transparency (Holmer et al. 2003), provides important ecosystem services such as shelter to juvenile stages of various marine species, protects the coast against sediment erosion, and carried out carbon sequestration, thereby helping to reduce CO_2 levels in the atmosphere. *Posidonia oceanica* are known to be considerably affected by fish farming (Diaz-Almela et al. 2008; Holmer et al. 2008, Apostolaki et al. 2009, 2010), when the fish cages are sited close to the farm (<400m according to Holmer et al. 2008). However, fish farming is only one of the human pressures affecting *P. oceanica* beds in the Mediterranean. A series of other, very common uses of the coastal zone have been reported to affect, to varying degrees, this important habitat (Orth et al. 2006; Boudouresque et al. 2006). These include:

1. Coastal eutrophication, which leads to growth of macro- and microalgae, reducing the amount of light reaching the *P. oceanica* beds and, consequently, the photosynthetic capacity of the plants (Alcoverro et al. 2001) and the maximum depth to which the seagrass could survive (Boudouresque et al. 2006 and references therein).
2. High water temperature and reduced light (Orth et al. 2006) conditions, which are typical of sites where thermal pollution is present, e.g. in the vicinity of power plant or desalination plant effluents (Latorre 2005; Sánchez-Lizaso 2008).

3. Herbivory by waterfowl, urchins, and fish, which is assumed to intensify as a result of anthropogenic pressures, such as the presence of sewage discharges (Jupp 1977).
4. Introduced species**,** such as *Caulerpa racemosa* and *C. taxifolia*, which colonize the seagrass meadows and have shown extraordinary rapid expansion (Boudouresque et al. 2006), especially when the *P. oceanica* beds are already stressed, thereby placing large areas of the habitat at great risk. Colonization of the alien algae is facilitated through transport by fishing and recreational vessels and commercial ships.
5. Dredging and coastal works**,** such as construction of harbours (Leriche at al. 2006) or coastal protection works (Gongora-Golzalez et al. 1996 in Boudouresque et al. 2006), artificial beach replenishment (González-Correa et al. 2008, 2009).
6. Destructive fishing activities, such as trawling, which is detrimental to various benthic habitats (Kaiser et al. 2006) have been shown to affect *P. oceanica* beds (Martin et al. 1997; Boudouresque et al. 2006 and references therein). It may take more that 100 years for the recovery of a *P. oceanica* bed after severe degradation due to intense trawling (González-Correa et al. 2005).
7. Anchoring by pleasure boats (Ceccherelli et al. 2007; Montefalcone et al. 2008), may cause direct mechanical damage to *P. oceanica* beds. Besides the overall loss of habitat area, there are potential effects of habitat fragmentation resulting from such disturbance (Kaiser et al. 2005), besides potential effects on species associated with the habitat and requiring a large territory.
8. Use of explosives either for military purposes or for (illegal) fishing causes total removal of seagrass and the resulting “dead zone” remains uncolonized for decades (Boudouresque et al. 2006).
9. Coastal salinity changes resulting from altered water flow for irrigation. Diversions of rivers (e.g Ebro in Spain, Nile in Egypt, and Acheloos in Greece) and hydroelectric dams reduce freshwater input to coastal ecosystems usually for the benefit of agriculture or to support the increasing freshwater demands of large cities.
10. Pulsed turbidity exacerbated by erosion due to poor land management (Orth et al. 2006). This situation is not unusual in the Mediterranean where desertification is triggered by climatic variability and demographic disequilibrium, both of which directly and indirectly affect water budgets and land degradation through associated changes in land use patterns (Puigdefábregas & Mendizabal 1998).

The recovery time of *P. oceanica* meadows when damaged may be very long, sometimes of the order of centuries, and losses of this species are thus considered to be irreversible at managerial time scales. The good water quality required by *Posidonia* makes this habitat “ideal” for fish farming and therefore there are fears that a large proportion of fish farming activity is sited above such meadows, despite existing regulations for the conservation of this seagrass in most Mediterranean countries. Research results from the last few years have provided information on the mechanisms of environmental deterioration related to the loss of *P. oceanica* habitat and of the spatiotemporal scales of the processes involved. Findings include severe degradation or disappearance of *P. oceanica* meadows in the vicinity of fish farms in the western Mediterranean (Pergent-Martini et al. 2006), changes in the flavonoid content possibly due to high grazing pressure (Cannac et al. 2006) and reduction in vertical rhizome growth of *P. oceanica* (Marba et al. 2006). Epiphyte assemblages of the leaves and rhizomes of *P. oceanica* located close to fish farms have shown different patterns of composition and abundance in comparison to those at reference sites (Balata et al. 2008). Decreased meadow density was recorded in the vicinity of fish farms in Croatia (Kruzic 2008), and high shoot mortality rates were noted in the vicinity of fish farms (*ca* 20 times higher than at the control sites) in Spain, Italy, Greece and Cyprus (Diaz-Almela et al. 2008).

Table 2 - Sensitivity of key Mediterranean habitats and species to aquaculture pressures (modified from Huntington et al 2006).

Pressure category / Habitat species	Smothering	Turbidity	Dissolved 02	Nutrients	Change in coastal processes	Infrastructure impacts	Visual land & seascape modification	Disturbance	Predator control	Chemicals	Pathogen transmission	Inter-breeding with wild organisms	Introduction of alien spp	Indirect ecosystem pressures
Reefs: Polychaete Worm Communities	3	1	3	?	1	3				?	?			
Seagrass Beds on Sub littoral Sediments	3	2	3	3		3			1	3			3	
Sandbanks, Mudflats & Sandflats	3	2	3	3	1	3	3	3	1	3			1	
Maerl Beds	3	2	3	3	2	3				?			3	
Kelp and Seaweed Communities	3	3	3	3		2				?			3	
Saltmarsh Communities	1		1	1	1	2	2	2	1	3	?			
Sand Dune Communities					2	2	2	2	2	1				
Shingle Communities	1					2	2	2	1		?			
Cetaceans								2	3	2				
Pinnipeds								2	1	2				
Fish	1		1					1		1	3	3	1	3
Birds	3	2	3			3		1	1	2				3

Sensitivity Key :	High	Moderate	Low	Negligible	Uncertain
	3	**2**	**1**	**0**	**?**

Perez et al. (2008) have shown a significant effect of fish farming on *P. oceanica* physiology, particularly of the total nitrogen content and of $\delta^{15}N$ in epiphytes. Invasion by sulphide in the seagrass habitat has resulted in higher plant mortalities close to fish farms (Frederiksen et al. 2007). Holmer & Frederiksen (2007) have shown that despite the low accumulation of the organic matter (which is expected due to the highly dispersive characteristics at such sites), the sulphate reduction rates remain at very high levels, inducing significant habitat degradation. Recovery of the meadows after the cessation of fish farming which has been referred to above is very slow (Delgado et al. 1999).

A synthesis paper from the MedVeg project (Holmer at al. 2008) has examined a series of drivers of seagrass decline due to fish farming effects and identified sedimentation of waste particles in the vicinity of fish farms as the main driver of benthic habitat deterioration. Holmer et al. (2008) have recommended a safety distance of 400m from fish farms for the conservation management of *P. oceanica*, together with establishment of permanent seagrass sampling plots for monitoring the health of the meadows.

The health of *P. oceanica* beds in marine protected areas has been found to be not much better that of beds in unprotected areas in the western Mediterranean (Montefalcone et al. 2009). On the other hand, according to Boudouresque et al. (2006), the most degraded *P. oceanica* beds are found in the vicinity of urban areas and/or close to harbour zones, implying that local multiple stressors are behind seagrass declines (Orth et al. 2006); this is also compatible with the positive dynamics of *P. oceanica* beds found in Mediterranean marine protected areas (MPAs) by González-Correa et al. (2007).

Maerl habitat

Maerl beds are formed by an accumulation of unattached calcareous red algae (*Rhodophyta*), growing as a superficial living layer on sediments within the photic zone. They are are spatially complex habitats with a high degree of species and trophic group diversity (Barbera et al. 2003). Mediterranean maerl beds are to be considered for inclusion in national inventories of sites of conservation interest, as required by the SPABIM Protocol of the Barcelona Convention. In spite of their importance, and the requirement for their conservation management, European maerl grounds suffer a variety of anthropogenic perturbations, including direct exploitation through extraction, fishing impacts and chemical pollution by organic matter and excess nutrients. Hall-Spencer et al. (2006) carried out a survey in 3 shallow sites (10 m – 15 m) in Scotland and found that fish farming affects negatively maerl beds. A similar survey by Sanz Lázaro (2009) in the Mediterranean also showed significant negative effects, verifying the predictions of laboratory experiments by Wilson et al. (2004). Maerl has a very low growth rate; approximately 0.1 mm - 1 mm per year, and the production and accumulation rates are similar to the lower end of growth rates for tropical coral reef environments (Bosence and Wilson, 2003). Although rapid on a geological time-scale, these accumulation rates are far too low for the maerl to be regarded as a sustainable resource for extraction for agricultural and industrial use. In a recent study by Georgiadis et al. (2009) undertaken in the Aegean Sea (Eastern Mediterranean), coralligène formations were recorded at water depths ranging from 60 m to 114.0 m, with 81% of the total surface being restricted to water depths between 70 m and 90 m. Within 50 m – 120 m depth range, maerl habitats occupied 4.3% of the seabed area. Therefore, a problem with maerl conservation becomes important when considering moving fish farming offshore. In this case, the site selection process should ensure that there are no maerl beds in the close vicinity of the proposed farm site.

Marine protected areas

There is particular concern on the effects of aquaculture on sensitive areas such as Marine Protected Areas (MPAs). In the Mediterranean, some fisheries (mainly small pelagic planktivore species) have increased due to an increase in nutrient supply, whereas some others (mainly benthic and high value slow growing) have decreased as a result of overfishing (Goni et al. 2000). Species like lobster (*Palinurus elephas*) and red coral (*Corallium rubrum*) have been identified to be under pressure more than a decade ago (FAO 1997). Yet, professional fishing is not the sole agent of overexploitation of Mediterranean species; sport fishing, mainly with harpoons, spears and rods, has a substantial impact, especially on the largest and less abundant species such as groupers and croakers (Goni et al. 2000). A series of measures have been adopted by various countries to reduce the effects of these threats, including a ban on some fishing gears, exclusion of some types of fishing from sensitive areas (such as trawling at depths shallower than 50 m) and the creation of MPAs. However, conserving or replenishing exploited species is not the only or main objective of all MPAs. A number of other objectives exist, ranging from the protection of sensitive habitats of endangered species (e.g. the Sporades National Park of the eastern Mediterranean for the monk seal (*Monachus monachus*), to the protection of singular assemblages (e.g. the coralligenous community of the Columbretes Islands Marine Reserve, western Mediterranean), and to conserve or restore relatively pristine habitats (Goni et al. 2000).

Compatibility of mariculture with MPAs is not straightforward. The size of the farms, the characteristics of the receiving environment, and the specific objectives of the MPAs are critical issues. However, it is reasonable to assume that impacts from aquaculture must be minimized to prevent any deterioration to such sites. The management of aquaculture activities falls under a number of high level objectives defined under the Convention for the Protection of the Mediterranean Sea against Pollution (the Barcelona Convention 1976).

As noted by Huntington et al (2006), as well as national or international legislation applicable to SPAMI management plans, the Barcelona Convention also requires a number of specific provisions which would be directly applicable to management of aquaculture activities:

- the strengthening of the regulation of the release or dumping of wastes and other substances directly or indirectly to impair the integrity of the area;

- the strengthening of the regulation of the introduction or reintroduction of any species into the area;

Where such legislation does not exist, however, the requirements of the Barcelona Convention should ensure that management plans are suitably robust to afford a high level of environmental protection.

Effects on biodiversity in general, including species diversity
Although some species are directly affected by aquaculture and there is a general tendency for species diversity beneath cages to decrease, it has not yet been established with certainty that fish farming is a threat to biodiversity. According to Margalef (1997), there is a clear distinction between biodiversity (i.e. the total number of available species or genotypes in an area) and ecological diversity or eco-diversity, which can be inferred by sampling local biotic communities. In this context, local changes in community structure that affect a small patch of the seabed or a few cubic meters of seawater, cannot be considered as a decline in biodiversity. By contrast, threats to biodiversity arise when a specific type of habitat (usually rare or supporting an endangered species or a key-habitat supporting life over a very large area) are severely degraded over large spatial scales or when populations of K-selected species (i.e. those having a large size and low reproduction rate) are reduced to unsustainable sizes. At present, most of the scientifically documented effects of fish farming are those on macrofaunal invertebrates (see section on organic enrichment below) within a zone beneath and close to the farm cages. These organisms are ecologically important but it is very unlikely that they will become extinct or that their population at the larger spatial scale will be significantly affected. The potential problems affecting biodiversity in relation to aquaculture

are mortality of large fauna, effects on seagrass meadows and changes in the trophic status of large water body ecosystems. Important issues concerning the reduction and/or loss of biodiversity in the Mediterranean are:

- **Effects on key habitats:** Concerns relate particularly to *Posidonia oceanica* meadows and maerl habitat (Barbera et al. 2003); see sections above. Maerl beds are structurally complex habitats with a high degree of species and trophic group diversity, and are already under pressure from fishing activities. However, there is little information on the presence of this habitat at sites used for aquaculture in the Mediterranean, and also little action to prevent establishment of farms over such beds. On the other hand information from the North Sea (Hall-Spencer et al. 2006) has shown that the effects of fish farming of maerl is severe and probably irreversible.

- **Effects on wild fish**: Interactions between farmed and wild fish in the Mediterranean have been addressed by various authors during the past couple of decades. Studies by McDougal & Black (1999) from the Mediterranean and by Angel et al. (1995) from the gulf of Aqaba, have attributed the relatively low impacts of organic enrichment on the seabed to consumption of some of the organic matter (OM) by demersal fish and invertebrates. Diving and video surveys made beneath fish farms in the Western and Eastern Mediterranean (Dempster et al, 2002; Smith et al. 2003; Vega Fernandez et al. 2003; Golani 2003) confirmed that large numbers of fish of various species were aggregated in the vicinity of the fish cages during feeding. This aggregation of wild fish has been shown to be related to the feed supply rather than to an FAD-effect (Tuya et al. 2006) and their densities approach natural values following cessation of fish farming. Dempster et al. (2002) have shown that the abundance, biomass and species richness of the aggregated wild fish assemblages are negatively correlated with distance from the shore and positively correlated with the size of the farm. These authors suggest that coastal cage fish farms may act as small pelagic marine protected areas (MPAs), although in a later paper (Dempster et al. 2004) they also emphasize the potential effects of such large aggregations, including increased vulnerability to fishing and pathogen transfer between caged and wild fish. Vita et al. (2004) conducted field experiments with sediment traps and concluded that 80% of the particulate OM released from the rearing pens may be consumed before settling on the seabed and have attributed a large part of this consumption to the wild fish aggregating in the vicinity of the farms. On the other hand, Dempster et al. (2005) have shown that there are differences between aggregations in the Mediterranean and these outside the region with respect to vertical variation in the distribution of the wild fish assemblages, and thereby concluded that there is some uncertainty in modelling nutrient dispersal prior to the installation of fish cages. Fernandez-Jover (2007a) have shown that the leaching of ammonia from fish faeces was generally higher compared to that of food pellets, and that the large biomass of wild fish in the vicinity of cage farms may reduce adverse impacts on benthic habitats but they increase nitrogen (N) and dissolved organic carbon (DOC) loading of the water column, thereby affecting the pelagic system and modifying the partial dispersion of wastes. Furthermore Fernandez-Jover (2007b) found that wild fish associated with fish farms had significantly higher fat content than those at the control area; therefore, there is some potential for increase in their spawning ability, particularly if they are also protected from fishing. A series of papers published from the Eastern Mediterranean have addressed the issue of interactions with wild fish at larger spatial scales i.e. beyond the FAD effect. Machias et al. (2004) have shown that fish densities in a coastal bay in the Aegean Sea where a fish farming zone was established are now higher by a factor of two in comparison to those recorded in 1987, i.e. before the start of fish farming in the area. Furthermore, Machias at al. (2005) used experimental trawling in three fish farming zones in the Aegean to show that the abundance, biomass and diversity of demersal fish was significantly higher there than at the control areas. Time series analysis of commercial fisheries landings in areas with and without fish farming (Machias at al. 2006) also showed a sudden increase in landing biomass after the start of aquaculture in the fish farming zones. These authors have attributed these changes to a shift of primary production coupled with rapid transfer of dissolved waste nutrients up the food web in a nutrient-starving oligotrophic system.

- **Effects on K-selected species: These** include potential negative interactions between fish farmers and sea-turtles and marine mammals, and tuna preying on caged fish. Recently, it has been suggested that there is a potential link between the decline of the short-beaked common dolphin *Delphinus delphis* population and prey depletion due to the exponential growth of aquaculture (Canadas & Hammond 2008).

- **Introduction of alien species**: Although shipping is by far the most important vector (particularly through ballast water) for species introductions (Bax et al. 2001), aquaculture and particularly shellfish farming is also a significant source of intentional or unintentional introduction of alien species (Galil 2000, Verlaque et al. 2002; 2005). A series of studies have also demonstrated that non-native escapees from fish farms have been caught 5 years after escaping (CIESM 2007 and references therein).

- **Disease and parasites:** Although aquaculture in the Mediterranean is relatively young, some signs of spreading of diseases and parasites have been recorded (Breuil et al. 2001; Papapanagiotou & Trilles JP 2001; Delepee et al. 2002; Pujalte et al. 2003; Mladineo 2005; Diaz Lopez et al. 2008), occasionally causing considerable mortalies to the farmed stocks. The establishment of fish farming zones with production levels much higher than those found at present, is very likely to favour negative biotic interactions of various kinds, including the introduction and spread of parasites, disease or even attraction of predators (e.g. *Pomatomus* spp, see Sanchez-Jerez et al., 2008). The effects that these biotic interactions may have on native populations and particularly on endangered species are difficult to predict under the current status of knowledge.

Physical effects on habitats and species

Finally, there are concerns on the physical effects of aquaculture on habitats and species. The very presence of aquaculture floating structures imposes changes in water circulation (Iwama 1991), they provide a hard substratum for attachment of various organisms and serve fish aggregating devices (FAD). Currently there is little information from the Mediterranean regarding the effects of floating structures or on other direct physical impacts despite the distinctive peculiarities of both the marine environment and the characteristics of the fish farming industry.

Changes in chemical and physical properties of the seabed beneath the cages (decrease in redox potential, accumulation of organic material, increase in water content etc.) result in changes to the structure of benthic communities present in the vicinity of the farm (Karakassis et al. 2002). Some important Mediterranean marine habitats, such as seagrass *Posidonia oceanica* meadows, are severely affected by the release of nutrients and/or change in optical properties of seawater (i.e. reduction in the amount light penetrating through the water column). There is fear that some large species, such as tuna, birds and mammals are at risk due to various interactions with fish farms and fish farmers. However, it is not known whether these negative interactions can have a significant effect on populations of such species.

2.4 Effects on the water column and nutrients

The Mediterranean is the largest oligotrophic water body on Earth (Krom et al. 2005) and, unlike most marine areas it is, at least in part, P-limited (Krom et al. 1991). A recent lagrangian experiment carried out in the Eastern Mediterranean (Thingstad et al. 2005) showed no increase in primary production or chlorophyll *a* (Chla) content after an episodic addition of phosphorous (P). This was interpreted as being due to rapid grazing of the increased phytoplankton production. Comparative experiments with nutrient addition in mesocosms studied within the framework of the COMWEB project (Olsen et al. 2001, 2006) showed that the nutrients added to Mediterranean, Baltic and Norwegian coastal mesocosms were effectively removed from the water via photosynthesis, but only in the case of the Mediterranean experiment did the autotrophic biomass not increase. Olsen et al (2006) provided several explanations for this Mediterranean peculiarity, such as a high phytoplankton lysis rate (Agusti & Duarte 2000), or efficient grazing by mesozooplankton (mainly dominated by doliolids in their experiment). Karakassis et al. (2005) have shown that there is little risk of hypernutrification at the large spatial scale in the Mediterranean due to nutrient input from fish farms and concluded that water quality effects are likely to occur at small spatial scales. In a recent series of investigations on the water column in the vicinity of fish farms located adjacent to the Mediterranean coast, there was little observed increase in Chla content (Pitta et al. 1999, La Rosa et al. 2002, Pitta et al. 2005) which was also the case in other surveys made in the vicinity of fish farms in other parts of the world (Nordvarg & Jahansson 2002; Soto & Norambuena 2004). This was despite the continuous nutrient supply which is known to be discharged from fish farming activities (Holby & Hall 1991, Hall et al. 1992; Karakassis et al. 2005 and references therein). A recent study by Dalsgaard & Krause-Jensen (2006) using macroalgal and phytoplankton bioassays revealed high primary productivity near fish cages, which decreased rapidly with distance from the farm. The experiment with dialysis bags was repeated using filtered and unfiltered seawater (Pitta et al., 2009) and showed that grazing played an important role in the regulation of phytoplankton communities, which is also compatible with the findings of Thingstad et al. (2005) regarding addition of P, as well as with the findings of Machias et al. (2004, 2005, 2006) regarding rapid transfer of nutrients up the food web. Recent studies using meta-analysis of a large number of papers dealing with the ecological effects of aquaculture (e.g. Sara 2007) have shown that the effects of nutrient addition on the water column in marine ecosystems are much less than in freshwater or estuarine ones.

2.5 Organic enrichment of the seabed

Nutrient enrichment of the seabed (i.e. increased organic content of the sediment) is the most widely known effect of fish farming globally. Such effects have been reported from various parts of the world, including Scotland (Brown *et al*. 1987), the East coast of Canada (Hargrave *et al*. 1993), as well as for a farm sited on a sandy bottom in Puget Bay in the north-eastern Pacific (Weston, 1990). Increased levels of organic material in sediments by a factor of two were reported for a soft bottom by Brown *et al*. (1987) and Hargrave *et al*. (1993), as well as by Holmer and Kristensen (1992) for non-specified sediment types. Considerably higher levels of increase (by a factor of four) were reported by Weston (1990) for a salmon farm located over a sandy seabed. The loose and flocculent black sediment beneath the farms, commonly named "fish farm sediment" (Holmer, 1991), is characterised by low values of redox potential, a high content of organic material, and accumulation of nitrogenous and phosphorous compounds (Hall *et al*. 1992). The severity of the impact on the seabed depends largely on the type of sediment. In the case sites characterised by coarse sediments, impacts are generally low or even undetectable (Apostolaki et al. 2007), whereas at muddy or silty sites the effects are more pronounced. This difference is due to the considerably higher water movement over coarse sediments, which induces resuspension and reduces anoxia of the seabed. The results of a study in the Mediterranean (Karakassis *et al*. 2000) showed that the organic carbon and nitrogen content of the sediment near the cages was found to increase by a factor of 1.5 - 5, and microbial content by a factor of 4 - 28.

Sediment anoxia, patches with *Beggiatoa* and absence of macrofauna have been reported in relation to salmon farming in the North Atlantic (Rosenthal and Rangeley, 1988; Hansen *et al*. 1991) and in the Baltic Sea (Holmer and Kristensen, 1992). Notwithstanding the microtidal regime of the Mediterranean, none of the studies carried out on fish farms located in the region showed the presence of an azoic zone, in terms of macrofauna, in the vicinity of or even directly below the cages (e.g. Karakassis *et al*. 2000, Tomassetti & Porrello 2005, Klaoudatos et al 2006, Yucel-Gier et al. 2007, Dimitriadis & Koutsoubas 2008). Furthermore, Maldonado et al. (2005) showed that in five semi-offshore farms in Spain, the effects on benthic macroinvertebrate communities were even less detectable and found no substantial differences between farm and control sites. In most cases, the effects of fish farming on macrobenthic diversity and community structure were detectable and compatible with the Pearson & Rosenberg (1978) model up to a distance of 10 m - 25m from the edge of the cages. Kalantzi & Karakassis (2006) have shown from meta-analysis of data from different parts of the world that a small number of variables (depth, distance and latitude) can be used to predict changes in geochemical variables and biotic response of macrofauna. Regarding the EU's Water framework Directive, data from Aguado-Gimenez et al. (2006) from Spain and Karakassis et al. (unpublished) from Greece indicate that the benthic quality directly beneath fish farms cannot be considered "High" or "Good", no matter the index used. Therefore, there is a need to investigate the possibility of adopting the concept of the AZE (allowable zone of effect), which is already used in the UK, to the Mediterranean as well.

A series of studies have attempted to use meiofauna as a means for detecting changes in benthic habitats due to fish farms (Mirto et al. 1999, 2002; Mazzola et al. 1999; 2000; La Rosa 2000, 2001; Sandouli et al. 2001, Kovac et al. 2001; Vezzuli et al. 2003; Lampadariou et al. 2005; Najdek et al 2007). The results have been contradictory in terms of showing that the abundance of benthic meiofauna was higher (Lampadariou et al. 2005) or slightly lower (Najdek et al 2007) or significantly reduced (Mazzola et al. 1999; Mirto et al. 2002) as a result of the fish farming activity. The diversity of meiofauna and functional groups seemed to be reduced beneath the cages (Mirto et al. 2002). However, the lack of a general theory regarding the response of meiofauna to organic enrichment, as well as problems related to identification resulting from the limited number of taxonomic experts for this group, implies that there is still a lot of research to be done before meiofauna can be used as a standard monitoring tool.

The effects of tuna farming on the seabed are generally similar to those for sea bream and sea bass but they seem to be more widely spread around the farms. Partly, this is due to the large size of the farms but also to the very low Food Conversion Ratio (FCR) and consequently to the large amount of wastes produced (Aguado-Gimenez et al. 2006). Vita & Marin (2007) have shown that despite the water depth at the tuna farming site, the effects of tuna farming on macrofauna was detectable up to 200m from the farm, although there was no anoxic zone in this case. The six-month fallowing period was not sufficient for the system to fully recover. A tuna farm in Croatian waters investigated by Matijevic et al. (2006) also showed remarkable changes in redox conditions in the sediment, a two-fold increase in sediment phosphorus, and a significant increase in nutrients in the bottom water layer. Recently Vezzulli et al. (2008) investigated a tuna farm located at a site off the south-western Italian coast that is exposed and has deep waters. Although they found little change for most of the studied benthic and water column variables, they detected significant changes in redox potential and higher bacterial production rates. In addition, indigenous potential pathogenic bacteria were recorded in higher counts at stations located in the vicinity of the fish farm, which served as a warning signal for an undesirable event that may result from aquaculture activities in oligotrophic environments.

2.6 Mediterranean initiatives related to aquaculture-environment interactions, and to site selection and carrying capacity

The Environmental Aspects of Aquaculture Management in the Mediterranean (EAM) initiative produced a state-of-the-art leaflet in 1996 with the title 'Approaches for zoning of coastal areas with reference to Mediterranean aquaculture'. Although this document had summarized the most important issues (known at that time) which need to be taken into account for proper site selection of aquaculture, it has been very little used in actual policy making in most Mediterranean countries. Therefore, for a considerable period of time, the phase of rapid expansion of fish farming in the Mediterranean has been implemented without any coordination with regard to environmental issues. The combined GFCM/CAQ/FAO/FIMA effort, which was initiated with the workshop in Rome (December 2005) has started a new period of interest on this issue, which is mow more mature in terms of knowledge obtained and more urgent in terms of policy required. Among the recent and ongoing activities/initiatives that are relevant to the objectives of environmental regulation of aquaculture, the following are the most likely to be of use:

a) **The initiative of the International Union for the Conservation of Nature (<u>IUCN</u>) in collaboration with the Federation of European Aquaculture Producers (FEAP)** is the most recent and suitably structured effort to bring together scientists and stakeholders to produce guidelines for environmental sustainability of aquaculture in the Mediterranean. It has so far resulted in publication of a book with guidelines for 'Sustainable Development of Mediterranean Aquaculture' and has led to finalisation of a second book with guidelines for 'Aquaculture Site Selection and Site Management'. These works are a good starting point for further discussion of these issues with regulators from different Mediterranean countries who have not very actively participated in this initiative so far.

b) **<u>Thresholds IP</u>** (<u>http://www.thresholds-eu.org/</u>) is a FP6 project aimed at developing an innovative target-setting procedure, encompassing both the environmental and socio-economic dimensions required to formulate robust policies ensuring sustainable development. Part of the project (one of the case studies) is designed to address the issue of environmental variables for assessing aquaculture activities that may be critical for the development of the industry. There are about 8 partner institutions in the consortium that hail from Mediterranean countries.

c) The recently completed European FP5 projects MERAMED, MedVeG, AQCESS, and BIOFAQs have focused exclusively on the Mediterranean marine environment or had a strong Mediterranean component and have addressed several specific aspects of aquaculture-environment interactions that need to be taken into account. More specifically:

o **<u>MERAMED</u>** (<u>http://meramed.akvaplan.com/</u>: Development of monitoring guidelines and modelling tools for environmental effects from Mediterranean aquaculture) has been designed to provide a specific model (MERAMOD) for assessing effects of fish farming on the Mediterranean benthic environment and to address a series of hypotheses relating to environmental effects and monitoring.

- **MedVeg** (http://ec.europa.eu/research/agriculture/projects/qlrt_2000_02456_en.htm: Effects of nutrient release from Mediterranean fish farms on benthic vegetation in coastal ecosystems) was undertaken in 4 Mediterranean countries (Spain, Italy, Greece, Cyprus) and focused on the effects of fish farming on *Posidonia oceanica* meadows; the project assessed a large number of variables at different fish farms in the Mediterranean.

- **AQCESS** (http://www.abdn.ac.uk/aqcess/: Aquaculture and Coastal Economic and Social Sustainability) has examined both environmental and socio-economic aspects of aquaculture performance in Europe, analyzing conflicts of uses, labour mobility as well as large scale effects of aquaculture zones in different areas, including 3 Mediterranean aquaculture zones. Some of the results are of very high value for the Mediterranean.

- **BIOFAQs** (http://biofaq.sams.ac.uk/link.htm: BIOFiltration and AQuaculture: an Evaluation of Substrate Deployment Performance with Mariculture Developments) in which the project consortium involved 4 partners from Mediterranean countries, and which carried out research on the potential for use of floating biofilters as a means for mitigation of aquaculture impacts on the water column. Although the feasibility of this method is questionable according to the results of this project, the data obtained are very useful for assessing the dynamics of fouling communities on fish farm structures and can be used to evaluate the potential of polyculture as a means for environmental-friendly aquaculture practices.

d) The **SAMI** EU FP6 project (http://www.sami.biology.sdu.dk/: Synthesis of Aquaculture and Marine Ecosystems Interactions) provided a synthesis of the above projects in EU-FP5, and incorporated other issues such as the shortage of fish meal and fish oil, and the potential ecological risks from pressure on marine ecosystems with the foreseeable reduction in freshwater resources and consequent limitations of terrestrial agriculture and livestock production.

e) The **ECASA** EU FP6 project (http://www.ecasa.org.uk/: Ecosystem approach for sustainable aquaculture) involved 16 research partners (8 from the Mediterranean) from 13 member states. ECASA included both fin and shell fish marine aquaculture and has actively sought stakeholder participation from the onset. The outcome of this project is the most up-to-date toolbox of environmental models related to aquaculture, and an extensive list of indicators that have been developed by a large number of experts, which have been discussed with various stakeholders in Europe.

f) The ongoing **SPICOSA** EU FP6 project, (http://www.spicosa.eu/: Science and policy integration for coastal system assessment) has a Mediterranean and fish farming component and is likely to be of some interest when it is completed.

g) The **PREVENT-ESCAPE** project: (http://www.sintef.no/Home/Marine/Fisheries-and-Aquaculture/Aquaculture-Technology/Aquaculture-constructions/Prevent-Escape/) is a new EU FP7 project which is started in 2009. It is designed to address the environmental impacts of fish escaping from fish farms and to propose mitigation measures. Almost half of the scientific effort will be used to address this issue in the Mediterranean.

h) The **CIESM** workshop (www.ciesm.org/online/monographs/lisboa07.pdf) held in Lisbon in February 2007 provided a synthesis of the effects of aquaculture on the Mediterranean marine environment, and indicated a significant number of unresolved issues between various uses of the coastal zone and environmental integrity.

i) Initiatives in the framework of particular Mediterranean countries to determine holding/carrying capacity by adapting production levels to the environmental attributes of the receiving environment. Such initiatives, which exist in Greece and Cyprus, use evaluation panels of international experts.

j) **WGEIM** is an ICES working group on environmental interactions of mariculture (http://www.ices.dk/iceswork/wgdetail.asp?wg=WGEIM). Although not focused on Mediterranean issues, this working group is one of the oldest initiatives addressing the environmental impacts of aquaculture and has gone into considerable detail and adopted a systematic approach mainly for the salmonid farming industry.

k) Other relevant projects include **CANO** CArrying capacity in NOrwegian aquaculture (http://www.imr.no/cano/) which addresses questions that are of high relevance to aquaculture in the Mediterranean, while the methodology used and problems encountered should be taken into account for planning similar surveys in the Mediterranean.

Finally, a relevant and important document is the one produced by IUCN titled '**The IUCN guide for the sustainable development of Mediterranean aquaculture: aquaculture site selection and site management.'**[5] This document is reproduced in the present report as Appendix 2.

2.7 List of key works on aquaculture-environment interactions from the Mediterranean

During the past 13 years there has been a spectacular increase in the number and quality of published research results concerning aquaculture-environment interactions. A list of key works dealing with aspects of aquaculture-environment interactions is given in Appendix 3. Since a substantial amount of information is available, the focus of the list is on articles published in peer reviewed journals and does not include other unpublished works such as abstracts, reports and grey literature.

It has been just over 5 years since the report by Soto & Crosetti (2005) was published, which includes a list of references to works on Mediterranean aquaculture and the environment yet, in the meantime, there have been no less than 80 new papers published on the subject i.e. 29 in 2006, 35 in 2007, 20 in 2008, 26 in 2009, and 24 in 2010.

Amongst the 281 scientific articles (Appendix 3), 234 focus on fish farming (10 of which focus on tuna farming) and 45 on shellfish or invertebrates (particularly oysters and mussels). Most of the papers (>200) are related to aspects of the benthic environment and processes - typically geochemical variables and macrofauna or meiofauna - but several articles (>50) also deal with nutrients and/or plankton, effects on *Posidonia oceanica* meadows (>30) and interactions with wild fish (30). The frequency of publications on the latter two aspects has been relatively higher compared to previous years.

Some of the works listed in Appendix 3 have used recently developed techniques (bioassays, stable isotopes) or other specialised tools (meta-analysis etc) to address specific questions regarding different processes or different scales or to propose new monitoring methods. Issues such as recovery following cessation of fish farming, mitigation techniques, effects of offshore aquaculture, as well as some of the models developed, are probably of global interest since they are among the very first works to be published on such topics.

[5] IUCN 2009. Guide for the sustainable development of Mediterranean aquaculture.n.2 Aquaculture site selection and site management. Gland, Switzerland and Malaga, Spain: IUCN, VIII+303p[5]

In conclusion, the corpus of knowledge accumulated during the past few years on aquaculture-environment interactions in the Mediterranean is quite substantial and may be used as basis for establishing good practice principles and for adopting common standards for environmental sustainability.

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3. Ecological monitoring of aquaculture activities

by Ioannis Karakassis and Angel Dror

On the local scale (tens of meters from the edge of a farm), finfish and bivalve shellfish consume oxygen and release ammonia and phosphate, as well as particulate wastes which may impact benthic communities (ECASA Toolbox; http://www.ecasatoolbox.org.uk/). In addition, filter-feeding shellfish remove phytoplankton from the water column, which may have beneficial, bad or no effect. Ammonia and phosphate released from aquaculture may stimulate increased growth of phytoplankton or macroalgae, potentially leading to harmful algal blooms and deep water anoxia. Moreover, algal blooms affect light penetration through the water column, thereby reducing the depth of the photic zone and impacting important benthic primary producers such as seagrasses and macroalgae. In order to ensure sustainable use of the natural environment, these effects must be kept within tolerable levels - i.e. within the assimilative capacity of the site or water body. For some variables (such as oxygen concentration), it is in the interest of the farmer to do so. Other impacts need to be monitored by public authorities. In weighing the interaction of aquaculture with the surrounding marine environment, we should also consider the concept of an ’allowable zone of effect (AZE)’, as established by SEPA in Scotland (e.g. Rosie and Singleton 2002). This concept establishes that it is impossible to have "pristine conditions" in the immediate vicinity of the aquaculture site, but that beyond the AZE the environmental impacts should be minimal to non-existent. There are a number of indicators that can be used to monitor the effects of aquaculture on environmental quality; some of these are reviewed below.

The GESAMP Expert Working Group on Environmental Impacts of Coastal Aquaculture reviewed monitoring of coastal aquaculture and recommended that “monitoring effort” should be proportional to the “scale and intensity” of the operation and to the sensitivity of the environment (GESAMP, 1996). In their comprehensive review, they evaluated the efficacy of the variables commonly employed in monitoring ecological effects of aquaculture and scored them on the basis of their use, cost and value.

In the following, we provide indicators for monitoring the ecological effects of aquaculture on sediments and water quality (see also Table 3). We describe various means to monitor change at aquaculture sites and proceed from to describe change in sediment quality, including both physico-chemical and biological aspects. This is followed by a description of changes in water quality and how these may be monitored. All of the above will be discussed with respect to the level of expertise and time needed and requirements for special instrumentation and facilities. Cost per analysis will vary greatly from country to country and is linked to availability of suitable analytical equipment and experience in performing the analyses.

3.1 Monitoring change at aquaculture sites

Visual, photographic and video surveys

Surveys using photography, video or direct observation may be conducted at sites where visibility and conditions permit. This approach is especially suitable for many parts of the Mediterranean where light penetrates through the water column to great depths and the high water transparency and visibility allow good quality underwater photography and videography to be made. The length, number and locations of transects are site-specific and related to the monitoring strategy to be adopted. For intertidal shellfish farms, photographs of the lease area at low tide are normally sufficient. However, most aquaculture sites in the Mediterranean are sub tidal and visual, videographic or photographic surveys must be done by means of diving or using remotely operated vehicles (ROVs). The video survey approach is relatively inexpensive and readily provides qualitative or semi-quantitative information on benthic impact and sediment quality, and can provide information on much larger areas than other methods. This form of monitoring can identify both areas of organic enrichment and inorganic debris (e.g. bivalve shells and farm litter) beneath the farm. Moreover, video surveys may indicate the spread of fish feed from the cage area, hence also serving for management and husbandry, in addition to ecological objectives. Whereas it is relatively easy to generate large volumes of underwater photography and video footage, this must be followed by time consuming analysis of the images or videos to determine sediment status along the transects and the extent of the impacted seedbed area. Another option is to use diver-based observations to determine conditions around aquaculture facilities. This approach relies on the assumption that the divers are familiar with a suite of features that characterize healthy and unhealthy conditions in the benthic and pelagic environment around a farm and are able to record these along transects during underwater surveys. This approach has been used below fish farms in Maine (Heinig 2000) and in the Red Sea (Angel et al. 1998). The advantage of on-site direct observations using diving is that there is no need to carry out post-dive viewing and assessment of video recordings (e.g. as has been done in Tasmania; see Crawford et al. 2001) and the data may be analyzed by techniques such as fuzzy logic (Angel et al. 1998). If the seabed at aquaculture sites lies in very deep waters (>30m), it may not be possible to use SCUBA divers efficiently for visual/video/photography surveys. Another option is to use ROVs equipped with underwater cameras and video cameras.

> Time required: depending on factors such as visibility and site characteristics; between 0.5 - 1 day per transect.
>
> Necessary equipment and infrastructure: submersible video or digital photography camera with appropriate underwater lighting, electronic equipment for post-collection viewing.
>
> Level of expertise required: SCUBA divers experienced in laying transect lines, with training in underwater videography and/or photography; high-resolution monitor for viewing and analysis of underwater footage.

3.2 Use of chemical and physical attributes to assess status of sediments

Sediment sampling
Station positions should reflect gradients of impact, with one or more stations situated in the area of maximum impact. Stations may be chosen by modelling or by means of a pre-survey using redox potential, video, etc. It is preferable to maximise the chance of detecting a gradient and this is generally manageable by taking a minimum of 5 stations per transect. A reference station (or preferably 2) should be allocated, which should have similar water depth and sediment characteristics to those of the farm but would be at a sufficient distance from the farm so as not to be influenced by the farming activities. For chemical analyses, three replicates taken at each sampling station are generally sufficient to determine variability among samples.

Visual assessment of sediment cores
This should be carried out prior to processing the core samples and undertaking redox analysis, and consists of a written description of changes in sediment appearance, composition and colour with depth. This may provide valuable information on the degree of organic enrichment, sediment bioturbation and other important characteristics.

> <u>Time required</u>: cores taken by divers – 1 - 4 h; sampling with box corer – 0.5 - 1 day
>
> <u>Necessary equipment and infrastructure</u>: sediment sampling by means of: SCUBA divers (hand-held core samplers) or box cores (sediments in box core are subsampled with small cores)
>
> <u>Level of expertise required</u>: SCUBA divers experienced in taking sediment cores, or ship with box-corer

Redox potential
This is one of the most popular proxies for determining the level of oxygen in marine sediments (Bagander 1978). Redox potential is generally performed in sediment cores (Hinchey and Schaffner 2005) and indicates the degree of organic loading in the sediments (Pearson and Stanley, 1979). It is often correlated with changes in benthic community structure. A limitation concerns coastal fine sediments (mud, silt) that are not necessarily organically enriched and often have relatively lower values of Eh even in the top few cm of the sediment, thereby limiting comparability with coarse sediment sites. However, for sand or coarse grain sediments, redox is a good means to detect changes in Eh at sites where aquaculture is practiced and where an impact is present e.g. beneath cages, and therefore should be retained as an analytical tool for environmental monitoring. Aquaculture carried out in locations having fine-grained sediments is rapidly becoming the exception rather than the rule (especially in the Mediterranean) because such sediments generally occur in depositional bodies of water that are highly sensitive to organic loading. As such, redox potential is a very useful tool for rapidly establishing the potential for benthic impact. Hargrave (1994) designed the Benthic Enrichment Index (BEI) which is calculated as the product of the flux of organic carbon to the seabed and redox potential in surface sediments. This index was successfully used to assess the status of sediments in Canadian waters and can be applied in the Mediterranean. Displacing aquaculture offshore (at depths >40m) is likely to involve deployment of cages over bottoms characterised by finer sediment and therefore calibration is needed to obtain “optimal” Eh values for such environments as well as to establish thresholds for acceptable deviation.

> <u>Time required</u>: 15 min per core.
>
> <u>Necessary equipment and infrastructure</u>: redox potential electrodes, plastic sediment corers with holes in sides to insert redox electrodes.

Level of expertise required: measurement – minimal; experience with calibration of electrode.

Organic Enrichment

In monitoring the impacts of both finfish and shellfish farms on marine sediment quality one would be looking for evidence of accumulated organic material beneath the aquaculture installation as this material may cause both physico-chemical and biological alterations in the sediments. Redox potential often indicates the degree of organic enrichment and how chemically "reduced" sediments are. Particulate carbon, nitrogen and phosphorus levels are elevated under fish farms as a result of diagenesis of the organic material settling on the seafloor. Although it is possible to measure particulate organic matter (POM), total organic carbon, total nitrogen and total phosphorus in the sediments, it is not necessary to include all of these in regular aquaculture monitoring programs. Each of these nutrients, measured on their own, provides evidence of the enrichment process. Carbon/nitrogen ratios may be used to indicate the degree of organic enrichment compared with baseline levels, but since these are generally positively correlated with particulate organic matter, it may suffice to measure POM. Total phosphorus is a strong indicator of nutrient enrichment from a fish farm and should be monitored on a regular basis along transects.

Sediment organic matter

Sediment organic matter content is generally determined by the loss-on-ignition (LOI) method, which quantifies the amount of combustible material (organic matter) in the sample. Cores are typically sliced at a resolution of 1 cm deon to a depth of 10 cm. One of the new modifications of this method, based on the work of Kristensen (1990), separates the labile (combustion at 250 C) from the refractory (combustion at 500 C) organic material (Loh et al. 2008) and may provide further insight on the spatial extent to which farm effluents are spread. This modified method is less complex and time-consuming than total organic carbon (TOC) measurements, which are routinely carried out in EIA studies, yet correlate very poorly with impact, as TOC includes both labile and refractory material. On the other hand it has been shown that high TOC levels are a good predictor for benthic diversity (Hyland et al. 2005). The LOI method has been criticized by various workers because it does not quantify carbon or nitrogen, but rather bulk 'organic matter'. The alternative chosen by some workers is to measure sediment carbon, nitrogen and phosphorus by means of element analyzers, but these generally accept only extremely small samples (milligrams) after preprocessing (pulverization and acidification) which may: a) be very unrepresentative of the sediments, and b) introduce artefacts. Considering the above, low cost and easy methodology, and the conclusions of several studies comparing methods (Sutherland 1998, Leong and Tanner 1999, Heiri et al. 2001), the Loh et al. (2008) procedure is recommended.

Time required: core processing – 15min/core; drying, weighing and multiple combustions – 4 days/3 cores.

Necessary equipment and infrastructure: digital balance, drying oven, muffle furnace.

Level of expertise required: basic technical skills – weighing, recording.

Total phosphorous in sediment

A variety of methods are available for measuring phosphorus in sediments. One of the preferred procedures is that of Strickland and Parsons (1972) with modification by Aspila (1976). This method enables quantification of inorganic, organic and total phosphorus.

Time required: core subsampling – 15min/core; processing samples - 20 hrs (multiple samples may be analyzed simultaneously) for inorganic P and 20 hrs for total P.

Necessary equipment and infrastructure: analytical chemistry lab, mortar & pestle, sieve, digital balance, drying oven, muffle furnace, spectrophotometer.

Level of expertise required: analytical chemistry skills

Sediment grain size

Grain size can indicate the flushing characteristics of an area and serves as one of the key attributes that is examined in considering a site for aquaculture. Sand is usually found in well-flushed sites, whereas silt and clay (mud) are indicative of depositional areas with poor flushing. Moreover, the nature of the particulate matter deposited from fish and shellfish installations is different to the natural background flux of particles in the area, in terms of flux rates, chemical composition and in particle size distribution. Therefore, sediment grain size distribution may indicate changes in the sediment conditions below aquaculture installations, compared with control sites. Changes in such physico-chemical attributes of the benthic environment may have profound effects on the sediment infauna. Sediments may be sampled by cores, either directly by divers or subsampled after sampling with a box corer. Sediments are then sliced and analyzed using dry or wet sieving (for the >2mm fraction) methods or by laser diffraction techniques (for the <2mm fraction) (Poppe et al. 2000).

> Time required: depends on methods used; after slicing of the sediment core and drying, 2 – 4 h per core.
>
> Necessary equipment and infrastructure: sediment granulometry equipment (drying oven, sieves, sieve shaker, digital balances), and/or access to a laser diffraction system.
>
> Level of expertise required: sediment sieving (simple); operation of laser diffraction system (trained personnel)

Benthic community

It is generally accepted that the key indicator of the ecological impacts of aquaculture and other anthropogenic activities in the coastal region, is change in benthic community structure. The groups generally studied are those that comprise the soft-bottom benthos because these are relatively sedentary (i.e. do not avoid deteriorating water/sediment quality conditions), have relatively long life spans (thereby temporally integrating water and sediment quality conditions), generally consist of different species with a variety of tolerances to stress, and play an important role in the flux of nutrients in the sediment-water interface (Borja et al. 2000).

Although the majority of studies and monitoring projects have focused on the macrobenthic community, recent studies have shown that changes in the benthic meiofauna community may be also useful in detecting impact although there is still need for research to obtain reliable estimates of meiofaunal variables relating to environmental quality. Sample collection is relatively easy and may be done using grabs, box cores or SCUBA divers (Holme and McIntyre 1984). If the benthic community is not rich (i.e. characterised by low abundance), or is very patchy, it may be necessary to take more than 5 samples per station. After fixation and preservation, animals are separated from the sediments to allow taxonomic identification. If the organisms are sorted and identified to the family level, the work may be done fairly rapidly. In many cases, identification is done to the genus or species level and this is extremely labour intensive and requires taxonomic specialists. With respect to benthic communities, one approach is to focus efforts on indicator species (or bioindicators), such as the polychaete *Capitella sp*. This polychaete is a ubiquitous indicator of organically enriched sediments that are both hypoxic (or anoxic) and sulphidic. Thus, the presence or absence of such indicator species (when highly abundant) may provide a strong indication of ecological impact. Unfortunately, many of these bioindicators have a limited distribution and cannot be used as cosmopolitan indicators.

Numerous indices have been used to describe the benthic communities, including relatively simple ones, such as: Biomass/abundance, Abundance/number of species, ABC Method (Ritz et al., 1989), Shannon-Wiener H' (diversity), Pielou's (Evenness), etc. Each of these indices has advantages and disadvantages. One advantage of the ABC method is that it does not require a large number of samples to assess the status of the sediments, and can be very useful in locations where suitable reference stations or historical background data are not available.

There are also more complex indices such as the AMBI (marine biotic index) and the BTI (benthic trophic index). These indices require identification to species level and an understanding of the trophic characteristics and ecological grouping (from undisturbed to extremely disturbed communities) of each of the species.

Time required: sampling – depends on sea conditions and the method used, 1 – 2 days per site; sorting and identification of species – depends on the species richness and taxonomic level used, two weeks – several months per site.

Necessary equipment and infrastructure: SCUBA divers taking large diameter sediment cores, or van Veen grab or box core; sieving & washing gear for large-volume sediment samples, dissecting microscopes and keys for identification of the fauna. In the event that meiofauna are studied, smaller-volume sediment samples are sufficient.

Level of expertise required: for sampling, basic technical knowledge and experience; for sorting and identification to the family level, a moderate amount of experience with benthic fauna; for taxonomic work to species level – very high level of expertise and experience are necessary.

Water Quality

Changes in water quality around aquaculture facilities may be caused by a number of processes. The farmed fish or shellfish, as well as associated biota (e.g. biofouling communities or plankton) may severely reduce dissolved oxygen levels through respiration. In addition, the release of metabolic waste products and their breakdown by-products may lead to elevated nutrient levels, which may impact both planktonic and benthic biota.

In the case of filter-feeding bivalves that feed on suspended plankton and detritus, aquaculture is considered "extractive" in that the cultured stocks actually remove (extract) organic particles from the water column rather than add organic matter. In addition to quantifying the environmental impacts of aquaculture, monitoring the ambient water quality around aquaculture sites is essential in order to protect the cultured stock against toxins and pollutants. In such cases, this reflects the impact of the environment on aquaculture rather than that of aquaculture on the surroundings.

We generally find that the influence of aquaculture activities on surrounding water quality is barely measurable. This is mainly due to the rapid dispersive (transport by currents) and uptake (chemical and biological) processes. Thus, sampling should be scheduled around times of peak farm production and warmest water conditions to capture maximal impact conditions. Samples should also be taken along a diel or tidal cycle since these may reveal fluxes and important fluctuations in key variables. Although the water residence time (or the flushing rate) is a key variable that affects the sustainability of aquaculture facilities, it is interesting to note that local trophic conditions have little effect on water quality. In well flushed oligotrophic waters, nutrient uptake rates are extremely rapid and it is difficult to detect nutrients outside the aquaculture zone. In mesotrophic and eutrophic waters, uptake rates may be lower, but the flux of nutrients released from aquaculture is often very small in comparison to the pool of ambient (background) nutrients and, ultimately, no dramatic effects on water quality are detected. Determining water quality at a given site typically includes physical, chemical and biological characterization.

3.3 Use of physical, chemical and biological variables to assess water quality

CTD (conductivity, temperature, depth) profilers

These are deployed from a boat are the most convenient and efficient to characterize the physical structure of the water column. In addition, CTD profilers may be equipped with sensors to measure dissolved oxygen, chlorophyll *a*, photosynthetically active radiation, light transmission and turbidity.

Time required: 1 day per site, assuming stations for vertical CTD profiles will be placed at different distances and azimuths from the aquaculture facility.

Necessary equipment and infrastructure: CTD profiler, boat equipped with GPS and winch suitable for deploying the CTD profiler

Level of expertise required: experience with operation of a winch to avoid the CTD hitting the seabed, training and experience in calibrating the CTD sensors, and to process and interpret the data.

Table 3 – Aspects of environmental monitoring of aquaculture activities

	Water quality					Sediment quality						
ASPECT	qualitative assessment of organic enrichment, inorganic debris	physical	clarity	Organic / inorganic nutrients	Algal growth	All	sediment appearance, composition and colour with depth	Oxygenation of marine sediments	Organic Matter	Total Phosphorous	Sediment Grain Size	Benthic Community
ANALYSIS	Benthic photograph, video, diver observation	CTD cast	Secchi disk depth	various	Algal growth bioassay	CORE EXTRACTIO N	Visual inspection of cores	REDOX	Modified LOI	Various	Granulometry	Various
TIME REQUIRED	0.5 - 1 day per transect	1 day per site,	several hours per site	Water sampling – ½ day Sample processing – 1 week	Set up - 1 day; processing – 2 days Dismantling - 1 day	Diver taken cores – 1-4 hrs; box cores – 0.5-1 day	Visual inspection of cores: ca 10min/core	REDOX analysis: 15 min per sediment core	core processing – 15min/core; core drying, weighing and multiple combustions – 4 days/3 cores.	core sub-sampling – 15min/core; processing samples - 20 hrs for inorganic and total P	after sediment slicing and drying 2 – 4 h per core	sampling –, 1 – 2 days per site; sorting and identifying – several months per site
EXPERTISE	SCUBA divers trained in laying transect lines and underwater videography	Familiarity with equip-ment; calibration of CTD sensors; data pro-cessing and interpretation	minimal	basic water-sampling; extensive in marine analytical chemistry	minimal for set up & dismantling; experience with chlorophyll extraction and fluorometric measurement	SCUBA divers experienced in taking sediment cores of different sizes, Veen grab or box-cores		minimal; experience with calibration of electrode	basic technical skills – weighing, recording	analytical chemistry skills	sieving (simple); operation of laser diffraction system (trained personnel	sampling-basic; sorting and identifying - moderate experience with benthic fauna; taxonomic work to species level – very high level
INFRA-STRUCTURE	Submersible video, digital video camera, underwater lighting, viewing equipment	boat with GPS & winch	boat with GPS; Secchi disk, rope	boat with GPS & winch; Niskin bottles; analytical chemistry laboratory with auto-analyzer	boat with GPS, mooring and floatation system, diffusion chambers	hand-held core samplers or box cores		redox potential electrodes, plastic sediment corers with holes in sides to insert redox electrodes	digital balance, drying oven, muffle furnace	analytical chemistry lab, mortar & pestle, sieve, digital balance, drying oven, muffle furnace, spectrophotomet	sediment granulometry equipment (drying oven, sieves, sieve shaker, digital balances) and/or access	sieving & washing gear; dissecting microscopes and keys for identification

										er	to laser diffraction system.	fauna.

Secchi disk depth
This is a simple and quick method used to assess water clarity (or inversely, water turbidity). In practice, it is used to measure how deep a person can see into the water (Cole 1994). A more accurate measurement of underwater irradiance can be made by means of a photometer, but this is often unnecessary. Vertical light penetration, as measured by a Secchi disk, may also provide a rough estimate of phytoplankton biomass in areas where Secchi depth is measured on a routine basis. Indeed, the greatest value of Secchi disk measurements is obtained when readings at each station are recorded and compared over time. Several factors are involved in determination of the depth value, including the viewer's eyesight (it is best if the same person determines Secchi depth), time of day the readings are taken (the preferred time is midday, or around 10:00 and 14:00), reflectance of the disk, colour of the water, amount of clay particles or other materials suspended in the water; hence all these must be considered when interpreting Secchi depth data.

> Time required: several hours per site, assuming (on average) 10 stations/site.
>
> Necessary equipment and infrastructure: Secchi disk, rope, boat equipped with GPS
>
> Level of expertise required: minimal.

Sampling the water column
Additional chemical and biological features that impact water quality may be quantified by taking water samples using bottle samplers (e.g. Niskin bottles) at representative depths; e.g. surface, mid-depth and near the bottom.

Organic and inorganic nutrients
If the fish farm is managed properly (e.g. eliminating feed particles from the food pellets and minimizing wasted feed), loading of particulate organic wastes from aquaculture systems is relatively small and consists mainly of feces or pseudofeces from the stocked finfish or shellfish. The release of dissolved inorganic nutrients such as ammonia and phosphorus from aquaculture installations is much greater as these are excreted directly by the stock, leached from deposited wastes or released following decomposition of organic wastes in the sediments. In addition to the potential for eutrophication when nutrient levels are high, elevated concentrations of certain dissolved nutrients (*e.g* ammonia) may be harmful to aquatic life and can indicate overstocking or waste accumulation. In order to monitor nutrients in the water column, water samples are taken using sampling bottles and brought back to the laboratory for determination of ammonia, nitrate, nitrite, phosphate, total nitrogen (TN), total phosphorus (TP). Detailed protocols for these measurements are provided in Grasshoff et al. (1999), Kirkwood (1994) and ICES (2004). Although nitrate and nitrite are not released by the stocked organisms, and are not toxic to most marine organisms, they may help in determining the risk of eutrophication at a given site. The measurement of TN and TP (which includes both organic and inorganic forms) enables us to detect whether there is an increase in the levels of organic nutrients, as an increase in these may lead to more dramatic (and undesirable) changes in water quality. In addition to the above, the sampled water may also be used to determine chlorophyll *a* levels and to measure suspended particulate matter and the concentration of particulate organic carbon, nitrogen and phosphorus (ICES 2004).

> Time required: sampling the water column along a transect with 5 or 6 stations, and sample processing should take 1/2 day. Sample processing for chemical analysis of water based on this number of samples will take ~1 week, provided there are sufficient technical staff and that the samples are analysed using an autoanalyzer.
>
> Necessary equipment and infrastructure: boat equipped with GPS, Niskin bottles and a winch; analytical chemistry laboratory with autoanalyzer (an autoanalyzer is not obligatory, but will greatly reduce the effort to analyze samples by wet chemistry).
>
> Level of expertise required: basic experience in water-sampling in the field; broad experience in marine analytical chemistry.

Algal growth bioassay

This is an innovative method that enables assessment of the flux of dissolved inorganic nutrients released from fish farms (and their potential to cause eutrophication) without actually measuring nutrient levels. The rationale for the use of this method is that nutrient levels vary considerably in waters around aquaculture sites over a diel cycle, but they are traditionally measured at only one point in time. The solution to this is the use of a method developed by Dalsgaard and Krause-Jensen (2006) that integrates the flux of nutrients released from aquaculture by examining changes in phytoplankton or macroalgal biomass over time. The algae are suspended in the upper layer of the water column (where there is sufficient light) within diffusion chambers at varying distances from an aquaculture site for a period of 3 – 6 days, and are harvested and analysed at the end of the incubation period.

> Time required: 1 day to set up the experiment, 1 day to dismantle it, 2 days to process the samples, assuming that the change in algal biomass is based on the determination of the level of chlorophyll *a*.
>
> Necessary equipment and infrastructure: boat equipped with GPS, mooring and floatation system for the bioassay experiment, diffusion chambers.
>
> Level of expertise required: minimal expertise is needed to set up and dismantle the experiment; experience with chlorophyll *a* extraction and fluorometric measurement.

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4. Thresholds for major environmental changes

by Ioannis Karakassis

According to Groffman et al (2006), an ecological threshold is the point at which there is an abrupt change in an ecosystem quality, property or phenomenon, or where small changes in an environmental driver produce large responses in the ecosystem. Analysis of thresholds is complicated by nonlinear dynamics and by multiple factor controls that operate at diverse spatial and temporal scales.

On the other hand, thresholds may also be defined in a legal framework as the point beyond which the pollution load becomes unacceptable. This threshold defines the legal boundary between acceptable contamination and unacceptable pollution (Hassan 2006). However, many factors affect the drawing of the boundary line; these include the type of contaminant, economic priorities and social consensus. In the context of regulation of marine aquaculture activities, the thresholds needed are probably substantially lower than the ecological ones in order to ensure environmental integrity. However, there is a need to increase our understanding of the ecological thresholds in question to make sure that the selected values are indeed within the safe range.

When considering thresholds it is important to keep in mind that aquaculture-environment interactions operate at various spatiotemporal scales and, therefore, the indicators of impact should be assess/monitored at the proper scales.

A typology of the scales and the associated phenomena is given by Tett (2008) who defines 3 zones that occur with distance from the farm, based on residence time of neutrally buoyant particles. If such particles were released from a fish farm, most of them would be after a few hours in zone A, after a few days in zone B and after a few weeks in zone C. Therefore, the **zone A scale** comprises the water volume and sediment area immediately affected by the fish farm, where benthic effects are usually readily detectable, unlike pelagic impacts which are more difficult to detect. The **Zone B scale** depends on the residence time of water in a larger water body such as that in a loch or a bay or off an open coast. In this zone there is sufficient time for phytoplankton to capitalize on the dissolved nutrients and therefore to increase in biomass up to the point that it will be controlled by zooplankton. The **zone C scale** is the regional scale, with residence times of weeks to months that are sufficiently long for nutrients to become phytoplankton and then be grazed and recycled.

4. 1 Oxygen

One of the most obvious thresholds to be considered is the effect of aquaculture on dissolved oxygen levels. This is because the organic wastes discharged into the marine environment, as well as the OM produced *in situ* by phytoplankton exploiting nutrient wastes, induce microbial metabolism, thereby consuming oxygen. Gray et al. 2002 have described different thresholds related to O_2 level in seawater:

- <0.5 mg l^{-1}: catastrophic effect
- 2.0-0.5 mg l^{-1}: mortality
- 4.0-2.0 mg l^{-1}: metabolism affected
- 6.0-4.5 mg l^{-1}: growth affected

To avoid undesirable effects, it would be reasonable to use as a management threshold a value higher than 6.0 mg l^{-1} and it should be ensured that the level will not decrease below 2.0 mg l^{-1} during any period. It has been found that dissolved oxygen near salmon farms decreases to a distance of 30 meters from the cages (Gowen & Bradburry 1987). In the Mediterranean, the only published information (La Rosa et al. 2002) did not show a similar change in oxygen level, and values in the vicinity of the farm remained close to saturation levels. However, it should be noted that oxygen solubility decreases with increasing temperature and salinity; therefore, at sites in the Mediterranean where there is excess organic loading, the water column is more likely to become depleted of oxygen.

This above proposed oxygen level criterion has been used in Japan (Yokoyama 2003) where levels of >4mg l^{-1} for healthy farms and <2.5 mg l^{-1} for critical farms were used as threshold. In Scotland, the environmental quality standard used for dissolved O_2 at sites occupied by salmon farms is 7mg l^{-1} or 80% of air saturated value (Henderson & Davies 2000).

4.2 Sedimentation and allowable zone of effects

Sedimentation of organic material deriving from accumulated fish feed and faeces, causes significant geochemical changes in the seabed beneath fish farms. The spatial extent and the severity of these changes depend on the water depth, distance from the cages, the species farmed and the sediment type (Kalantzi & Karakassis 2006).

Hyland et al (2005) used a very large data set covering very different geographic areas and benthic habitats and found that the organic material expressed as total organic carbon (TOC) may be used as a predictor of benthic diversity. The changes in benthic diversity become somehow abrupt beyond the TOC level of 35 mgC g^{-1} sediment (or 3.5%), whereas below 10 mgC g^{-1} sediment, the risk of reduced species richness from organic loading and other associated stressors in sediments should be relatively low. The Scottish Environment Protection Agency (SEPA) has developed a regulatory tool, called the allowable zone of effect (AZE), which is used to control the degree and spatial extent of impacts of marine cage farming on marine sediments. Currently, this is set at 25 m beyond the perimeter of the farm cages (SEPA, 2000), although it is proposed to relax this limit for highly dispersive sites (Dean at al 2007). SEPA applies a lower standard for a variety of benthic and sediment indicators within the AZE to that which pertains to areas outside the AZE. Sediment quality criteria (SQC) have been set for a range of indicators including community indices, medicine residues and metals. Regarding total organic carbon (TOC), in the AZE TOC should be lower than 9% (or <27% loss on ignition), while free sulphide in the sediment should be lower than 4800mg kg^{-1}, and the redox potential of the sediment (Eh) higher than 150mV.

In the system used in Japanese legislation (Yokoyama 2003), sulphide content (as acid volatile sulphide, AVS-S) of the sediment is considered to be acceptable when it is "less than the value at the point where the benthic oxygen uptake rate is maximum", and is considered indicative of environmentally critical conditions when is exceeds 2.5 mg g^{-1} dry sediment. AVS is an operational definition for sulphides removed from the sediment by cold acid extraction. In a recent survey involving data from various fish farms in Japan, Yokoyama et al. (2004) identified a series of indicators/thresholds for cautionary and critical conditions related to marine sediments (Table 4)

The MOM system (modelling ongrowing fish farm monitoring) proposed for salmon farming in Norway (Maroni 2000, Hansen et al. 2001) does not include specific threshold values for sediment geochemical variables but, instead, adopts a system with combinations of redox potential and pH values in 5 zones (0, 1, 2, 3 and 5); a score of 0 corresponds to a well-oxygenated environment with low organic input and favourable conditions for the presence of viable benthic communities. Increasing input of organic matter will drive the sediment environment through successive stages of increasing oxygen deficits and corresponding changes in microbial communities. A score of 2 frequently represents an environment with hydrogen sulphide, which gives low redox potentials in the pore water. A score of 5 represents an environment with methane gas in the sediment and low pH values. Scores of 1 or 3 are allocated to transition zones (Hansen et al. 2001). If the average of 10 samples is >3, the conditions are unacceptable.

Table 4 - Values of benthic components for identifying cautionary and critical conditions of fish farm environments (After Yokoyama et al. 2004)

Benthic components	Cautionary condition	Critical condition
Sediment		
Total organic carbon (mg g^{-1} dry)	>20	>30
Total nitrogen (mg g^{-1} dry)	>2.5	>4
Total phosphorus (mg g^{-1} dry)	>4	>6
Chemical oxygen demand (mg g^{-1} dry)	>30	>75
Acid-volatile sulphide (mg g^{-1} dry)	>0.5	>1.5
Macrobenthos		
Biomass[a] (g m^{-2})	<10	0
Density (individuals m^{-2})	<1500	0
Number of species (/0.04 m^2)	<20	0

[a] Wet weight of animals excluding the shell of molluscs.

4.3 Benthic fauna

The Norwegian MOM approach (Hansen et al. 2001) suggests that the presence of macrofauna (i.e. at least one macrobenthic species) is critical to allow a certain degree of bioturbation which will enhance aerobic mineralization of the deposited organic material. According to the Japanese criteria (Yokoyama 2003), occurrence of macrofauna throughout the year can be used as an indicator of healthy environmental conditions at fish farm sites, and azoic conditions prevailing in the sediments for more than 6 months, as an indicator of critical environmental conditions. The system proposed for the regulation of aquaculture in Scotland (Henderson & Davies 2000) requires that macrofauna beneath and very close to the farms (the AZE zone) should include at least two polychaete species (in all the replicates pooled together) whereas outside the AZE, the number of taxa should be at least 50% of the reference station value. This regulatory scheme is very interesting since it combines standards for both the AZE and the zone in the close vicinity of the farm. Some of the quality criteria for benthic communities using the system are shown in Table 5. It should be noted that:

a) the number of taxa is highly sensitive to sampling effort (i.e. in nearly azoic sediments, the greater the number of samples, the higher the probability to collect some benthic species);

b) in the Mediterranean, areas in the vicinity of the AZE tend to support a species diversity (in terms of both taxa present and Shannon-Wiener index) that increases above reference values (Karakassis et al 2000), while the number of macrobenthic taxa beneath the cages is normally considerably higher than 2 (Karakassis et al 2000; Apostolaki at al 2007; Papageorgiou et al. 2009).

c) Beggiatoa mats are quite often present beneath the fish cages, particularly in silty sediment sites (Karakassis et al 2002), but they are unlikely to be present at distances greater than 25 meters.

4.4 Nutrients and Chlorophyll a

Substances released from aquaculture activities may be transported far from the farm site. Therefore, wastes in solution could be expected to be a more important source of nuisance to other uses of the coastal zone than e.g. particulate organic material which settles closer to the farm. However, several studies have failed to find significant changes in water quality attributes in the vicinity of fish farms; this is particularly true in the Mediterranean (Pitta 2009 and references therein), although the productivity of phytoplankton and macroalgae are probably affected, at least as shown by bioassay experiments, up to at least a distance of 200 m from the cages (Dalsgaard & Krause-Jensen 2006).

The complex dynamics of nutrient dispersion and uptake, and the bottom up and top down control and co-limitation of primary productivity by various trace elements make it difficult to establish nutrient levels as 'safe' or 'critical' in the vicinity of fish farms. However, the UK 'Comprehensive Studies Task Team' on coastal eutrophication (CSTT 1997) has recommended EQSs for winter nutrients Scottish lochs; these are 168 $\mu g\ l^{-1}$ for dissolved inorganic Nitrogen (DIN) and 62 $\mu g\ l^{-1}$ for dissolved available inorganic phosphorus (DIP). Although in some sheltered areas of the Western Mediterranean these values may be approached at sampling stations close to fish farms (Pitta et al 2006), the recorded background levels in most typical (semi-exposed or even moderately sheltered) sites in the Mediterranean are 50% lower than these EQSs (Pitta et al. 1999, 2005).

Table 5 - Sediment quality criteria in Scotland: action levels within and outside the Allowable Zone of Effects (AZE), modified from Henderson & Davies (2000)

Component	Determinant	Action level within AZE	Action level outside AZE
Benthos	Number of taxa	Less than two polychaete taxa present (sample replicates bulked)	Must be at least 50% of reference station value
Benthos	Number of taxa	Two or more replicate samples with no taxa present	
Benthos	Abundance	Organic enrichment polychaetes present in abnormally high densities	Organic enrichment polychaetes must not exceed 200% of reference station value
Benthos	Shannon-Wiener diversity index	N/A	Must be at least 60% of reference station value
Benthos	Infaunal trophic index (ITI)	N/A	Must be at least 50% of reference station value
Sea bed	*Beggiatoa*	N/A	Mats present
Sea bed	Feed pellets	Accumulations of pellets	Pellets present
Sediment	Copper	289 mg kg^{-1} (dry wt)	
Sediment	Zinc	169 mg kg^{-1} (dry wt)	
Sediment	Free sulphide	4800 mg kg^{-1} (dry wt)	3200 mg kg^{-1} (dry wt)
Sediment	Organic carbon	9%	
Sediment	Redox potential	Values lower than -150mV (as a depth average profile OR Values lower than -125mV (in surface sediments 0-3 cm)	
Sediment	Loss on ignition	27%	

The CSTT (1997) group has also suggested a critical value of 10 $\mu g\ l^{-1}$ for Chlorophyll *a* in water, assuming that above this level there is a high risk for phytoplankton sedimentation to cause sediment anoxia. These values are quite difficult to find in most typical Mediterranean mariculture sites but, nonetheless, this EQS value is a useful stimulus for research on the potential impact of eutrophication, even if in extreme cases. The fact that the water quality standards proposed for Scotland are currently quite high in comparison to what has been measured in the Mediterranean does one necessarily mean that the water quality is not a relevant issue. The concentration of fish farms in specific zones dedicated for aquaculture, and/or the increase in production levels to achieve an economy of scale, might lead to an increase in levels to ones that are much higher than present day ones. To this end, the establishment of efficient and long term monitoring programs in areas with an increasing concentration of fish farms and/or increased aquaculture production will allow collection of data on dose-response that will be useful for the assessment of the ultimate ecological thresholds is such a scenario. Very large scale production e.g. aquaculture parks (such as the 'polygonos' in Spain) with high farm densities may increase the potential for eutrophication. The Phytoplankton Community

Index (PCI) is a recently proposed method (Tett et al. 2008) that could be used for monitoring of the water column in enclosed bays that support high production. To our knowledge, this index has not been evaluated in the Mediterranean.

4.5 Seagrass (Posidonia oceanica) meadows

One of the most important documented effects of aquaculture on biodiversity in the Mediterranean are those on *Posidonia oceanica* meadows. It has been documented that sedimentation is the main driver of the negative environmental changes in *P. oceanica* meadows and is a strong indicator of fish farming impacts; the threshold value is 50 mg P m^{-2} d^{-1} or 1.5 g organic matter m^{-2} d^{-1} (Diaz-Almela et al 2008). Through coupling measurements of sedimentation rates with distance and sediment quality, it has been possible to identify a threshold of 400 m as the minimum distance required between the edge of the farm and *P. oceanica* meadows (Holmer et al 2008); this should be accompanied by a monitoring programme to ensure that there is no regression of the meadow.

A European Integrated Project titled 'Thresholds of Environmental Sustainability' (http://www.thresholds-eu.org/) has addressed the issue of thresholds in relation to coastal processes, and includes *inter alia* a case study for thresholds related to fish farming. In this project, some of the most discussed thresholds were those pertaining to effects on seagrass meadows.

Finally, in the UK Marine SACs Project (2001), as well as in Henderson & Davies (2000), there are numerous regulatory thresholds and EQSs concerning the accumulation of metals and organic pollutants in the tissues of farmed fish and in waters and sediments. Most of these, however, have been designed in the context of public health rather that in an ecosystem perspective, and they have little relevance to site selection and carrying capacity other than the general requirement for avoidance of highly polluted zones.

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5. Environmental criteria for site selection

by Pablo Sanchez Jerez

5.1 Main environmental challenges and bottlenecks for site selection and carrying capacity

Olsen et al (2008) have described the most important bottlenecks for further development of aquaculture during the next decades. These may be categorized into three main clusters:

1. resource cluster (availability for resources such as space, feed and energy;
2. attitudinal cluster (public and consumer attitudes, legislation etc);
3. innovation cluster (new technology and market developments).

In the Mediterranean these clusters may also be regarded as the main bottlenecks for future aquaculture development in general, although presently there are some Mediterranean peculiarities affecting the significance of various components of these clusters. For instance, Mediterranean mariculture is largely an exporting industry and therefore consumers tend to become interested in the quality of product rather than in the impacts of the production system as, for example, is often the case with salmon. Legislation is also quite variable among countries or even regions and there is, therefore, no uniform effect of the state on aquaculture production, when making comparison. In many countries there is lack of specific and well defined environmental quality standards related to aquaculture. This deficiency has occasionally an effect on the environment but, more often, on aquaculture since it leaves the industry vulnerable to sudden political decisions (e.g. orders to move offshore at very short notice), not because standards are exceeded but because other uses of the coastal zone have more political power than that of the relatively recently developed aquaculture. Aquaculture is exposed to accusation of being a polluter of the coastal zone because it does produce a certain amount of waste and it will probably continue to do so regardless of any progress in feed technology, genetic improvement of the stocks, or farming practices. However, the release of wastes (and particularly carbon, nitrogen and phosphorous compounds) does not necessarily cause pollution. According to the GESAMP definition, pollution is the "*Introduction of man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazard to human health, hindrance to marine activities including fishing, impairment of quality for use of sea-water, and reduction of amenities*". Therefore, pollution needs to be defined in relation to agreed environmental standards beyond which action should be taken. Although some fish farmers may think that postponing the adoption of such standards may reduce pressures on the industry, it is probably to their benefit to have such an agreement with the society.

Innovation is, of course, an important issue for all types of production, but so far Mediterranean aquaculture has mainly followed the technological advances achieved in the salmon industry. Therefore, issues like fish meal and fish oil replacement will probably follow the general solutions that will become available for fish farming globally. It has been estimated (Bell & Waarbo 2008) that by 2010, more than 85% of the fish oil and >50% of the fish meal will be consumed by aquaculture. This is not an ecologically sound situation, and certainly it will not be sustainable in an overpopulated world where food from the sea will be more and more costly. The problem becomes more serious with the increased levels of polycyclic biphenyl compounds (PCBs) and other persistent organic pollutants (POPs) found in European farmed salmon (Hites et al 1994), but also with Mediterranean aquaculture species (Carubelli et al 2007). The bioaccumulation/biomagnification is more visible in farmed carnivorous fish; this is because general contamination of the marine environment has increased the levels of POPs, including in wild fish (Bayarri et al 2001; Cirillov et al 2009). In this context, future strategies for aquaculture production must aim to reduce the current dependence on fish oil and fish meal while taking all possible steps to reduce contaminant levels in fish and at the same time ensure that we preserve current levels of n-3 highly unsaturated fatty acids (n-3 HUFA) in farmed fish (Bell & Waarbo 2008).

Marine aquaculture requires a clean and unpolluted environment because it produces food for a concerned and critical market, since the issues of food safety has, for the past decade, been on the political agenda, particularly in industrialized countries (Olsen et al 2008). In this context, mariculture production is completely incompatible with industrial pollution and also with pollution that originates from mariculture activity itself. In several aspects, water quality is adversely affected by aerial deposition of persistent pollutants, with little hope of recovery as can be seen with the example of PCBs and other POPs.

Considering the above, site selection, therefore, is a central issue for the development of aquaculture. Aquaculture, as any other human activity, influences and impacts the environment. Planning activities for the development of aquaculture at a selected site inherently require some spatial analysis because of the specific environmental and socio-economic aspects that would characterise the area. Therefore**,** preliminary studies made beforehand to define a location as an optimal one for aquaculture must be carried out. Such studies, dealing with site selection, can be developed at different spatial scales; at the national level (hundreds of km), down to the regional level (tens of km) or even further down to the local (km) level.

Site selection for aquaculture development has been worked out for several production systems such as fish (Benetti et al., 2001), oysters (Chenon et al., 1992), mussels (Scout et al., 1998), clams (Arnold et al., 2000), scallop (Halvorson, 1997), shrimp (Alarcon & Villanueva 2001) and seaweed (Brown et al., 1999). The appropriate location of an aquaculture facility is one the most effective environmental management tools available. Mistakes regarding to allocation of sites for aquaculture facilities can produce conflict with marine environmental conservation and other user competing for space or water quality.

Additionally, it is important to differentiate between site selection procedures for defining new sites in pristine areas (development of aquaculture in pristine localities) and site selection within an area already under production (new facilities within a region with aquaculture facilities). Also, because of the lack of planning during the last decades for developing aquaculture, it may be necessary to reallocate farms already under production to avoid environmental problems and/or social tensions. In such a case, additional consideration should be taking into account, such as the capacity of recovery of the ecosystem, the cost of reallocation and social cost for local population.

A spatial analysis for proper site selection should include the following aspects that are usually considered for land facilities (Pillay, 1990; Kövári, 1984):

- **land analysis:** a general topographic appraisal and an assessment of drainage characteristics and flood risks present at the site), and soil analysis;

- **soil type:** texture analysis and chemical analysis of major and minor nutrients;

- **water analysis**: water source characteristics, investigation of access to source water, chemical analysis of major and minor elements plus heavy metals, dissolved oxygen, pH, temperature and salinity.

- **meteorological analysis:** analysis of meteorological data from the region, with data on seasonal patterns of rainfall and temperature, including disaster risk assessment

- **traditional infrastructure analysis:** analysis of site access, transportation networks, logistics, export channels, communications networks, energy sources, labour pools and other relevant infrastructure needs.

- **fish farming infrastructure analysis:** brood stock and fry suppliers, feed suppliers, fish farming equipment suppliers and processing options that exist within the region

- **market analysis:** local and regional markets assessment and exporting opportunities to foreign markets.

- **government regulation and economic assessment:** local and regional administrative, political and socio economic conditions and regulations.

Because the complexity of coastal areas and marine ecosystems, site selection is one of the bottle necks for sustainable and enduring progress. In coastal areas, the site selection analysis usually requires data which are more complex to obtain; some of them also require complex collection procedures. Therefore, for coastal farms, other considerations should be also taken into account:

- **marine habitat mapping:** distribution of marine habitats and information about their level of legal protection and sensitivity to increase of organic pollution;

- **oceanographic conditions and carrying capacity:** current and wave analysis, profiles of temperature and salinity, nutrients and chlorophyll levels;

- **interaction with fisheries:** fishery grounds and interactions with wild fish;

- **negative impact from other users:** sources of organic and chemical pollution and other risks such as maritime transport activities and oil spills.

Site selection is closely related to carrying and holding capacity. Both these terms are usually used indistinctively. However, carrying capacity of a defined area refers to the potential maximum production of a species or population that can be maintained in relation to the available food and environmental resources. Carrying capacity may be estimated for site selection in the case of filter feeding organisms, such as mussels or clams. On the other hand, holding capacity is the potential maximum production that is limited by a non-trophic resource, for example, the capacity of an ecosystem to hold a determined biomass of fish. Holding capacity is closely related to other terms such as assimilative capacity, production capacity or environmental capacity (Halide et al. 2009).

Site selection for aquaculture should take into account a series of basic requirements which are related to the interests of the farmer but also to those of the society. These may be economic nature but also of environmental economic or political (see Table 6).

Table 6 - Basic requirements for site selection and levels of compatibility with different site characteristics

Type of interest	**Site** / **Requirements**	**Coastal**	**Offshore**	**Sheltered**	**Exposed**
Envir. / Econ	High water quality for the farm (dissolved oxygen levels)	**N**	**Y**	**N**	**Y**
Environmental	Low effects on benthos	**N**	**Y**	**N**	**Y**
Environmental	Low effects on the water column	**N**	**Y**	**N**	**Y**
Political	Low competition level with other users	**N**	**Y**	**N**	**Y**
Economic	Low investment cost	**Y**	**N**	**Y**	**N**
Social	High safety for personnel	**Y**	**N**	**Y**	**N**
Economic	Low risk of physical damage	**Y**	**N**	**Y**	**N**
Economic	Low transport cost sites	**Y**	**N**	**Y/N**	**Y/N**

5.2 Environmental aspects for site selection in coastal areas

In European waters, cage aquaculture has been developed in coastal bays, fjords, and lochs. Because of the potential environmental impact and user conflicts in a limited space, aquaculture has recently received attention with respect to identification of new sites for grow-out production. Therefore, before selecting a location for marine aquaculture, it is important to take into account several ecological aspects.

Water quality for use by the farmed species e.g. in terms of oxygen level or absence of algal blooms, is more likely to be high in exposed and offshore sites as opposed to coastal and sheltered sites. In the Mediterranean, most of the production is carried out in relatively exposed sites (as opposed to Scottish lochs, for instance) but not so often in offshore sites. Regulation is also diverse in the Mediterranean: some countries (e.g. Cyprus, Malta etc) have for several years adopted a distance limit (from the shore and between different farms) for fish farm sites. Turkey has also introduced this. Greece has adopted a gradual adaptation scheme, allowing expansion of production only in offshore sites and imposing reduction or stability for farms in coastal shallow sites.

The environmental effects of aquaculture depend a lot on the exposure and water depth of the site, which are rather intercorrelated. Deep, offshore, exposed sites will, for example, not affect seagrass habitats (if located beyond the 50m isobath), and will have less effects on benthic communities (if carefully placed outside maerl beds, which tend to occur in deep waters) i.e. without causing anoxic zones and outgassing. This will be also the case with the water column variables and the necessary dilution of the solute wastes which will be rapidly taken up by the plankton and microbial food web. Moving offshore will also greatly help reducing conflicts with other users of the coastal zone, particularly tourism and artisanal fisheries. However, not all aspects are positive. In offshore and exposed sites, the cost of the cage moorings and general construction at the farm increases and follows an increased risk of physical damage to the installation. On the other hand, the safety of personnel is put in higher risk in case of sudden storms, and some diving operations become more dangerous with increased water depth. Finally an increase in distance from the shore for siting the farm imposes a higher cost for the transport of personnel, the fish feed, and the harvested fish. From the above it is evident that there are divergent interests in the site selection process that need to be considered in the specific context of each particular site.

Furthermore, future changes may considerably affect the priorities in the balance of the above requirements. For instance, the availability of fuel and energy may affect the decisions for site selection towards the coast, or the emergence of a disease or parasite may impose a much more pressing need to move offshore. Proximity to major transport routes is also an issue of importance affecting site selection at a “macro” scale, i.e. there are regions, islands etc which are more preferable for investment due to easier and faster transport of the aquaculture products to the main markets.

5.2.1 Organic discharge

The capacity of a water mass to assimilate an external input of organic matter will be very different depending on the several ecological and oceanographic features. For coastal aquaculture, major concerns come from the discharge of wastes in form of uneaten food and fish excretions, which will especially have an effect on the benthos and species that are particularly sensitive to an increase in input of organic matter. Organic matter input is closely dependent on species, production, culture method, hydrography, feed type and management (Wu, 1995).

Organic waste is particulate and will sediment, in a high proportion, causing a change in the properties of sediment in the vicinity of the farm, leading to modification of the sediment chemistry and macrofaunal community structure (Karakassis et al. 2000), and favouring the proliferation of opportunistic species and an increased abundance of opportunistic scavengers. Aquaculture increases carbon and nutrient inputs to the sediment, mainly, nitrogen and phosphorus, which will accumulate in the sediments and will lead to an higher oxygen demand, production of anoxic sediments and, eventually, production of toxic gases (such as ammonia, methane and hydrogen sulphide), all of this will contribute to a decrease in benthic diversity (Wu 1995). These effects can be detected at the locality scale. Boyra et al. (2005) found that sea bass and sea bream aquaculture modified the intertidal community structure in the Canary Island by modifying the species composition and coverage of the benthic assemblages; this was manifested as an increase in the abundance of filter-feeding fauna such as the anemone *Anemonia sulcata* and of species tolerant to organic enrichment such as the algae *Caulerpa racemosa* and *Corallina elongata.*

The effects of sea cage farming on the water column have not been as deeply studied as the effects on the benthos; some studies have shown a decrease in dissolved oxygen and increases in BOD, nutrients (P, organic and inorganic N and total C); these have been generally noted in the water column around salmon farms (Beveridge 1985). However, in the Mediterranean, no consistent results have been found; studies failed to detect eutrophication in the pelagic ecosystem as a consequence of aquaculture activities (Pitta et al. 2005). Dilution by hydrodynamism, grazing by zooplankton or heterotrophic bacterial activity have been proposed as the main factors resulting in the lack of detectable impacts.

5.2.2 Chemicals

Within the components of commercial food pellets used for feeding the cultivated species, some chemicals can be found; i.e. antioxidants, antibiotics, or additives such as heavy metals. Two common compounds are the antibiotic oxytetracycline and the antioxidant butylated hydroxytoluene (BHT) which has bioaccumulating properties (Hektoen et al. 1995). Moreover, use of antibiotics for treating cultivated fish diseases could lead to the development of a resistant bacterial population in the sediments as reported by Austin (1985) and Holmer (1991). Aquaculture can also favour the accumulation of heavy metals. Derain et al. (2006) found that fish farms modified sediments allowing mercury to accumulate in the carnivorous fish *Sedates* spp. to levels that recommended lower consumption of this fish in children and women of child-bearing age, according to the toxic levels guidelines of the Canadian Health Department. It should be noted that while cultivated fish are consuming food pellets over a period of approximately one year until harvest, wild fish may eat these compounds for longer periods if they remain resident around the cages or return to the farm site seasonally. Therefore, site selection should take into account the potential effects of chemicals from aquaculture on fishery grounds, especially because of the potential negative impacts on both wild fish and human health.

5.2.3. Sensitive habitats

During site selection, one should consider the spatial distribution of sensitive habitats as these are affected by inputs of organic matter. Of special concern are Mediterranean key species and habitats, such as *Posidonia oceanica* and maerl beds, which are known to be affected by fish farming activities. *P. oceanica* and maerl habitats are main sources of biodiversity in the Mediterranean (Boudouresque et al. 1991), and a much effort is being made to protect these key ecosystems. Ruiz et al. (2001) found that fish farming provoked a decrease in shoot density and cover in a *P. oceanica* meadow within a radius of almost 300 m from the perimeter of a fish farm in the south-western Mediterranean. The physical structure of cages reduces the amount of available light. Moreover, the increased input of particulate and dissolved organic matter increases sedimentation and promotes the proliferation of epiphytes on *P. oceanica* leaves, thereby reducing its photosynthetic capacity. Such effects are more adverse in the case of *P. oceanica* as it is a very slow growing seagrass.

Maerl beds comprise unattached coralline red algae (Corallinales, Rhodophyta) that can build-up over millennia to create carbonate-rich gravel deposits that form habitats of high benthic biodiversity (Hall-Spencer et al. 2006). The algae making up maerl beds require light for photosynthesis and growth, and usually occur in areas with clear water and strong currents. In the Mediterranean Sea, maerl habitats occur at water depths of between 20 m and 60 m (Barbera et al. 2003). Maerl beds slowly build and contribute to a diverse ecosystem, consequently, the resilience capacity will be limited; salmon aquaculture has been shown to have an adverse effect on this habitat, as shown by studies at three Scottish fish farms which showed that the farm activities provoked significant reductions in live maerl cover and diversity, while they led to an increased abundance of species tolerant to organic enrichment (Hall-Spencer et al. 2006). The displacement of fish farms to deeper offshore locations to avoid adverse effects on *Posidonia oceanica* meadows, can have a negative impact on maerl communities if their spatial distribution is not well know and no habitat mapping has been carried out at sites indentified for aquaculture activities.

5.2.4. Escapes from reared stocks

As in agriculture, the aquaculture industry has been striving to improve the characteristics (e.g. food conversion ration) of farmed fish in order to enhance production. Breeding programmes have been undertaken to enhance strains that feed and grow better. This has lead to largely different genetic profiles of cultured fish compared to their wild counterparts; consequently, escapes of such cultured fish strains can lead to interbreeding and competitive interactions that may provoke detrimental effects on wild fish stocks. McGinnity et al. (2003) experimentally documented that hybrids from crosses between cultivated and wild salmon had a lower survival capacity and reproduction success than wild salmon; moreover, these workers notioned that this could lead to extinction of vulnerable wild populations. Escapes of fish from sea cages have been reported for almost all species presently cultured across Europe, including Atlantic salmon, Atlantic cod, rainbow trout, Arctic chart, halibut, sea bream, sea bass and meagre. The present level of escapes is regarded by many as a problem for the future sustainability of sea cage aquaculture (Naylor et al. 2005, WWF 2005) as escapees can have detrimental genetic and ecological effects on populations of wild conspecifics (see review by Thorstad et al. 2008).

Three decades of Atlantic salmon mariculture have shown that it is impossible to develop culture technologies and routines which guarantee that fish will not escape from farms (Naylor et al. 2005). Therefore, site selection for aquaculture facilities should consider the potential impacts of escapes on natural stocks. Under several circumstances, including extreme weather events and operational accidents, fish escapes will occur. The Europe-wide industry trend of locating sea cage farms in more exposed locations (Sunde et al. 2003) in response to regulatory mechanisms (e.g. Turkey), together with the search for production advantages related to water quality, has increased exposure to extreme weather conditions and thus stresses on farm installations. Although knowledge-based improvements of technology and operational routines are the key to success for substantially reducing escapes of farmed fish, it is still highly likely that escapes will occur. In this context, efficient, accurate and cost-effective tools for identifying escapees are central for assessments of the extent and consequences of fish escapes. Moreover, knowledge of short- and long-term post-escape dispersal of fish is directly applicable to assessing the prospects for recapturing escapees and for developing efficient recapture technologies. Knowledge of dispersal patterns after escape are fundamental for predicting possible negative ecosystem effects caused by escapees, including competition for resources with wild fish, interbreeding between escaped and wild fish and transfer of diseases from farmed to wild fish (e.g. Naylor et al. 2005; Weir and Grant 2005; Uglem et al. 2008). In addition, knowledge of the movement patterns of fish after escape may provide information that will assist in the selection of farms sites that might minimize the negative effects of escapees.

Knowledge regarding identification of escaped fish and ecological consequences caused by escapees varies greatly among the fish species being farmed in Europe. For Atlantic salmon, it has been demonstrated that escapees can cause negative environmental effects through interbreeding with wild conspecifics (e.g. Fleming et al. 2000; McGinnity et al. 2003; Hindar et al. 2006) and possibly also through propagation of parasites and diseases (e.g. Heuch & Moe 2001; Bjørn & Finstad 2002, Krkošek et al. 2007). Concerns that escapees may act as vectors of pathogens to wild fish and to farmed fish at adjacent farms have heightened recently with the escape of 60,000 salmon infected with infectious salmon anaemia (ISA) from a farm in northern Norway. In another case, 11 5000 salmon infected with pancreatic disease (PD) escaped from a farm in southern Norway in 2007[6]. Several studies have mapped the dispersal of adult farmed salmon after escape and have shown that they disperse over large geographical areas and that they migrate in significant numbers up rivers during autumn where they spawn together with wild salmon (e.g. Furevik et al 1990; Whoriskey et al. 2006, Hansen 2006). Identification of escaped salmon is routinely performed by analysing growth patterns in scales (Fiske et al. 2006) and attempts to use genetic markers to trace salmon escapees are under development. Research to investigate the genetic effects of aquaculture on native species has been broadly developed through the FP-6 EU Coordinating Action GENIMPACT[7]. GENIMPACT's objectives are to study the genetic impact of farming activities and its implications for aquaculture management and the conservation of wild stocks. Among the project's conclusions was that improved technological measures to prevent escapes of fish from sea cages were paramount to reducing negative genetic effects (Triantafyllidis et al. 2007).

In comparison to Atlantic salmon, knowledge of the extent and effect of escapes of Atlantic cod is very limited. Methodologies for simple and cost effective identification of escaped individuals of these species do not exist and detailed knowledge of the short- and long-term behaviours and dispersal of fish following escapes of farmed juveniles is sparse. Uglem et al. (2008) documented the short- and long-term dispersal of escaped adult cod in a single Norwegian fjord using telemetry. In general, the escaped adult cod dispersed rapidly away from the farm in random directions. Recapture rates of these escapees in the local commercial and recreational fisheries was surprisingly high (approximately 40%), indicating that recapture of high numbers of escapees may be feasible if recapture fisheries are properly organised. Results from releases of hatchery-produced cod juveniles for stock enhancement purposes have shown that released cod generally have a variable fidelity to the release site, depending on the release location (Svåsand et al. 2000). At a scale of dispersal of within 50 km of the release site, Svåsand et al. (2000) stressed that results obtained in one area cannot be generalized to other areas. Moreover, fish released for enhancement purposes differ from escaped farm fish since the former were produced and released in a manner intended to make them fit for the life in the wild.

For other cultured species, like sea bream, sea bass and meagre, knowledge regarding identification of escaped fish and how escapes might affect ecosystems is virtually non-existent. Intentional releases of cultured sea bream for stock enhancement have been reported from the southern Atlantic coast of Spain, and in the Bay of Cadiz (Sanchez-Lamadrid 2004). Released fish moved less than 10 km from the release point. Good growth rates and condition indices indicate that the released fish adapted to life in the wild, and suggest that populations of wild fish could also be altered by released fish. For example, there is correlative evidence of a substantial increase in wild populations of sea bream after fish farming began in the Messolonghi lagoon, Greece (Dimitriou et al. 2007). For the Canary Islands, Toledo et al (2008) highlighted that sea bass (*Dicentrarchus labrax*), a introduced species in these islands, is commonly find in shallow coastal habitats. The escaped individuals use natural trophic resources, and their abundance depends strongly on distance from fish farms. Escaped sea bass are able to exploit natural resources by feeding mainly on wild fishes. Consequently, its diet overlaps with that of top predator species in the Canary Islands, and establishment of this species in the archipelago is assumed to lead to new and strong competition with the local species, affecting traditional fisheries.

Genetic interactions between wild and cultured fish have been deeply studied for salmon but very little attention have paid to cod (but see Moe et al. 2005) and Mediterranean species like sea bass and sea bream. Apparently, the interbreeding risk for sea bream is low, since there are no distinct genetic populations in the biogeographical area extended between the Azores and the Eastern Mediterranean. Nevertheless, a small reduction in genetic variability in cultivated sea bream has been detected (Youngson et al. 2001). In the case of sea bass, however, it seems that three different groups of sea bass populations exist, being present in the Atlantic, Western and Eastern Mediterranean (Cesaroni *et al*. 1997). Even though not well documented, Spain may have used a mixture of sea bass stock from the Atlantic and Western Mediterranean populations, while France, Italy, Greece and Eastern

[6] www.kyst.no
[7] http://genimpact.imr.no/

countries have used fish sticks originating from the Western Mediterranean. Studies of cultured sea bass have shown adequate levels of genetic variation within cultivated stocks (Youngson et al. 2001), However, there is increasing interest in the development of selective breeding programmes for sea bream and sea bass in order to improve the production of these cultivated species, which makes necessary further research and the adoption of precautionary measures to better protect wild fish stocks.

5.2.5 Marine birds and mammals

Wherever fish farms are present in the natural environment, an interaction between aquaculture and wild life is expected to occur. Selection of appropriate sites can avoid conflicts with wild life, which in places may include protected species. For example, if the fish farms are located near natural habitats of marine birds (e.g. coastal wetlands), the negative interaction between bids and aquaculture can be elevated, as is happening with the cormorant (*Phalacrocorax carbo*) in south-eastern Spain (Alamo, 2009). Marine birds use aquaculture facilities as resting areas and feeding grounds, very often attacking the cultivated species on which they attempt to feed. Farmers use much time and resources to try to avoid fish mortality due to bird predation; in doing so they use a variety of devices to protect their produce. The devices used may provoke mortalities in the bird populations due to accidental entrapment. Presently, mortality levels due to direct killing by farmers or by entrapment seem to be very low in the Mediterranean but they still remain undocumented. On the other hand, the birds can affect the farm negatively It is documented that the birds can transmit diseases to farmed fish. In Europe, birds were responsible for transmission of a number of viruses such as SVC, VHS and IPN (Price and Nickum, 1995).

Disturbance by aquaculture activities has been proposed as another source of impact on birds. This does not appear to have been substantiated, even though some species may be initially scared away by farm activities (Pillay, 2004); it has been noted that marine birds eventually become accustomed to the activities and continue feeding on the cultivated species. However, a source of impact may be a diet change of birds. For example, sea gulls learn to directly feed on the food pellets before they reach the water surface after being launched into the cage by the farmer (pers. obs.) or by feeding on cultivated species, which have a physiological composition that differs from that of non-cultivated fish; for example, their fatty acid composition (Saglik et al. 2003).

Effects of aquaculture on marine mammals seem to be quite similar to those fro marine birds; however, the available data is even scarcer. Otters (*Lutra lutra*) seem to be the most harmful mammals at salmon and trout farms. Rueggeberg and Booth (1989) reported that seals (*Phoca vitulina, Halichoerus grypus*) and mink (*Mustela vison*) were the principal causes of predation damage in Canada. In the Mediterranean, between 1992 and 2000, there were 40 attacks of monk seals (*Monachus monachus*) on sea-bass and sea-bream farms in Turkey (Güçlüsoy and Savas 2003). As a consequence, these mammals are killed by fish farmers; this seems to be the most severe impact on marine mammals in the Mediterranean. In Scotland, it is possible to get a licence to shot seals to conserve fish stocks. Additionally, deployment of fish farms provokes an increment of boat traffic which may cause disruption to marine mammals.

In the Mediterranean, dolphins seem to be affected by sea cage aquaculture. It is known that dolphins make excursions to fish farm facilities to feed on the associated wild fish; Díaz-López et al. (2005) reported a change in movements of bottlenose dolphins (*Tursiops truncatus*) as a result of the presence of high fish densities around floating farm cages. Furthermore, death of one dolphin per month due to accidental entrapping in nets at the fish farms during the 15 month study was recorded (Díaz-López, 2007). Dolphins are at the top of the food chain; therefore, they are also susceptible to accumulation of any pollutant that is present in the food items they consume. One source of impact may be the chemicals, such as antibiotics or antioxidants, that may be present in the food pellets, and which may have accumulative properties (DeBryun et al. 2006). If dolphins feed on farm-aggregated fish, such pollutants may accumulate in their body with, as yet, unknown consequences.

5.2.6 Wild fish and fisheries

Coastal aquaculture farms have considerable demographic effects on wild fish by aggregating large numbers in their immediate vicinity. Consequently, information on fishing grounds, marine protected areas, and migratory routes may be relevant for avoiding negative impact from coastal aquaculture developments. Carss (1990) in Scotland and Bjordal and Skar (1992) in southern Norway showed that saithe (*Pollachius virens*) aggregated around marine salmon farms in considerable numbers. Fernandez-Jover et al. (2008) highlighted that Mediterranean sea cage fish farms attract wild fish assemblages, which had at least 30 different species. These authors estimated that the aggregation biomass ranged between 10 t and 40 t at five of the nine farms investigated (Dempster et al. 2004). Similarly, large aggregations have since been noted in Greece (Thetmeyer et al. 2003), Canary Islands (Tuya et al. 2005) and Indonesia (Sudirman et al. 2009). While mussel rafts in the Mediterranean Sea (Brehmer et al. 2003) are also known to aggregate wild fish, the majority of studies concerning demographic impacts of coastal aquaculture on wild fish have focussed on aggregations around sea cage farms.

Although geographic differences in the species of fish that aggregate around farms exist, pelagic planktivorous and carnivorous species dominate the assemblages at most farms and these fish opportunistically feed on food pellets lost from cages. In warm water areas, such as Mediterranean Spain and the Canary Islands, over 30 different species of wild fish aggregate at farms, although only 1 to 4 taxa (principally Mugilidae, *Trachurus mediterraneus*, *Sardinella aurita* and *Boops boops*) dominate the assemblages (Dempster et al. 2002, Tuya et al. 2005). The sizes of aggregated planktivorous fish at farms in Mediterranean Spain are large and most are likely to be adult (85% adult: Dempster et al. 2002, 71% adult: Dempster et al. 2005). In cold-water areas, such as Scotland and Norway, fewer species have been noted to associate with farms: *e.g.* saithe (*Pollachius virens*, Bjordal and Skar 1992), cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), lyr (*Pollachius pollachius*) or mackerel (*Scomber scombrus*); a major proportion of associated fish assemblages are also formed by fish of adult size (Demspter *et al*., 2009). Aggregative behaviour of demersal fish also takes place beneath farms although the aggregation size varies greatly between locations; few species at low numbers occur beneath farms in Mediterranean Spain while large, multi-species aggregations occur under farms in the Canary Islands (Dempster et al. 2005). Large abundances of sparids such as *Pagellus* sp., large Chondrichthyid rays (8 species) and *Heteroconger longissimus* have been observed at farms in the Canary Islands (Boyra et al. 2004). Large, carnivorous fish, such as *Pomatomus saltatrix, Coryphaena hippurus,* and *Sphyraena spp*. aggregate around many farms (Dempster et al. 2002, Dempster *et al*. 2005). *P. saltarix* commonly occurs in shoals of hundreds to thousands of individuals at farms along the south-east coast of Spain (Dempster et al. 2002) and feeds mainly on wild *Sardinella aurita* around the cages (Sanchez-Jerez et al. 2008). Considerable spatial variability in wild fish abundance and biomass exists among farms located along the same stretch of coastline (Dempster et al. 2002). Aggregations are temporally stable over the scale of several weeks to months, both in relative size and species composition, indicating some degree of residency of wild fish at farms (Dempster et al. 2002).

Because the influence on wild fish, space occupancy and market competition, a wide variety of potential interactions may arise between aquaculture and commercial fisheries (Hoagland et al., 2003). Depending on the species and technologies involved, these interactions may be competitive or complementary. More frequently, however, the two uses are competitive; and user conflicts could grow as aquaculture is increasingly looked at as a source of supply of seafood protein.

5.2.7 Spread of benthic pathogens and alien parasites

Fish farms can act as sources of potential pathogens to both humans and fish (CIESM 2006). The concentration of fish biomass in cages leads to the introduction of a huge quantity of faeces to the marine environment, which may increase loading of viruses and bacteria. Therefore, the expansion of aquaculture at sensitive sites can invoke concern from both ecological and human health perspectives (La Rosa et al. 2001).

Aquaculture can create routes for transfer of alien parasites and pathogens from different regions (Diamant et al 2006; CIESM, 2006). New species bring with them a complement of parasites and pathogens, which may be transmitted to wild populations. The dispersion of particulate matter around fish farms exposes wild fish to increased risk of infection. Additionally, when fresh food is used, such as for fattening tuna, there is potential introduction of new pathogens. Gaughan (2002) indicated that mass mortality in wild Australian clupeid fishes could have been caused by an alien pathogen introduced via imported infected frozen fish used for feeding tuna.

5.2.8. Harmful algae blooms

The increment of harmful algal blooms for which coastal fish farms have been sometimes blamed may lead to fish mortalities. Information is required, with respect to harmful algae, on the risks associated with the introduction, transfer and harvest of shellfish, depuration of shellfish, site selection for shellfish and finfish aquaculture, and the determination of specific toxic compounds in harmful algae. This is particularly relevant to requirements for aquatic animal health control and documentation, and concerns on harmful algae and other invasive species being introduced to aquaculture sites through ballast water and other vectors.

Worldwide, harmful algal blooms have caused frequent and sometimes severe problems to industry and public health, especially in recent decades. The blooms take many forms and have many effects. Sometimes their effects may be lethal, as when drinking water and sea food become contaminated with potent toxins. They can cause extensive economic damage, for example to fish farm stocks, and they can be a nuisance to tourism, as when mucilage accumulates on beaches. Specific examples of harmful algal events include large accumulations of plankton stocks in the Black Sea, the effects of dinoflagellate poisoning on benthic animals and fish in the North Sea, serious public health problems in tropical coastal areas caused by a widespread species of dinoflagellate, and the effects of plankton blooms on beaches and fishing nets.

Episodic harmful algal blooms (HABs) are natural events, but once considered to be rogue blooms, they are now common (Smayda 1997). What is new is their global spread, raising considerable alarm and concern within the scientific community, commercial fisheries and aquaculture industries, and among public health officials (Hallegraeff 1993). Regions previously free from HABs now suffer such blooms; species previously benign have become toxic or nuisances and, in many regions, the frequency and intensity of HABs have been increasing (Hallegraeff 1993). A significant global increase in die-offs of commercially and ecologically important finfish, shellfish, and mammals has accompanied the global surge of HABs (Scholin et al. 2000). Financial losses to commercial fisheries and associated industries sometimes exceed US$ 100 million per bloom event. Diarrhetic shellfish poisoning (DSP) has been found to occur in Japan, Europe, Chile, Thailand, Nova Scotia, and possibly Tasmania and New Zealand (Hallegraeff 1993). HABs and the phycotoxin responsible for paralytical shellfish poisoning (PSP) historically have been primarily phenomena of colder water; their current proliferation in tropical and sub-tropical waters and increased outbreaks in temperate and boreal seas is ecologically profound. Increased toxic bloom frequency has also been reported from the Baltic Sea, North Sea, Adriatic Sea, Black Sea, South Africa, Hong Kong, Korea, and the Seto Inland Sea (Smayda, 1990). HABs accompanied by human illness and death have apparently spread to regions previously devoid of such blooms, including Spain, Central and South America, Tasmania, New Guinea, Philippines, Indonesia and Thailand.

5.2.9 Introduction of alien species

Aquaculture has been responsible for the introduction of many alien species during the last decades. The environmental impact of introduced species is relatively unpredictable, but it could be often critical and permanent. The Mediterranean Sea has received many species that are non-native and hence originating from other seas. Human activity has increased the rate of alien species introduction, affecting the marine biodiversity of the region. During the last 150 years, the number of exotic species has increased, with the introduction of more than 100 alien species (Minchin, 2001). Additional to the introduction of species, a main problem is when the exotic species becomes invasive, hence increasing its population size at the expense of native species. A clear example of this is the introduction of alien macrophytes by oyster farming. Transportation and transplantation of alien molluscs into the Mediterranean has resulted in numerous unintentional introductions. In this sense, oyster farms served as effective gateways for alien macrophytes into Mediterranean coastal waters. Culture of the Japanese oyster *Crassostrea gigas* has been, compared with other major vectors such as ballast waters, the main vector of introduction of exotic macrophytes (Verlaque et al., 2006).

5.3 Better management practices for site selection

An optimal site selection procedure can mitigate local environmental impacts. For example, from a regional point of view, cumulative impact resulting from a concentration of several farms needs to be assessed carefully. In these sense, even small management steps can minimize the negative influence of aquaculture on coastal environment. Belle and Nash (2008) provide a summary of better management practices for site selection with regard to cage fish farming in coastal areas. Their recommendations are summarise as follows:

a) conduct baseline environmental site surveys;

b) avoid sites with frequent or extreme weather or sea-state conditions;

c) select sites with good water exchange that are not depositional environments;

d) select sites with water depth are least twice that of the net pen;

e) select sites with appropriate bottom type and profile;

f) do not site facilities in areas subject to harmful algal blooms;

g) avoid sites where culture activities will negatively impact sensitive populations of fish birds or other wildlife;

h) select sites away from concentrations of predators and pests.

5.4 Global change and aquaculture

Fisheries, aquaculture and other uses of marine renewable resources are already affected by global changes in the marine ecosystem. Adaptation of management measures, such as reallocation of coastal facilities is, therefore, critical. Reallocation of aquaculture facilities may be required if ecological and environmental aspects are affected by global change; e.g. carrying capacity of a body water, sensitivity of a marine ecosystem, sea level or temperature changes etc. Adjustment of strategies should aim at enhancing the resilience of marine renewable resources and their uses, and the current capacity to respond to sudden changes. Already, uses of the natural environment are characterized by massive over-capacities, excessive resources exploitation and pervasive conflicts within and between uses. A variety of changes in climatic conditions following atmospheric CO_2 enrichment have been predicted. These predictions include increased air temperatures, regional shifts in precipitation, and seasonal changes in the timing and duration of precipitation events and sea level rise.

The latest report of the European Science Foundation's (ESF[8]) Marine Board 'Impact of climate change on European marine and coastal environment - Ecosystem approach' (2007) shows how even moderate climate scenarios have caused marked consequences on the European marine environment. After considering all the recorded impacts on European Seas, the ESF-Marine working group identified other possible future challenges in terms of climate change monitoring, modelling, indicators and research and development. Predicting the consequences of climate change for our marine environment related to aquaculture activities will require the development and measurement of several parameters, with improvement of regional climate models and the development of biophysical models.

Higher temperatures may stress organisms, increasing their susceptibility to disease (Kimet al. 2000), but an increase in susceptibility will depend on the relative sensitivity of hosts and parasites to temperature. Other indirect process, such as the proliferation of jelly fish (Purcell et al., 2007), increase of parasitism (Marcogliese, 2001) or harmful algae blooms (Peperzak, 2003) can be influenced by aquaculture and affect aquaculture itself.

5.5. Economical and sociological consideration for site selection

The success of an aquaculture project depends to a large extent on the proper selection of the site to be developed into a fish farm or hatchery, and this is a multifactorial decision. For site selection, additional to the environmental factors described above, others affecting the efficiency and economy of the operations are also crucial. The producer should consider beforehand the marketability of the product, after an evaluation of existing and potential markets and the stability of these markets. Once a market has been identified, a suitable site for production must be identified. Haphazard development of aquaculture without adequate planning and regulation can result in the production of conflicts because of environmental impact, lack of economical feasibility or the social conflicts.

It is important to consider the relative novelty of an aquaculture project and its magnitude in a given area. Aquaculture is practised at different levels, form small homestead pond faming to vertically-integrated farms owned by multinational corporations, and it is traditional practice in some parts of the world and an innovation in other areas (Pillay, 1990). Depending on this, an aquaculture activity can produce a positive or negative impact. In addition to the economical changes in the area, developing aquaculture in new location can produce important social changes, as has happened in Chile after the development of salmon aquaculture.

Competition with other users of coastal space will be a strong force in shaping the development of aquaculture in many areas (Staresinic & Popović 2004). Unless grow-out systems are developed that reduce negative interactions with other coastal users, growth in sea-based fish farming could stagnate (Dempster and Sanchez Jerez, 2008). For example, the increasing number of tourists visiting the Mediterranean coastline will amplify the current high level of pressure being exerted on many fish farms in the region to reduce their visual presence close to the coast by either shifting offshore or submerging. In some areas, a shift towards localising farms in more high-energy coastal sites is already underway, largely to provide better culture conditions for the fish and partly in response to environmental concerns and coastal use conflict.

[8] http://www.esf.org

5.6 Social conflicts

In the context of selecting potential sites, it is best to gather environmental knowledge once spatial information on possible conflicting uses has been obtained. In this sense, demands by aquaculture on natural and social resources can be competitive, compatible or conflicting with other users (Chong, 1988). Areas can thus be narrowed down and efforts concentrated in places 'free' from other uses. If aquaculture is located in public owned sites that are common property, for example, ones in use by artisanal fishers, controversies may arise about free access through farm sites, leading to lack of cooperation at the local level (Pillay, 1990). Thus, depending on the area where it is intended to locate the project and the type of aquaculture proposed, the most appropriate parameters needed to achieve technical viability can be chosen.

Socio-economical aspects must be assessed in the light of safety and security of aquaculture facilities. Site selection should consider the potential risk of stealing and sabotage, to avoid future costs of establishing precautions. Precautionary measures cost money to carry out. Exposure to loss from pilferage and theft is of prime importance because without the assurance of getting an economic return, the farm would fail. The costs of surveillance and protection show up in production costs (Chong, 1988).

These considerations could be very important if aquaculture facilities will be located near densely populated areas, in areas with heavy maritime traffic or in the vicinity of fishery grounds. These risks must be considered especially if there are community concerns about the development of aquaculture in a certain area and, therefore, it could necessitate the implementation of security against damage, poaching and sabotage (Lawson, 1995). In any case, an additional cost of patrol and security should be considered for avoiding vandalism or poaching. The farmer can make use of video recording, real time cameras connected to the internet or security personnel. Therefore, in addition to the political, legal and environmental aspects of aquaculture, it is important to get to know its culture and traditions, as well as the ideas and images associated with its practice. An in-depth study of this kind can help in designing the best procedure for site selection and management, with the aim of gaining the social acceptance that will facilitate the implementation of the aquaculture project (IUCN, 2009).

Therefore, in addition to the environmental consequence of a bad farm siting (e.g. habitat destruction, introduction of non-native species, eutrophication and benthic anoxia), a site selection process that also considers social aspects is a crucial planning issue. An inappropriate location can favour the abandonment of unviable enterprises because the additional operational cost due to poaching and sabotage is unsustainable.

5.7 Infrastructural needs

Infrastructure refers to the background facilities, which are needed for the development of aquaculture in a determined region. Operational and marketing concerns are important factors in determining the location of an aquaculture facility, in addition to the environmental characteristics of the location. For correct site selection assessment, one of the most important aspects to be considered is the presence of a nearby harbour and an optimal road system, as well as other transport system to consumers (e.g. airports). Suitable distances from ports to aquaculture facilities can be established by making a cost analysis. The farther away a potential site for aquaculture is from a port, the more time and cost is needed to reach the installations, and therefore the less suitable it will be.

Other important factors are cost and aspects of the facility's construction. To avoid the coastal zone, which is a high conflict area that places limitations and constraints on aquaculture development, aquaculture facilities can be located at sites that are further offshore. However, cost and technical difficulties increase with water depth and distance to the harbour, thus increasing the total cost of construction and maintenance.

Decisions regarding infrastructure, such as distance to the nearest harbour, can be made using a cost benefit analysis. Cost benefit analysis provides a means of determining the net benefit of a specific project and decision-making criteria. This type of accounting was first put forward by Jules Dupuis in 1848 and formalized by Alfred Marshall. It has become the dominant framework used in the assessment of public projects worldwide. The objective is to estimate the total economic value (TEV) of a project in order to select the one with the highest net benefit. In the case of site selection and management, the TECV will consider the total value of all the costs and benefits of a specific type (i.e. species cultivated, design and engineering, etc.) and size of a farming operation at a particular site. This total includes the economic value of externalities (Randall, 2002).

5.8 Risk analysis and site selection

Risk analysis is a technical procedure which is being applied to a broad type of process, including economical activities such as aquaculture, to manage the risk of undesirable events which can have negative effects. The risk analysis process has the potential for wide applicability to the aquaculture industry, especially during the planning process before the definitive location selection. A standard process for risk analysis has been developed for an objective application to a wide range of situations. Generally, this process involves identifying, assessing and treating risks, and can include social, financial and environmental aspects (Crawford, 2003). Risk analysis is an important tool in designing and justifying regulatory actions in the international market place. For example, the Office International des Epizootic (OIE)[9] manual for disease control uses risk analysis as the basis for justifying restrictions on movement of aquatic animals in response to concerns about disease transfer and control. Furthermore, the International Council for the Exploration of the Sea (ICES) has embraced this approach in their 2003 Code of Practice for the Introduction and Transfer of Marine Organisms. One part of the ICES Code is specifically designed to address the "ecological and environmental impacts of introduced and transferred species that may escape the confines of cultivation and become established in the receiving environment".

Risk analysis may consider the negative effects of other users on aquaculture. For example, in the past, most incidents involving chemical spills from ships have occurred at sea during sailing, with only a few occurring in port or in the coastal zone. However, the increase in coastal traffic will increase the risk to coastal areas. The transport of hazardous goods by sea is regulated under Annex II of the MARPOL 73/78 Convention and the International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk (IBC), which deals with pollution caused by hazardous liquid substances transported in bulk. Therefore, when planning to develop aquaculture in areas with chemical maritime transport, risk analysis should take into account the potential of chemical spills from ships. Risk analysis should also consider that, after an accident, the effects of chemical spills on aquaculture facilities can sometimes not be as immediately obvious as in the case of an oil spill, and it may be necessary to monitor the status of the ecosystem and the fish production over a long period of time. Indirect effects on the environment must also be considered e.g. the remobilisation of toxic metals absorbed in sediments that may result from a decrease in pH due to an acid spill. As well as chemical analysis, biological systems such as bioindicators and biomarkers can also be used.

On other hand, risk analysis can assess the risk of aquaculture to other factors, such as environmental conditions. For example, Crawford (2003) presents the risk of shellfish farming activities having detrimental impacts on the ecology of the Tasmanian marine environment. In this study, the results of the qualitative risk assessment of detrimental impacts of shellfish farming rated the risk of spread of introduced pests and/or pathogens as high. However, this high risk rating would also apply to many other activities in the marine environment, such as commercial and recreational fishing and sea transport. The level of risk due to habitat disturbance was rated as moderate within the lease area, but

[9] See http://www.oie.int

would not be expected to extend outside the farm. Risks of organic enrichment of the seabed and reduced food resources for other filter feeders were both rated as low.

The Guidelines for Ecological Risk Assessment of Marine Fish Aquaculture of NOAA (Cash et al., 2005) provide a basic set of guidelines for risk management of marine fish aquaculture. The document provides risk analysis of 10 areas (increased organic loading, increased inorganic loading, residual heavy metals, transmission of disease organisms, residual therapeutants, biological interaction of escapes with wild populations, physical interaction with marine wildlife, physical impact on marine habitat, using wild juveniles for grow-out, harvesting industrial fisheries for aqua-feeds), giving the degree of potential adversity, together with its mitigation. Other examples of risk assessment are provided by ICES (2006). The potential genetic interaction of non-salmonid farmer fish (cod, sea bass, sea bream, halibut and turbot) with local native wild stocks is examined by a risk assessment procedure.

Additional to the mitigation of environmental impacts, appropriate risk analysis can also accomplish the following goals: (i) reduce the need for technically based environmental mitigation measures and costly ongoing management and monitoring measures, (ii) substantially reduce the cost of establishment and operation, and (iii) reduce levels of public scrutiny. A lack of spatial planning without any risk analysis process can have negative impact on future aquaculture production because of the environmental or social consequences of the activity.

An example is the reallocation of fish farms in Turkey operating at Akbük; the order for translocation of the fish farms was issued because cages belonging to different companies were next to each to other and located close to the shore. Problems of pollution because of the low hydrodynamism that characterised the site, resulting in accumulation of fish wastes and food, led to complaints by the holiday homes owners, including objections to the unsightly fish pens. The Ministry of Environment and Forestry sent notices and the coastguard headquarters warned the fish farmers that they had to move their fish farms elsewhere. A total of 16 sea bass/sea bream fish farms in the Akbük Gulf and 133 in the Güllük Gulf, near Bodrum, were at the risk of being fined if they did not move to the new production areas allocated specifically for the purpose. The cost for farmers translated to around 2.4 million dollars for each farm because the existing facilities are not suitable for the open sea and therefore the installations required upgrading. Furthermore, there are problems with regard to the duration of the new concession as there is no guarantee that this will be permanent (Fish Farming International).

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6. Interaction of aquaculture with other uses of the coastal zone

by Dror Angel & Shirra Freeman

The purpose of this chapter is to elaborate on issues that have received limited attention in existing studies. Specifically, it reviews interactions among multiple stakeholders in the coastal zone that affect and/or are affected by site selection and aquaculture activities. Of particular interest is the identification of key stakeholders. The present review also attempts to classify the interactions according to whether they are competitive, conflictual, complementary or neutral. This classification should provide preliminary indications for developing policies that enhance synergistic relationships and reducing conflicts between aquaculture and other stakeholders. This may also increase the potential for improving the social acceptability of aquaculture and participatory planning in the sector (McCausland et al. 2006). Stakeholder engagement plays a central role in several recent European initiatives including CONSENSUS[10], IUCN-Med Working Group on Sustainable Development of Aquaculture in the Mediterranean[11], FAO (2007), and AQCESS[12].

Three classifications are provided. The first is according to the interests of the stakeholders themselves, the second is according to zones of influence, and the third is according to the geographical location within the Mediterranean basin. Zones of influence are important to stakeholders, and their interactions will vary with the proximity to each other. Geographical location is important because the relative size of the aquaculture sector (in comparison to other sectors/industries), together with other socio-economic and political characteristics and policy priorities in a given locale will influence stakeholder interactions. In particular, countries on the Mediterranean's northern coast have more aquaculture than do those on the southern coast and more stakeholder conflicts have been observed in this part of the region.

6.1 Who are the Stakeholders?

The point of departure in understanding the question in caption is a review of stakeholders in the coastal zone. A functional definition is used as the basis for identifying stakeholders.

Stakeholders are individuals or groups who:

- have sufficient political clout to draw in officials with the public authority to make policy and management decisions;
- have legal standing and therefore the potential to block a decision;
- control resources (or property rights) necessary for implementation of a decision;
- may not be sufficiently organized to pose a formidable threat today, but who may in the near future. Identification of this last group relies on perceptions of potential political power, rather than established power. The rationale for including such groups is not based on any moral compulsion to "do the right thing", but rather it is based on a pragmatic consideration regarding potential delays and implementation;
- hold necessary information, which would include the scientific community. The range of necessary types of information can be quite broad, and complex issues often deal with phenomena about which data are limited or privately held. This includes parties who may have access to information that may be essential to developing wise and stable decisions.

For Mediterranean mariculture, stakeholders will vary with the proximity to farm sites and over different regions in the basin. They include (but are not limited to):

- Capture fishery sector
- Fish farmers
- Local communities and/or businesses reliant on processing, marketing, transport and other activities associated with fisheries and aquaculture
- Authorities (local, regional, national, other)
- Tourism (may need to treat local and international as distinct)

[10] ECASA-Ecosystem Approach to Sustainable Aquaculture. http://www.ecasatoolbox.org.uk/
[11] IUCN-Med Working Group on Sustainable Development of Aquaculture in the Mediterranean http://www.iucn.org/about/union/secretariat/offices/iucnmed/iucn_med_programme/marine_programme/aquaculture/
[12] AQCESS (2000-03) Aquaculture and Coastal Economic and Social Sustainability Project http://www.abdn.ac.uk/aqcess/index.html

- Environment
- Home owners
- Recreational users
- Other enterprises directly using the coast or marine body (marinas, ports, shipping, wind farms)
- Other enterprises indirectly using the coast or marine body (urban and industrial consumers of water, polluters, etc)
- Food and health authorities
- Scientific community
- Relevant authorities with jurisdiction over aquaculture (eg: ministries of agriculture, natural resources and environment, local planning authorities etc.)

In defining and engaging stakeholders, it is also useful to identify the extent to which they are central to the decision-making process. Simard (2003) uses a classification based on level of involvement beginning with the farm enterprise and other users in its immediate proximity as the primary stakeholders. The list of stakeholders varies from country to country. For example, in Algeria, aquaculture producers and SCUBA divers are the primary stakeholders and several environmental groups are secondary stakeholders. In Egypt, producers and hatcheries are the primary stakeholders, while there are no secondary stakeholders; and, as in Algeria, the main tertiary stakeholders are official groups and fisheries associations, universities, public organizations and conservation NGOs (Simard, 2003)

6.2 Stakeholder interaction scales and locations

The interaction among stakeholders varies over space and time. In terms of space, the present work considers both zones of influence of the various stakeholders, as well as geographical regions within the Mediterranean basin.

The UK's (1994) Comprehensive Studies Task Team (CSTT) defined three zones or scales for evaluating environmental impacts of point source discharges from fish farms. The same idea is adapted here for assessing stakeholder interactions (CSTT 1994; Tett 2007).

- **zone A** – the area immediately around the farm; the main stakeholder interactions here are those related to direct competition for space. This would include competition between adjacent farms, and between farms and capture fisheries, shipping lanes and recreational uses of the site.

- **zone B** - the scale of small water bodies, the main stakeholder interactions of concern are those stemming from spillovers among different uses (but not necessarily direct competition for space). Areas corresponding to zone B include those in which nutrient enrichment stemming from fish farm effluent could lead to a reduction in water quality that affects recreational users. Similarly, industrial pollution or accidental spills in the same zone could have negative spillovers that impact local fish farms.

- **zone C** - regional scale; at this scale, effects are potentially long term and stem from complex ecosystem processes which change ‘background’ conditions. Spillovers in zone C include changes in wild fish stocks and capture fishery landings.

The key stakeholders will vary from zone to zone, as will the nature of the interactions. In some cases, it is possible that interactions between identical stakeholders will be synergistic in one zone and competitive in another. For example, in zone A, fish farms and capture fisheries may compete for space but in zone C, capture fisheries may benefit from increased landings associated with aquaculture (Machias et al. 2005; Dempster & Sanchez, 2008; Dempster & Kingsford, 2003 Dempster et al. 2002, 2004, 2005, 2006). The example of the Murcia coast in Spain (elaborated below) illustrates one approach to the competition for space among coastal fisheries and aquaculture within the context of an integrated regional plan. Most aquaculture planning focuses on zone A issues.

Different regions of the Mediterranean basin have different amounts and types of aquaculture, as well as different policy priorities, and these determine key stakeholders and their interactions. Tables 7 and 8 show the region divided into four geographic sectors (North West, North East, South East and South West) and detail the amount and type of aquaculture and major policy issues and stakeholders.

Governmental stakeholders vary from country to country. Historically, aquaculture is administered by ministries with jurisdiction over agriculture. Most often, administration is at a national level, although in several cases, such as Israel, responsibility for administration is devolved to the level of the local authority or municipality. In Spain and Romania, responsibility for policy formulation and administration lies with local jurisdictions (Autonomous Communities and Prefects, respectively) (Chapela-Perez 2009). In a substantial number of countries, there are multiple executive and administrative bodies involved and a common problem is overlapping interests and responsibilities. In Turkey, responsibility for aquaculture is split among the Ministry of Agriculture and Rural Affairs; the Ministry of Transport (Marine Department); the Ministry of Health; the Ministry of Forestry; the Department of Water Works; the Ministry of Treasury and other authorities such as the Ministry of Tourism, the Ministry of Internal Affairs, the Ministry of Culture, the Ministry of Commerce and Trade, and the Ministry, of Finance (FAO 1999). Each body represents a different set of stakeholder interests and, recently, as the example below illustrates, several longstanding stakeholder disputes have been resolved to the detriment of the aquaculture sector.

Table 7 - Countries by sector

GEOGRAPHICAL SECTOR	**COUNTRIES**
Northwest	Spain, France, Italy, Monaco, Malta, Slovenia, Croatia, Bosnia-Herzegovina, Montenegro, Albania
Northeast	Greece, Turkey, Cyprus, Lebanon
Southeast	Israel, Palestinian Authority, Egypt, Libya
Southwest	Tunisia, Algeria, Morocco

Table 8 - Aquaculture sector and stakeholders by sector

GEOGRAPHICAL SECTOR	COASTAL (COMMERCIAL SCALE) AQUACULTURE PRESENCE	KEY STAKEHOLDERS	AQUACULTURE POLICY PRIORITIES
Northwest	HIGH	CAPTURE FISHERY; SHIPPING; URBAN/INDUSTRIAL; TOURISM; RECREATION; CONSERVATION	EXPANSION/MAINTENANCE OF SECTOR; FOOD SAFETY; MARKETING AND DISTRIBUTION; LOCAL COMMUNITIES
Northeast	MODERATE (EXCEPT FOR TURKEY AND GREECE)		EXPANSION OF SECTOR; FOOD SAFETY; MARKETING AND DISTRIBUTION; LOCAL COMMUNITIES
Southeast	LOW (EXCEPT FOR EGYPT)	CAPTURE FISHERY; URBAN/INDUSTRIAL SECTORS; (TOURISM & RECREATION); ENVIRONMENTAL QUALITY	INTRODUCTION OF AQUACULTURE; LOCAL FOOD SECURITY; TRADE; LOCAL COMMUNITIES
Southwest	LOW		

6.3 Stakeholder interactions and their management – selected review

Although stakeholder interactions can be synergistic, competitive, neutral or antagonistic, the last category tends to receive the most attention because it generally requires the most intervention by local decision makers. For this reason, most of the cases considered here document conflicts and their resolution. Where possible, cases of positive spillovers among stakeholders are described as well. Moreover, it is the authors' position that greater attention needs to be given to identifying synergies among stakeholders. Synergies tend to emerge spontaneously and often escape the planner's attention, yet, they may be the key to successful integration of the aquaculture sector into ICZM.

TURKEY

This is a case of a legislated resolution to ongoing conflicts between tourism, environmental and aquaculture stakeholders. In Turkey, 56% of aquaculture (including both freshwater and mariculture) is located inshore. The absence of integrated coastal zone management plans has contributed to site allocation conflicts between the aquaculture and tourism sectors for space (Zone A). Environmental concerns have also played a part, but the main stakeholders were owners of tourism facilities and holiday properties and fish farmers. In 2006, the Turkish Environmental Law 2872 was amended to include the following provision: "Marine aquaculture facilities should not be constructed in sensitive areas such as enclosed bays and gulfs and in natural and archeologically protected areas. Fish farms existing in contravention of this article will be closed after 1 year of the publishing of this law" (MEF, 2006). The site selection criteria under this law proscribe farms in areas where water depth is less than 30 metres, distance from shore is less than 0.6 nautical miles and sea current velocities are less than 10 cm/s (MEF, 2007). The law applies to new farms and those already operating, and as of May 2009, has resulted in the removal of 16 sea bass/sea bream farms on the Akbük Gulf and 133 farms on the Güllük Gulf, near Bodrum. The costs of upgrading facilities and relocating to deeper water and more exposed sites are difficult to estimate with precision may be as high as US$2.4 million. This is beyond the capacity of most small and medium sized firms. Moreover, in the absence of comprehensive, consistent aquaculture legislation, the farmers lack assurance that regulation will not change after they have complied with the current law. An additional source of uncertainty that may influence farmers' decisions is the availability of insurance. Offshore operations are among the most difficult to insure because of the large risks involved (Secretan 2007). Uncertainty is widely acknowledged as a major factor inhibiting investment since firms are less willing to incur sunk cost if they are concerned that there is a risk that they will not receive returns to their investment (Dixit and Pindyck 1994). In this Turkish case, risks of complying with current legislation plus the chance of future changes in regulation could be a very real deterrent to investment in the sector.

The stakeholder conflict and its resolution are not unique to Turkey. As the aquaculture sector has grown there have been an increasing number of conflicts. Since few Mediterranean countries have implemented one or both of ICZM or a national plan for aquaculture and since aquaculture often has a rather negative public image, a significant number of conflicts are resolved to the detriment of the sector. In Israel, for example, in 2008, a combination of poor public image and mobilization of environmental NGO's led to a court-ordered removal of two fish farms that had operated in the Gulf of Aqaba for nearly twenty years.

In order to learn from the Turkish experience and improve management practice, a project involving a wide range of stakeholders was implemented with a focus on resolving current conflicts and avoiding future ones (White et al. 2008). The project was supported by the Turkish Ministry of Agriculture and Rural Affairs and FAO technical cooperation project (TCP/TUR 3101). The objective of the project was to develop a roadmap for Turkish mariculture based on the ecosystem approach and engaging all relevant stakeholders. It consisted of a series of three workshops. Its outputs include recommendations for more coordination in mariculture policy and planning, integration of the sector within ICZM, improved site selection criteria, improved maintenance and logistical support for relocating farms, and measures for improving public education and social acceptability (Okumus et al. 2008; White et al. 2008)

GREECE AND TURKEY (CHIOS/KARBURUN-CESME)

This case documents the potential for both synergistic and conflictual interaction among stakeholders in the aquaculture and capture fisheries sector, as well as other local interests. It also illustrates some of the transborder challenges for management in the region. Chios Island is located in the Eastern Aegean, fairly close to the Turkish coast. Fish farming started there in the mid 80's and has grown to over 6,000 tonnes of sea bream and sea bass production in 2009. The area was extensively investigated during 2001-2003 in the framework of the MERAMED[13] and AQCESS[14] EU projects in terms of benthic impacts and aquaculture-fisheries interactions respectively

Fish landings in the area have increased substantially and there are strong indications that this is due to nutrification (increased levels of nutrients) of the water body (zone B) triggered by the release of aquaculture effluents. There are, however, conflicts between aquaculture producers and artisanal fishers over the use of coastal areas used as traditional fishing grounds by small fishing boats. Furthermore, local communities consider the growth of aquaculture as an obstacle for future development of the coast, mainly for tourism and recreation. Thus, in zone B, there are potential complementarities while, in zone A, there are several potential or real conflicts. Interestingly,

[13] MERAMED - Development of monotoring quidelines and modelling tools for environmental effects from Mediterranean aquaculture http://cordis.europa.eu/data/PROJ_FP5/ACTIONeqDndSESSIONeq112482005919ndDOCeq716ndTBLeqEN_PROJ.htm

[14] AQCESS (2000-03) Aquaculture and Coastal Economic and Social Sustainability Project http://www.abdn.ac.uk/aqcess/index.html

stakeholders in the capture fisheries are potentially in both harmony and competition with mariculture, depending on whether one considers zone A or B (Y. Karakassis, pers. comm.).

Regulation of site selection and determination of carrying capacity is currently under reform in Greece. Although as early as 1988, the need for national planning was recognized, unlike many other Mediterranean countries, national level debates on aquaculture strategy are very new in Greece, notwithstanding the fact that it is one of the largest producers in the region (FAO 1988; Marba et al. 2007). Basic data on the number of farms, their scale and production is unavailable and, aside from a few academic research projects, no systematic monitoring of the environmental performance of fish farms is carried out in Greece. A 2007 draft review of the Greek national aquaculture plan stressed the need for improved information, monitoring capacity and stakeholder involvement. In practice, recent policy directions favour providing incentives for fish farms to move to open water sites (Marbia et al., 2007).

Turkey and Greece have similar characteristics in terms of the physical environment (warm, oligotrophic waters, in coastal bays etc.), similar history (i.e. aquaculture development and types of conflict), similar policy provisions in aquaculture (i.e. favouring moving offshore) but very different social and economic and regulatory contexts. For example, Greece favours seasonal closures for its local fisheries while Turkey has fewer restrictions (Y. Karakassis, pers. comm.); the two countries share tendencies towards physical separation and zoning. Thus, the potential for transborder spillovers can be quite high. Offshore provisions are limited because of the proximity to national borders. Interestingly, the positive spillovers of increased fish landings accrue to both the Turkish and Greek fishing communities.

SPAIN (MURCIA)

Murcia on the southern Mediterranean coast of Spain is one of the most important Spanish regions in aquaculture production. Commercial operations began in the early 1980's and in 2006 there were 16 companies registered producing sea bream (*Sparus aurata*), sea bass (*Dicentrarchus labrax*), bluefin tuna (*Thunnus thynnus*) and meagre (*Argyrosomus regius*). The main stakeholders are capture fisheries, aquaculture, environment/conservation, tourism, defence and municipal interests (Chapela-Perez 2009). There is also an important recreational fishing fleet located on the Murcia coast and 285 commercial fishing boats in the ports of Águilas, Cartagena, Mazarrón and San Pedro del Pinatar. The commercial fleet is composed of small scale fishing boats (70%), trawlers (12%), purse seiners (10%), pelagic longliners (4%) and bottom longliners (1%). Landings are mainly pelagic species such as round sardinella (*Sardinella aurita*), melva (*Auxis spp*), sardine (*Sardina pilchardus*), horse mackerel (*Trachurus trachurus*) and mackerel (*Scomber scombrus*). One of the main aquaculture parks in San Pedro del Pinatar has important interactions with the Marina Cabo de Palos-Islas Hormigas Marine Reserve. This reserve was created in 1995 in order to protect local fishing resources and maintain sustainable artisanal fisheries in the area. The Aquaculture Park of San Pedro del Pinatar and the Marine Reserve are located respectively at the north and south of the most touristic area of the region called Mar Menor.

The management approach favours zoning and physical separation. Polygonos are specially designated areas for cage mariculture, that were established by the Ministry of Environment in consultation with the administrations for defence, marine navigation, tourism, ports, local authorities and coastal planning. There is also an Aquaculture Regional Strategic Plan (2007-2010) which includes biological and production research. Once designated for mariculture, the licensing procedure for individual farms uses a public tender system and selection is based on investors who meet clearly defined requirements of the tender. Licenses are granted for a minimum of five to ten years, can be renewed up to thirty years, and are transferable and include insurance provisions (Chapela-Perez, 2009). This means that there is a high degree of security of tenure for licensees.

EGYPT

Egypt is the largest aquaculture producer in the southern Mediterranean. Although dominated by freshwater culture, there is a significant amount of brackish water culture. The sector's growth has been the result of initiatives that have engaged policy makers, producers and other local stakeholders (NEPAD 2005). For example, in the coastal city of Alexandria, the aquaculture sector is explicitly included as one of the stakeholders in the city's plan for sustainable development (CEDARE 2007).

Although relationships among various stakeholders vary, there has been a fairly consistent effort to engage relevant individuals and groups. The exploitation of synergies between brackish water aquaculture and agriculture has resulted in the extensive cultivation of various species of mullet, sea bream, sea bass and shrimp in the saline Lake Quarun. Total production of all species is estimated at 23 000 tonnes, with a yield of 150 kg/ha per annum. Juvenile mullet are raised in earthen ponds adjacent to the lake and fertilizer and livestock waste is the main feed input. There are several long-standing conflicts between the aquaculture and environmental/conservation stakeholders. First, there is concern about excess effluent. Second, the primary source of fry for all species is wild stock and this is considered a serious non-sustainable practice, especially for mullet (ICES, 2005; El Gayar, 2003; Mega Pesca, 2001).

6.4 Synthesis and Conclusions

Even the brief case by case review above reveals the variety of stakeholders and type of interactions among mariculture and other activities in the coastal zone throughout the Mediterranean region. The interactions that tend to be most documented are those involving conflict and the most common conflicts are over space, that is in Zone A, the immediate area around the farms. Most farms are effectively no-go zones for bathers, divers and recreation and commercial vehicles. Visual disamenity (impacts to the sea-scape) is also a major source of conflict when tourists and homeowners are important stakeholders. Other conflicts in Zone A include those related to pollution, and these can be bi-directional, that is the effect of farm effluent on the receiving environment and the effect of pollution from other coastal users on aquaculture operations. For example, waste disposal from many sources (e.g. municipal, industrial, tourism, fishing, shipping and ports) poses a greater threat to fish farms compared to the spillover effects of fish farm waste on these other stakeholder uses (Y. Karakassis, pers. com.). Although such threats need to be considered in aquaculture site selection, they tend to receive less attention than spillovers originating from fish farms. Depending on the environment, the amount of fish farm effluent released and other variables, pollution effects may also extend to Zone B, but such effects have not been documented to date (Karakassis et al. 2005).

The approach to managing actual and potential conflicts is also highly variable. In certain regions in Spain, the process for allocating uses of the coastal zone and for licensing mariculture is, in the main, comparatively clear and transparent. In Turkey, and to a lesser extent Greece, conflicts are managed on a case by case basis and coastal zone management is less advanced than in Spain. Stakeholder involvement also varies across the region and ranges from planning that has a high degree of stakeholder leadership to processes that have lesser degrees of engagement. For example, currently, in Algeria and Egypt, stakeholder consultation was introduced from the very beginning of the planning process and resulted in specific project proposals (Simard, 2008). This contrasts with the Turkish case above, in which a stakeholder process was employed only after major changes in legislation had already taken place (White et al. 2008). Learning from examples such as these will be especially important for countries in the southwest quadrant of the Mediterranean as commercial scale mariculture is at a very early stage of development. These countries in particular stand to benefit greatly from the application of ICZM that includes aquaculture stakeholders.

The Working Group on Environmental Interactions of Mariculture (WGEIM) cites four advantages of integrating aquaculture in coastal zone planning (ICES 1998):

1. the activity is based on renewable resources and can be sustainable;

2. it is a source of seafood and related products that can potentially relieve pressure on already stressed wild fish stocks;
3. for communities previously reliant on capture fisheries, aquaculture and its upstream businesses (e.g.: processing, transport, marketing) can be a source of employment and economic opportunities;
4. properly managed, aquaculture installations can also help to guarantee good water quality as they are highly sensitive to environmental changes.

Finally, while the discussion in this section has focused on stakeholder aspects of integrated planning and conflict resolution, the aspect of identifying and capitalizing on synergies should not be overlooked. Recently, the issue of complementarities between aquaculture and increased fish landings has been the focus of attention. While tourism and aquaculture are often in conflict in the Mediterranean, cases elsewhere show that the two can coexist well. In Thailand, both tourism and aquaculture are economically important. Tour operators and fish farmers have developed day tours of farms for foreign tourists. These include boat rides out to the facilities, demonstrations and meals (P. Edwards, pers. com.). In Malta, tuna farms accept groups of SCUBA divers which are allowed to dive and swim with the tuna in the cages (J. A. Borg, pers. Com.)

The sector has become part of the tourist experience and offers benefits to the aquaculture operator. Artificial reefs in combination with fish cages may have similar potential for bringing together tourism/recreation and aquaculture. Artificial reefs have been used for a variety of purposes, including recreational diving and fishing in North America and Australia. The combination of fish cages and benthic artificial reefs was tested in the Red Sea to evaluate its potential to limit the negative effects of fish farms on the benthic environment (Angel et al., 2002). The idea was adopted in various countries (e.g. Gao et al 2008) and it appears that the combination of fish attraction and nutrients could create a micro-environment that could be very attractive for other purposes as well. With adequate attention to property rights to ensure that both farmers and recreational users benefit, cage/reef combinations could be an option for maintaining sustainable coastal operations. Efforts need to be made to identify potential complementarities such as these and this is best done in the context of integrated management with broad stakeholder participation.

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7. Economic bottlenecks

by Shirra Freeman and Dror Angel

In this section, economic bottlenecks with respect to aquaculture are discussed. The term bottleneck is used to describe circumstances in which there are actual or potential inefficiencies that affect production or marketing and thereby impinge on the performance of aquaculture enterprises and their attractiveness as investments. The term also includes interactions among neighbouring fish farms, or the aquaculture sector and other stakeholders in the coastal ecosystem. Of special concern are those interactions that have negative impacts on human welfare, even if they are not reflected in market variables. The present review therefore includes market issues such as diversification in production and consumer receptiveness to farmed fish; resource management issues, such as the dependence of fish farming on wild fish stocks for brood stock and feed; governance, especially with reference to site selection and licensing; as well as the economic implications of environmental impacts on sensitive habitats such as seagrass meadows.

Our objective is to obtain indications of the dimensions of economic bottlenecks that are relevant to a wide a range of stakeholders in coastal areas because this is the location of most Mediterranean mariculture. This approach is closely related to the Total Economic Value (TEV) of aquaculture ecosystem interactions. TEV is defined as the full range of economic effects stemming from a given activity. It includes all intended costs and benefits associated with the activity, as well as unintended consequences (also known as spillovers or externalities). Market and non-market effects from both direct and indirect uses, as well as intrinsic values are considered (Pearce and Turner 1990). Box 1 provides a breakdown of the key elements of TEV. Because of its focus on bottlenecks, this review considers only the negative side of TEV, but it is noteworthy that the approach also has positive aspects.

There is nothing new in the observation that the economic prospects of aquaculture cannot be separated from the ecosystems in which it operates. The explosive growth in the sector over the last forty years has been due to a combination of ecosystem resource constraints, technology and economic factors. Increasing demand for fish was a major driver behind the depletion of wild fish stocks by capture fishing practices (FAO 2002; ICES 2002). In the Mediterranean, fish culture, previously dominated by artisanal and smaller scale enterprise became economical at the commercial level in the face of this higher demand. Moreover, as the profits within the sector grew, so did technological innovation. Aquaculture, once a set of backstop technologies[15] moved into the mainstream of

[1] 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 wildstock biomass falls, the cost of capture

production (Goulding et. al. 2000). At the same time, the proliferation of aquaculture installations, in particular in coastal areas has brought the sector into competition with a range of other stakeholders and subjects it to a range of environmental pressures (FAO 2007).

The three dimensions of economic bottlenecks considered in this section are financial, economic and environmental (see Box 1). Together, they capture the linkages among production, markets, governance and spillovers (externalities) that affect the welfare of aquaculture and other coastal zone stakeholders. Many of the bottlenecks can be measured by market prices and their effects are seen in indicators of financial performance such as sales and profits. Others, especially environmental spillovers can only be measured using non-market and quasi-market valuation techniques such as the contingent valuation method, choice experiments and hedonic methods[16]. Notwithstanding the absence of conventional market prices for many ecosystem services, they make considerable contributions to human welfare (Becker and Horesh 2006; OECD 2001; Pearce and Turner, 1990). For example, many of the conservation priorities that guide the management of marine protected areas have an implicit economic dimension. Two of the many services provided by seagrass *Posidonia oceanica* meadows are the prevention of coastal erosion and enhancement of biodiversity. If seagrass meadows are damaged by aquaculture, or for that matter by other activities, these two services may be jeoporadised. The first can be measured in terms of monetary losses (e.g. business incomes and property values). Measurement of the second must include consideration of non-market sources of welfare, such as the intrinsic value that people hold for maintaining local biodiversity.

7.1 Bottlenecks related to site selection and licensing

Aquaculture planning, site selection and licensing are interdependent and critical to the performance of individual fish farms and the aquaculture sector as a whole. Serious bottlenecks exist in many parts of the Mediterranean region because planning and site selection provisions are unclear and lead to numerous difficulties in the licensing process. Although recently, several countries have moved towards implementing comprehensive, consistent national aquaculture policies, they remain the exception rather than the rule and the sector is subject to a patchwork of laws and regulation under different jurisdictions. In many cases, dialogue and communication between the various relevant authorities is lacking. In most Mediterranean countries, multiple government ministries (e.g.: environment, fisheries, natural resources, agriculture, etc.) at different levels (e.g.: national and local) play a role in site selection and licensing, but only in exceptional cases are there explicit provisions for coordinating activities among these (FAO 2005). The result is that the process of obtaining or renewing an operating license can be lengthy, expensive and fraught with uncertainty (see review on licensing in FAO 2009).

For example, in Turkey, aquaculture comes under the jurisdiction of eleven national ministries ranging from Agriculture and Rural Affairs to Health; two national agencies (Department of Water Works and Treasury) and local authorities (Christofilogiannis 2001). Following conflicts between the tourist and aquaculture sectors in the Akbuk and Gulluk Gulfs, new site selection criteria were put in place requiring the removal of coastal farms to offshore sites (see Chapter 6 of this document for further details). The costs of relocation were beyond the capabilities of most small and medium sized farms and, as of May 2009, a total of 149 farms had been removed and/or relocated. The implications of this for Turkish aquaculture prompted the organization of a project to map a path forward for the sector (Okumus et. al. 2008; White et. al. 2008).

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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.

[16] For readers interested in a comprehensive review of environmental valuation techniques and studies can refer to The Environmental Valuation and Cost Benefit Website (www.costbenefitanalysis.org) and the NOAA Coastal Services Center, Coastal Ecosystem Restoration webpage (www.csc.noaa.gov/coastal /economics/envvaluation.htm).

Although the Turkish case is an extreme example, there is a general recognition of the need to develop efficient and transparent procedures that will provide aquaculture investors with secure tenure at a reasonable cost while protecting the interests of other stakeholders (IUCN 2008). Without secure tenure, investors will be less likely to risk a costly undertaking such as starting or refitting a fish farm. Moreover, inefficiencies have public sector costs, in material terms and more broadly in the context of fostering economic opportunities and this has been recognized at the level of the European Commission: ….public authorities do have a significant role to play in establishing the conditions and the framework in which an industry can – or cannot – develop. This analysis concluded that these challenges should be addressed from the point of view of the role of the public authorities in the EU, including at national and regional levels, since they are still responsible for a number of factors which greatly influence the development of aquaculture (e.g. licensing and spatial planning). Given the numerous EU policies that have an influence on aquaculture development, a coordinated approach under a common vision was deemed appropriate (EU 2009a).

Box 1 - Dimensions of Total Economic Value (TEV)

Financial

The financial dimension is mainly relevant at the enterprise (i.e. farm) level and refers to different investment or operational options as well as insurance. In this case, the decision-maker considers revenues, production and investment costs, determined by the market and in certain cases the costs of regulation. For example, the direct and indirect costs of obtaining an operating license would be part of the fish farm's financial considerations.

Economic

This aspect reflects concerns of government planning agencies for the net benefits of individual enterprises as well as industries, sectors or geo-political jurisdictions. The purpose is generally the identification of the combination of activities that yields the highest return in aggregate. It accounts for spillovers among projects as well as aggregate effects in the market. For example, the financial dimension for a single farm would take the price of fish feed as a given. A sectoral analysis would consider the effect of changing aggregate demand for feed on its market price. Similarly, a single farm would not consider changing costs of transport infrastructure in its analysis whereas a planner considering the expansion of local aquaculture would need to consider the costs of modifying existing roads. This dimension also includes trade-offs between different options especially if they are mutually exclusive. These trade-offs are especially important in congested coastal zones where competition for space is intense. For example, in countries such as Greece that favor zoning of different activities, one of the costs of having an exclusive aquaculture zone would be the potential earnings from activities such as capture fisheries that would be excluded from the zone.

Environmental

The environmental dimension includes ecological impacts and encompasses a range of values, not traditionally determined in the market. Environmental aspects of TEV include the welfare impacts of pollution on water quality and the benthos, changes in wild fish stocks, sensitive areas and biodiversity. These affect the enterprise (fish farm), government planners and the public at large..

Spillovers or externalities are especially relevant for environmental effects. Pearce and Turner (1990) define an externality as an activity by one agent that causes a loss/gain to welfare of another agent and the loss/gain is uncompensated. If a fish farm produces unpleasant odors and people living nearby suffer as a result, these odors are a negative externality. Resident's welfare is affected and the disamenity may result in lower real estate prices in affected areas. Similarly, if untreated urban sewage contaminates a fish farm, the lost revenues to the farm are a negative externality. Externalities can operate in two directions and may be positive or negative. For example, fish farms are both fish attracting devices and sources of nutrients for migrating species (Dempster et. al. 2002, 2004, 2005, 2006). In some places, the migrating organisms have been shown to both reduce net waste discharges from fish cages (Angel et. al. 2002) and increase fish landings (Machias et al. 2005). This is especially true if an artificial reef is placed in proximity to the farm (Angel et al. 2002) as fish farms and recreational activities such as diving and fishing may actually complement each other and create a "win-win" scenario.

Bottlenecks stemming from planning, site selection and licensing practices have several dimensions, as described above, but largely originate in insufficient governance of the aquaculture sector at the EU, regional, national and local levels. Although the problem is widely recognized, attempts to deal with it in an organized fashion are just beginning. The solution will depend on finding coordinated regional approaches that accommodate national and local priorities and practices. At the most basic level, the focus must be on administrative processes such as licensing. On a larger scale, aquaculture planning needs to be part of more integrated frameworks such as integrated coastal management that are capable of accommodating many stakeholder interests, thereby avoiding or resolving conflicts.

7.2 Bottlenecks related to market issues

This section addresses 3 bottlenecks specifically related to aquaculture market issues; institutional support for market stability, lack of diversification in finfish aquaculture and consumer perceptions and acceptance of aquaculture products

7.2.1 Institutional support for market stability

Market stability is not an issue that is restricted to the Mediterranean region but is certainly a major determinant of performance of the aquaculture sector. Aquaculture has characteristics of both terrestrial agriculture and fisheries. Like fisheries, it depends fundamentally on the state of the marine ecosystem, including the condition of wild fish stocks that may be the source of fry and/or feed. Like agriculture, its production cycles may not always match consumer demand leading to alternating periods of excess and under supply and highly variable prices

At the European level, efforts are being made to reform the common organization of markets in the fishery and aquaculture sector, focusing on providing support for sustainable production practices and marketing activity. Particular attention is being given to fostering flexibility to adapt to changes in markets, greater harmonization with the Common Fisheries Policies and other EU policies in trade, health, consumer protection and the environment. Efforts are also being made to simplify regulations and reduce the administrative burden both for the sector and government agencies (EU 2009a; EU 2009b).

7.2.2 Lack of diversification in cultured finfish

Finfish culture in the Mediterranean heavily favours two species, sea bass and sea bream. There are several reasons for this. Among the more important is path dependence, the technologies for hatching and rearing the two species were developed earlier than those for other species, and markets rapidly developed for these two products. In many countries there was also generous support at the European Community (especially the Financial Instrument for Fisheries Guidance (FIFG)) and national levels for the sector making it possible for small operators to open new farms and expand existing ones. Greece has historically dominated production in both species, while Italy and Spain respectively consume the largest amount of bass and bream. The bream-bass industry grew from 1,100 tonnes in 1985 to 144,000 tonnes in 2000, with Greece consistently producing about half (FAO 2002). Growth in turbot production was also high in the 1990's in producing countries (Portugal, Spain, France and Italy; Abellan and Basurco 1999).

Over the period January 2001 to March 2002, prices in all markets fell by between 30% and 40%, and in many cases, the market price dropped below the cost of production (University of Stirling 2004). The industry, the EU and many countries responded to the crisis by taking measures to suspend support for initiatives that could create more over-production. Although unit costs of production are known to vary widely (by region, size of fish produced, size of the firm, etc.), exact figures are difficult to obtain because this type of information is proprietary. Based on ex-farm price statistics, Spain and Greece appear to have had wide scale over-production and contraction of the sector within these countries supports this conjecture. Similarly, in France, nearly half of the farms reported losses in 2002 (University of Stirling 2004). Although the crisis was largely restricted to seabream and sea bass, because of their dominance in Mediterranean production, the crisis really affected the region's entire cage aquaculture sector.

A review of seabream and sea bass cultivation, included recommendations for greater diversification in production and processing that would allow, among other measures a larger range of fish sizes and a movement away from whole fish towards more profitable final products such as fillets and other processed products (University of Stirling, 2004). Others have addressed the need to diversify cultivated species to reduce the risk of depending too heavily on two species (UNEP/MAP/MEDPOL 2004).

7.2.3 Consumer perceptions and acceptance of aquaculture products

Although until recently consumer awareness of aquaculture products was relatively low, the situation is rapidly changing. This is especially true in western and northern Europe, the main export markets for Mediterranean mariculture (with the exception of bluefin tuna whose main market is Japan). This is a potential bottleneck, and consumer acceptance will depend heavily on how Mediterranean producers can position their products in the market and the social acceptability of aquaculture. It is likely that products from North Africa will face greater challenges compared to products from the European parts of the Mediterranean basin. This in part stems from negative attitudes towards ‘alien products’ and partly from competition for market share in Europe between more established sources and the newer North African sector. The need to develop domestic and export markets for the output of African aquaculture is recognized by the New Partnership for African Development (NEPAD 2005).

Consumer trust in regulation of the sector and participation voluntary certification programmes (e.g.: organic pollution) can be expected to influence consumer acceptance of aquaculture products.

7.2.4 Bottlenecks that are related to spillovers that have social or environmental costs

Social and environmental spillovers are a major challenge to the aquaculture sector. They are often the cause of widespread opposition that results in hostile regulation and difficulties in obtaining operating licenses. In this section the issue of social acceptability and cost of negative environmental externalities stemming from aquaculture in sensitive areas are highlighted.

Social acceptability

Aquaculture is the source of more than 40% of the finfish on the global market, yet most people are unfamiliar with the sector and it often suffers from a negative public opinion. The level of social acceptability has been an important determinant of the success of coastal aquaculture in many parts of the world. It is relevant at the operational level, where mobilization of various stakeholders can influence policy, planning and licensing. The social acceptability of aquaculture is framed in one of three inter-related dimensions: stakeholder interests, environmental impacts and the economy.

A study of how environmental NGOs and the salmon farming sector in British Columbia (Canada) communicate with the public found that both focused on "economic health" (Schreiber et al. 2003). The NGOs stressed the economic cost of environmental impacts and accidents to tax payers, such as the $10 million paid by the province of New Brunswick to slaughter caged salmon in order to prevent the spread of infectious salmon anaemia (Times-Colonist 1999). In addition, they claimed that fish farming disrupts the economy because “it undermines industries like tourism and the commercial fishery" (Georgia Strait Alliance 1999). In contrast, farming advocates tended to stress issues of employment, industry advantages and the community’s need for fish. Advertisements for the salmon fishing industry in British Columbia stressed the professionalism of skilled workers and the contribution to local communities (Eliott et al. 2003). Similar attitudes were found in a 2006 survey in the United Kingdom. Whitmarsh (2006) reported that of all respondents, those living in areas dependent on fishing and aquaculture were most likely to stress the importance of employment and economic advantages of the sector.

Although stakeholder conflicts and social acceptability are among major bottlenecks for coastal aquaculture, recently, some common ground has emerged including several collaborative initiatives to improve farm performance and the conditions under which farms operate, thereby reducing conflicts. Environmental groups have begun advocating specific technologies that are considered environmentally friendly because they have fewer negative environmental spillovers. For example, in 2008, The Coastal Alliance for Aquaculture Reform (Canada) published a report promoting closed system aquaculture (CSA) as an environmentally friendly and economically efficient alternative to conventional practices (CAAR 2008). There have also been a number of initiatives that have brought together a range of aquaculture stakeholders. Under the auspices of the FAO's programme, *Building an Ecosystem Approach to Aquaculture*, representatives from industry, NGO's, trans-national organizations and academia have been putting together guidelines that address major stakeholder concerns (FAO 2007). One of the project's outputs has been three technical papers on integrated aquaculture (INTAQ), a set of farming techniques in which two or more commercially-viable species occupying different trophic levels are reared together in order to reduce farm effluent into the surrounding environment and increase farm output without incurring significant additional feed costs (Angel and Freeman 2009, Barrington et al. 2009; Troell 2009). In another initiative, the International Union for the Conservation of Nature (IUCN) and the Federation of European Aquaculture Producers (FEAP) have been collaborating to produce a set of guidelines to improve Mediterranean Aquaculture Practice. In addition, the American Society of Limnology & Oceanography has repeatedly held sessions on sustainable aquaculture at their annual meetings, and the World Aquaculture Society held symposia with variable suites of stakeholders to discuss farming practices and their interactions with the environment.

Sensitive habitats - the case of seagrass meadows

Seagrass *Posidonia oceanica* (P. Oceania) meadows have multiple ecosystem functions whose services include provision of habitat, support of marine biodiversity and prevention of coastal erosion. The economic values associated with these services range from the value of coastal real estate and business activities that would be impaired if coastal erosion increases to the intrinsic value that people place on the existence of rare and endemic environmental assets (Becker and Horesh 2006).

Results of monitoring have revealed that aquaculture activities negatively impact the health of *P. oceanica* meadows (Delgado et al. 1999, Diaz-Almela et al. 2008; Ruiz et al. 2001, Cancemi et al. 2003). Often, the damage is irreversible and occurs very soon after farms begin operations. Effects are observed within 400 m of farm sites (Marba et. al. 2006), although in some cases effects are indicated for farms that are more than 800 m away (Ruiz et. al. 2001). In cases where the effect is temporary, observed recovery after the removal of fish cages has been rapid, with seagrass regrowth beginning within twelve months (IUCN 2004).

Potential bottlenecks stemming from depletion of wild stocks

Two types of interaction between stocks of wild fish and aquaculture have the potential for creating bottlenecks. One is the dependence of certain aquaculture industries on wild stocks for fingerlings and the second is the dependence on wild stocks for the production of manufactured feed. Both are reviewed here.

Capture based aquaculture is the farming of species that rely on wild stocks for larvae, juveniles or adults and accounts for 20% of total cultured fish. Although for some species, such as sea bream and sea bass, the dependence has been reduced by the development of cost effective hatchery technology, in other cases such as certain mullet species and bluefin tuna, the pressure has been increasing and there is evidence of increasing dependence for molluscs as well (FAO 2004, FAO 2006). In addition to the technological factors underlying capture-based fisheries, there are also significant economic incentives, primarily in developing countries where the collection and sale or use of juveniles may generate significant income for local communities (Ottolenghi et. al. 2004). Capture based fisheries becomes a concern when it increases pressure on an already stressed wild stock species. The culture of bluefin tuna and mullets are two examples in which capture from wild stocks has been implicated in actually or potentially having negative effects. In addition to tuna and mullet, there is also concern for groupers, eels and yellowtails.

Capture-based mullet culture

Unlike seabass and seabream, which are reared from eggs produced in commercial hatcheries, most of the mullet production, e.g. the huge Egyptian mullet industry, is largely dependent on capture of wild "seed" (Mega Pesca, 2001). Notwithstanding promising pilot stage results from rearing juvenile thick lipped grey mullet in mesocosms (Ben Khemis et. al. 2006), commercial scale mullet culture remains heavily dependent on wild captured juveniles. In 2004, Egypt collected between 100 and 135 million mullet fry to support its production of 133,000 tonnes of adults (GAFRD, 2004). Self-sufficiency of this sector will only be possible through the development of mullet hatcheries that will also guarantee the long-term sustainability of Mediterranean mullet culture (IUCN 2008).

Capture-based tuna fattening

Currently, one of the most pressing concerns on aquaculture relates to the tuna fattening industry. Farming of bluefin tuna is a highly sophisticated and competitive business, with a large percentage of Mediterranean output sold in the Japanese market. The crisis in tuna wild stocks has prompted action at official levels.

Lleonart & Majkowski (2005) and Lovatelli (2005) predicted the collapse of the bluefin tuna fishery given pressures from capture fishing and capture-based aquaculture. In March 2009, the European Parliament plenary session voted in favour of new cuts in bluefin tuna catch levels and fisheries campaigns under the Mediterranean Sea and Eastern Atlantic Ocean Bluefin Tuna Recovery Plan. The measures described in the bluefin tuna recovery plan were agreed upon by the members of the International Commission for the Conservation of Atlantic Tunas (ICCAT) in Marrakesh, Morocco in November 2008, and entail:

- Reducing total fishing capacity to 2007-08 levels for vessels that target bluefin tuna, followed by a plan to reduce and adapt fishing capacity to national quota levels;
- Reducing total captive breeding capacity, which is not to surpass the maximum quantity of annual raw material allowed for the 2007-08 period, which will continue dropping in successive years;
- Defining control mechanisms along the bluefin tuna marketing chain (Murias 2009).

Response by the industry has been variable. Reported catch levels in EU member Mediterranean states have largely declined since 2001, though there has been some variability. In contrast, catch levels in a number of non-EU-member states, including Libya and Croatia have fluctuated with a tendency to increase. Moreover the scale of the crisis has been disputed by a number of bodies. The Advanced Tuna Ranching Technologies group criticizes reporting by the aquaculture and capture fisheries sectors, especially with respect to the numbers of juveniles sold at auctions. Their 2009 report compares production statistics with statistics from the Japanese point of sale and claims that:

1. increasing numbers of very small blue fin tunas are captured for farming during the Mediterranean spawning season;

2. most of the farming industry that was traditionally oriented towards larger (8 years and older) fish has become reliant on juveniles; this is especially true in Spain;

.

3. the quantity of juvenile tunas in the Japanese markets points to failure of control of illegal capture in current programmes and consistent under-reporting by operators.

The report concludes that the scale of the crisis is underestimated and therefore official restrictions are insufficient and must be reassessed (Advanced Tuna Ranching Technologies 2009).

Feed production

Aquaculture can be divided into the culture of higher trophic species, such as sea bream and sea bass which require input of manufactured feed and culture of lower trophic species such as mollusks, shellfish and algae, which extract nutrients from the surrounding environment. The amount of fish oil and fish meal needed to maintain production of carnivorous fish species is very high. It is estimated that 30% of the world fish catch plus trimmings are converted into feed (IFFO 2002). There has been dispute as to the extent to which production at these levels can be sustainable and as yet there are no certification programmes that track the production of fish feed. Naylor et al. (2005) indicated that the situation is not sustainable. The scenario in the Mediterranean largely corresponds to the one that prevails worldwide (UNEP/MEP/MEDPOL 2004) and indicates that the situation needs to be monitored given the growing demand. They also strongly recommend the development of more efficient feeding systems that generate less waste and the replacement or combination of fish meal with vegetable-based lipid and protein sources, such as oilseeds and vegetable meals for species for which it is feasible. They also recommend the farming of lower trophic and omnivorous species and the promotion of integrated aquaculture, involving the combination of different trophic level marine species or in conjunction with agriculture in order to maximize production for a given level of feed input.

7.5 Synthesis and conclusion

This review examined actual and potential economic bottlenecks facing the Mediterranean mariculture sector. Particular emphasis was placed on finfish cage aquaculture as it is the dominant form of mariculture in the region. The four types of bottlenecks discussed are related to:

1. site selection and licensing;
2. market issues;
3. spillovers with social or environmental effects, and;
4. impacts on wild fish stocks.

The full range of welfare impacts have been considered: those that can be measured through market activity and those that are derived outside the market; those that involve direct use such as the production and consumption of fish and those that involve indirect use, such as the benefits from amenity or intrinsic values. Many of these effects have yet to be quantified and, therefore, the discussion concentrated on identifying issues of importance that should guide future research and action. In some cases, especially in the case of governance and market development concrete action has been ongoing and directions are relatively clear. In other cases, such as the management of interactions between aquaculture and wild fish stocks, direction is less clear and would benefit from increased discussion and research.

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8. Procedures for site selection, regulatory schemes and EIA procedures in the Mediterranean

by Rosa Chapela & Marta Ballesteros

8.1 Introduction

8.1.1 Mediterranean aquaculture

Diversity and heterogeneity are intrinsic to aquaculture in the Mediterranean, both with regard to the activity itself as well as with respect to the legal and institutional frameworks that regulate it. In this region, a wide-range of species are cultured, and different production methods and technologies applied; there are small-scale farms and multinational companies with vertical integration in all the production process; there are mature companies that show clear signals of stagnation and others that have not yet reached their potential growth; and there are legal tools that enable aquaculture development and legal constrains that threaten the future of the activity in the medium and long term.

Nevertheless, several trends within the Mediterranean are quite homogeneous. For example, the evolution of production reflects the tendency of a global slow-down of aquaculture. As pointed out by FAO: "the overall the rate of growth in aquaculture (measured in production volume) has started to slow. For the world as a whole, while the average yearly growth rate has been 11.8% in the period 1985–94, it was 7.1% in the following decade (FAO, 2008). For the GFCM area, total marine and brackish water aquaculture production reached an average yearly growth rate of 10.55% in the period 1985-1995, falling to 5.04% in the period 1996-2007[17] (Figure 1).

Additionally, growth has not been uniform, neither by country nor by group of species or by species. Although Mediterranean mussels remain the main species in terms of volume (103.342 tonnes in 2007), the relative weight of this species has dropped from 83% in 1985 to the 27% in 2007, mainly due to the increase in the production of marine finfish. Currently, European sea bass (51.928 T in 2007), gilthead sea bream (101.010 t in 2007) and sea bass (41.900 t in 2007), represent together half of the Mediterranean and Black Sea production[18]. Based on these values, the same group of species has a production of 65% of the total versus the 6% of Mediterranean mussel production.

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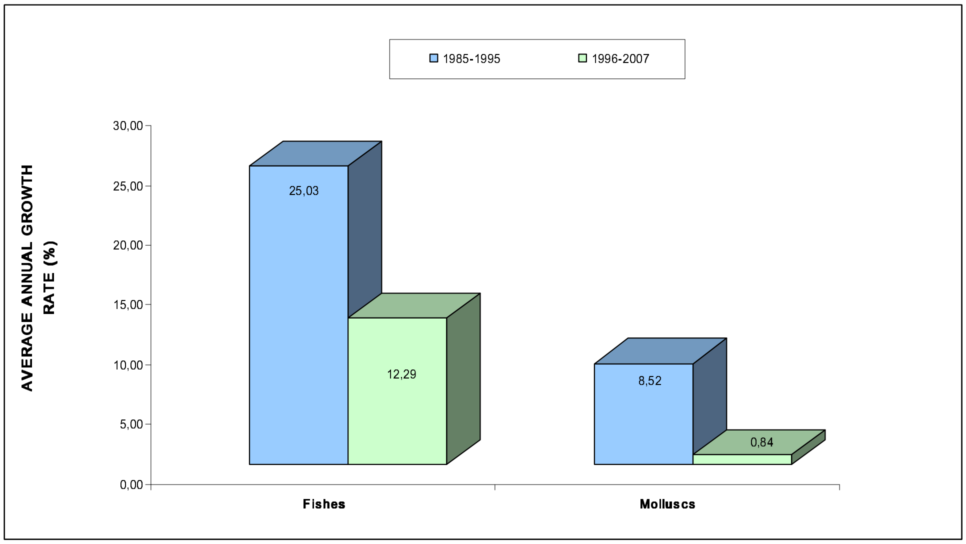
[17]Source: data analysed from FAO, FISHSTAT, 2007. Several documents and reports by the FAO have emphasised the numerous information gaps that limit our comprehension of Mediterranean aquaculture, as limitation in data sources related to technologies and production modes or the allocation of production volumes for countries as Spain or Egypt (see GFCM: CAQ/VI/2008/2)

[18]The Atlantic Bluefin tuna is the other finfish species with higher annual average growth rates for the period 1985-2007 (22,73%), although its relevance in terms of volume (less than 1% of total production in 2007) and value (2,7% of total value in 2007) remains low. As pointed by Cardia and Lovatelli (2007) "Commercial activities on fattening captive Atlantic bluefin tuna (*Thunnus thynnus thynnus)* in large floating cages have been reported since the mid 1980s (Spain), but a significant expansion of this farming practice in the region started only in the mid 1990s. Atlantic bluefin tuna fattening should be viewed as a capture-based aquaculture practice considering that the fish are caught by purse seiners and stocked in cages usually for 10 months. Harvested fish are mainly for the Japanese market" .

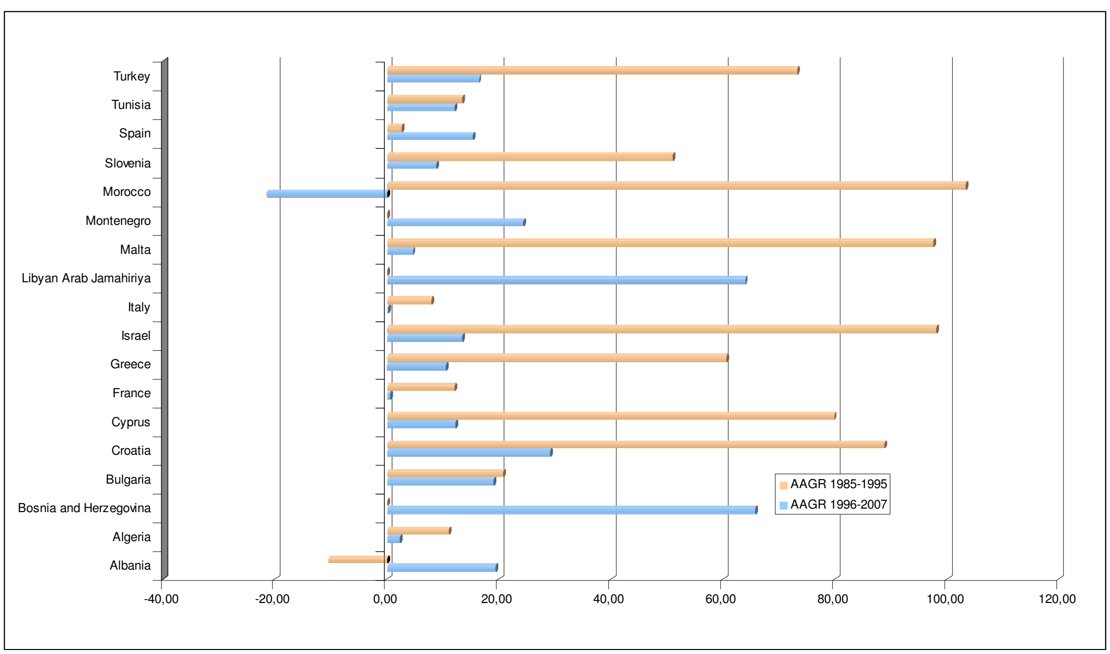
Figure 1 - Annual Average growth rate of production of marine and brackish water fish and mollusc species in the GFCM area (1985-2007)



Source: FAO (2009)

Within the GFCM area, analysis of the annual average growth rate of aquaculture production by country shows that Croatia, Turkey, Malta, Cyprus, Greece and Slovenia have their major growth in production registered in the period 1985-2007. In the period 1996-2007, virtually all the countries experienced a significant reduction in their growth rates, as shown in Figure 2. Spain, Albania, Montenegro, and Bosnia-Herzegovina are exceptions to this tendency, whereas Tunisia is the only country which maintains growth in production of the aquaculture sector (average annual growth rate of 13.49% for the period 1985-1995 and 12.11% for the period 1996-2007).

Figure 2 - Annual average growth rate of production of marine and brackish water aquaculture in the GFCM area (1985-2007) by country



Source: FAO (2009)

In this scenario, aquaculture policies and legal frameworks are strategic tools to ensure the sustainable development of the activity; besides the command and control designs, the institutional framework governing aquaculture needs to encompass a flexible but solid structure focused on:

- enabling development of aquaculture;
- ensuring the protection of the environment;
- guaranteeing the protection of the consumers;
- anticipating future developments, for example, offshore aquaculture; and
- Integrating aquaculture policy within Integrated Coastal Zone Management.

8.1.2 METHODOLOGY

As a starting point, it should be underlined that the analysis of legal frameworks in aquaculture tends to be biased by the heterogeneity of the norms and even the concepts used in this field. In this sense, it is relevant to define some basic concepts regarding aquaculture in the Mediterranean; concepts that, in the near future, could be used to set standards and common norms for the area. Figure 3 shows the legal and regulatory issues of aquaculture in national regulations:

Figure 3 - Legal and regulatory issues of aquaculture in national legislation

ALLOCATION/ SITING

- Areas: permitted / forbidden / selected (zoning).
- Interaction with other areas (protected) and activities.
- Regulation and use of the Public Domain
- Regulation and use of water
- Pre-existing rights (riparian, fisheries communities, etc.)
- Site selection: guidelines and criteria
- Licensing process: lease, tenure, concession, authorization and permitting process.
- Carrying/ holding capacity
- Environmental impact assessment (EIA)
- Canon, taxes and financial issues

PRODUCTION

Systems

- Monoculture / polyculture.
- Environmental product and process standards.
- Intensive/extensive
- Marine/brackishwater

Marketing

- Dealer license.
- Labelling (origin, etc.)
- Inspection of plans/products
- Barriers to trade

Process

a) Stocking: spat collection; breeding (including GMOs), density imports, transport.
b) Cultivation and fish health: feeding, disease control, predator control, non-native species, protected species interaction.
c) Harvesting: closed seasons, depuration
d) Animal welfare
e) Genetic policies: genetically modified organisms.

Control

a) Limits to production volumes: restrictions, maximums, etc.
b) Seed: wild /hatched seed, import seed.
c) Traceability
d) Process and Organic production
e) Periodic environmental reports
f) Certification systems
g) Accidental releases
h)Economical viability reports

MONITORING

- Monitoring programs
- Water quality
- Sediments
- Information:
  a) to be gathered by producers
  b) to be gathered by public administrations
- Compliance, including sanctioning

GOVERNANCE

- Allocation of competencies
- Legal duties/commitments
- Governance and transparency
- Decision-making processes (strategic planning, ICZM)
- Position of aquaculture in the legal framework.
- Education, research and development
- Association and organization

Source: Own elaboration based on Bermúdez, J (2008: 73) and Duff *et al*. (2003: 24).

In the past decades, several attempts have been made to analyze the legal and institutional frameworks of aquaculture whether by general approaches[19] or thematic reviews. The present review is primary focused on legislation related to aquaculture planning and aquaculture site allocation processes, as well as with the environmental aspects linked to monitoring, compliance and EIA, in relation to marine and brackish water aquaculture in the GFMC area.

Background and primary research on aquaculture's institutional settings allows identification of issues that may be used as indicators to assess the legal framework (Table 9). The comparative analysis developed in this review considers the following criteria which are not intended to be exhaustive; moreover, there are other topics that should be addressed (for example, alignment between aquaculture and environmental policies) although they are beyond the scope of the present contribution.

Table 9 - Indicators for the assessment of the legal framework

Indicator	Rationale and context	Unit (how is it measured)
Status of aquaculture regulation	- It defines the position of aquaculture in the national legal framework. - It provides legal certainty for the development of aquaculture - It establishes the degree of flexibility of aquaculture rules.	Legal instruments: law, regulatory norms (legally binding commands with a lower level in the normative system that a law, as decrees, regulations, orders, etc.)
Authorities involved in the licensing process	- It reflects the degree of complexity of the process[20]	Number of public bodies/agencies/departments
Validity of the aquaculture license	- It determines the timeframe of the activity for aquaculture operators - It determines the timeline for investment and returns.	Years
Duration of the administrative procedure to get a license	- It sets the period of time between the presentation of the proposal by aquaculture promoters and the authorization to start building facilities and running operations	Months
Planning for aquaculture	- It indicates the priority of aquaculture in the political agenda - It establishes the strategic position of aquaculture in the economic activity of the country - It reveals a medium/long term view for the development of the activity	Yes/No
Areas under public domain	- It defines zones where implantation of aquaculture activities requires specific provisions and procedures by the State, besides the general ones for	Geographical areas: - Maritime waters

[19]Notwithstanding the studies by Van Houtte (2001) and Van Houtte *et al* (1989).

[20]Obviously this indicator does not measure the efficiency and effectiveness of the process. A model with a high number of authorities involved in aquaculture licensing but with a well managed coordination system could be more effective and efficient than other with two authorities involved but without coordination between them.

Indicator	Rationale and context	Unit (how is it measured)
	private areas.	- Terrestrial zone (coast) - The shoreline zone
Zones reserved for aquaculture	- It reserves a physical space for aquaculture facilities - It simplifies the licensing process - It anticipates and solves conflicts of uses	- Yes/No
Monitoring systems	- It describes the control and follow-up of the activity. - It implies the measurement of the impact of aquaculture activities	- Yes/No

Aquaculture is considered a key contributor to provide opportunities of employment increase in coastal areas highly dependent on fisheries, as well as a source of nutritionally healthy, affordable protein. This fact is particularly significant when the demand of aquatic food is increasing and reduced catches by the fisheries sector lead to a reduction in consumption of fish for food. In this context, aquaculture would increase availability of aquatic foods in many countries, not only in those with low fisheries landings but also in those without a tradition of fisheries.

Many parts of countries worldwide are developing some kind of aquaculture, but the definition of a clear legal framework is crucial in order to launch aquaculture activities successfully. In fact, many countries with a high level of aquaculture activities started by increasing production and allowing new facilities without considering legal issues, which would help to plan and organize aquaculture activities in a sustainable way. This has been the case in Spain, Greece and Italy for a long time, and more recently Turkey, Morocco, Egypt, among others. These countries point out the lack of a legal framework as the main barrier for sustainable development of aquaculture. Management, planning, organizational and decision-making tools are needed. Capacity building for operators intending to start aquaculture should be clear before starting the activity.

The SHoCMed project's main goal is to develop site selection and carrying capacity guidelines for Mediterranean aquaculture within appropriate areas. In order to ensure appropriate selection and management of areas of interest for aquaculture, it is essential to have an adequate and clear legal framework that guarantees legal security for the industry and ensures ecological, economical and social sustainable development of aquaculture. Consequently, this review is focused on highlighting the benefits of adequate regulations for aquaculture, and identifying major gaps and outlining best practices for public administrations; this will enable establishment of a robust aquaculture regulation permitting system and hence ensure proper planning and coordination between different administrations having competences in the coastal zone, and use of the best criteria for environment impact assessment (EIA), and consideration of other issues related to governance and the aquaculture legal framework.

Recently, the International Union for the Conservation of Nature (IUCN), in cooperation with the Federation of European Aquaculture Producers (FEAP) and the Spanish Ministry of Environment, Rural and Marine Affairs (MARM), published 'Guidelines on Site Selection and Site Management on Aquaculture' (see appendix 2). In this guide, one can find the first comparative study on legal frameworks in aquaculture in Mediterranean countries, including needs, gaps and best practices. A further step is the need – currently being considered within the framework of the SHoCMed project - to consider a more detailed analysis with particular attention paid to planning, site selection criteria, regulatory procedures, EIA and monitoring of aquaculture activities.

The present review is based on two major sources of information. Principally, the information comes from the analysis of laws, decrees and aquaculture and fisheries policies currently in existence in the target countries. We also consider reports and other information provided by competent authorities responsible for aquaculture in some Mediterranean Countries. Unfortunately, the quantity and quality of available information varies from country to country. Therefore, the most important information presented here is based on primary data obtained from questionnaires send to all Mediterranean countries (Appendix 3). The survey carried out allows us to organize the information and identify in a homogeneous way, gaps and best practices for the aquaculture legal framework. Since the first data obtained from the survey showed a prevailing 'conceptual misunderstanding' among countries (the same concept with different meanings and or several concepts alluding to the same reality) they were validated with a second questionnaire that was more specific and with closed descriptions on the legal aspects and definitions. This second questionnaire was developed during a workshop held in Vigo[21] (Spain). We also used information from legal studies on aquaculture issues developed by FAO[22].

Accordingly, questionnaires were designed and sent to experts and policy makers in twenty Mediterranean countries (Figure 4), of which 75% submitted a response whereas 25% did not respond.

[21] GFCM - CAQ - WG on Site Selection and Carrying Capacity - Meeting on National legislation on site selection, monitoring programmes and EIA regulatory framework for finfish marine aquaculture (SHoCMed) held in Vigo on 13 and 14 July 2009. Detailed information is available on-line at:
http://www.faosipam.org/?pag=content/_events&id=43&dt=Jan%202009

[22] FAO, NALO: Aquaculture Governance. Contains the National Aquaculture legislation Overview of several countries; Consultation on the application of Article 9 of the FAO code of conduct for responsible fisheries in the Mediterranean region: Synthesis of the National Reports (TEMP/RER/908/MUL), Roma, 1999; Development of Marine and Inland Aquaculture, Greece, Draft National Aquaculture Plan. Rome, 1987. 18 p. FI:DP/GRE/85/002, FAO, Technical Report.

Figure 4 – Map showing countries that contributed to the SHoCMed questionnaire surveys

Source: own elaboration.

Legend: Countries that responded to the SHoCMed questionnaire.

Countries that did not respond to the SHoCMed questionnaire.

8.2 Aquaculture policies and legal frameworks in the mediterranean

Once good progress has been achieved in tackling issues concerning biological and disease aspects of culture of aquatic animals, the next challenge for aquaculture is to set up a suitable legal framework to promote and support the activity.

A regional successful position in aquaculture requires that both private sector and public administration face a significant challenge: to develop a policy and legal framework for aquaculture. In order to succeed, the responsible authorities in areas of fisheries and aquaculture must set up an appropriate framework with regulations for licensing, planning, access to land and water, environmental impact assessment, administrative organization and coordination. A general guideline for planning and site selection for use by aquaculture promoters is required. Policy makers and legal institutions should bear in mind the importance of good and clear regulation with common standards and criteria for site selection, in order to increase the legal security of aquaculture promoters and the equally access conditions to aquaculture markets in Europe.

Since investment in aquaculture can be risky, aquaculture promoters need information on regulatory requirements, associated costs and information on available sites for the facilities. Before accepting a concession or authorisation that would permit the allocation of rights to exclusive use of land, coast or sea space, the aquaculture promoter will need to be assured that his/her rights are adequately protected. So, a clear legal framework is crucial in order to guarantee the investor’s legal security in being involved in a frequently unfamiliar activity.

Lack of continuity of political and economic processes is the main problem which challenges countries and generates instability. This issue puts off aquaculture investors because many projects are slow-progressing businesses.

Van Houtte (1994) pointed out several aspects that affect the complexity and diversity of the legal frameworks among countries: the legal status of water area used (public or privately owned); the nature of water used (marine/brackish water versus fresh water); the legal status and the nature of the land used (coastal area versus inland; private versus public); the need for a government to regulate aquaculture in general or a specific aquaculture activity and other questions it is called to deal with (use of natural/chemical feed, wild/hatched seed, fish health management, effluents, restoration, etc).

Additionally, new legal and institutional issues reinforce the complexity of the legal frameworks, such as coordination between competent authorities and public agencies, financial issues, the EIA process, planning procedures, etc.

8.2.2 The legal framework for aquaculture

Despite that the information on the Mediterranean legal framework for siting marine aquaculture is still limited to some countries and somewhat fragmented, some specific issues emerge; for example, the complex and time-consuming permitting process, the long and confusing procedures for granting licences, etc. The number of laws, regulations, directives, rules and procedures that the aquaculture promoter must comply with is extensive, as is the involvement of many different authorities at several levels. As shown in this report, the differences between countries are also clear. Similar problems are encountered on EIA procedures, where differences exist among countries in terms of studies and documents required.

Many countries have not yet elaborated a specific legal framework for aquaculture development. At the moment, only countries with a developed aquaculture sector have specific rules and regulations for aquaculture. This is the case in Spain, Italy, Greece, and Turkey. Others have some specific regulations for a certain types of aquaculture (i.e. shrimp, as in Ecuador or shellfish aquaculture). It is even remarkable that there is only one country - Lebanon - with no legislation at all for aquaculture activities, or with a minor regulation included in the Fisheries Act (Figure 5).

Regulation procedures for the use of water or land area vary from country to country. Procedures for aquaculture activities are also different and diverse. So, it is crucial to design an aquaculture policy framework to discriminate between different types of aquaculture systems (inland/off-shore aquaculture) and ownership systems.

Besides the strict legal framework, the overarching concept of aquaculture's public policies depends strongly on the political will; therefore, not infrequently, they are subject to the vagaries of the political struggle. There are situations in which aquaculture plans already approved are reviewed by a new government that will abandon the legislation already in place in favour of a new one. Without denying the definition of plans as tools to implement governmental action, it is advisable to design legal tools oriented to ensure legal certainty in aquaculture activities in the medium-term.

Figure 5 - Countries with a legislative framework: tools for regulating aquaculture in the Mediterranean

Source: own elaboration.

Legend:	(blue)	Countries with legislation for aquaculture (specific law/s regulating exclusively aquaculture issues)
	(light yellow)	Countries with legislation for fisheries and aquaculture.
	(orange)	Countries with other regulatory norms for aquaculture (legally binding guidelines with a lower rank in the normative system than a law, for instance decrees, regulations, orders, etc.)
	(grey)	Countries without legislation for aquaculture

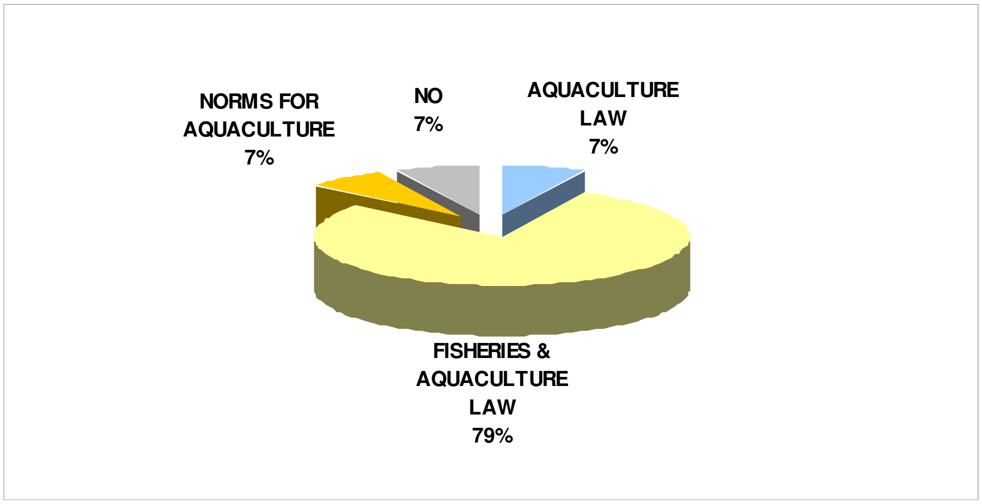
In the Mediterranean, as has been the global trend[23], the legislative framework for aquaculture is predominantly under the umbrella of a fisheries and aquaculture law (79%), and only Cyprus[24] has developed an exclusive law for aquaculture. Noteworthy is that none of the countries surveyed regulates aquaculture under water, agriculture or other general legislation, as has been the case in the last decades of the twentieth century.

As mentioned repeatedly, there is no direct relationship between the status of regulations on aquaculture and the importance of the sector. Moreover, the existence of a solid legal framework for aquaculture does not imply growth of aquaculture, and could even act as a deterrent for aquaculture activities. These aspects will be considered carefully in the conclusions.
Several authors have remarked that a legal definition of "aquaculture" reinforces the relevance of aquaculture as an economic sector whereas contributing to provide 'legal security' (Van Houtte, 2001). The outcome of this report stresses also that aquaculture site selection and aquaculture planning reinforce the legal security of the activity.

[23] Exceptionally, some countries have developed an aquaculture-specific law, as for instance Chile.

[24] Cyprus Aquaculture Law of 2000 (N. 117(I)/2000). In Spain, although there is a law for marine culture since 1984 (Ley 23/1984, de 25 de junio, de Cultivos Marinos), the distribution of competences between the central and the regional governments has led to a situation within which many of the articles of the law are not applicable, falling under the competence of the Regional governments.

Figure 6 - Legislative framework: tools for regulating aquaculture



In terms of site selection and aquaculture planning, the existence of a law is positive in order to guarantee, in a mandatory way, the criteria and requirements for site selection. Aquaculture has a strategic role in maritime and coastal zones in relation to its competitors such as tourism, navigation, fisheries, marine protected areas etc. The law provides the aquaculture sector with the first step to obtain a defined strategic position into the legal framework of a country.

Generally, there are no homogeneous or common criteria that enable the undertaking of a common legal analysis for the whole of the Mediterranean; on the contrary, the legislation of each country is primarily based on criteria of local regulation, depending on the type of aquaculture, its legal tradition and the greater or lesser importance of the activity in that country. Besides, the legal framework for aquaculture is not limited to the strict regulation of this activity, i.e. the conditions and characteristics of access to the activity in the form of licences and permits, validity periods, the rights and duties of establishment operators, the characteristics of aquaculture facilities and their production systems, etc.

Additionally, we must consider extremely important rules that, although not issued by the administrative authority responsible for aquaculture, directly affect the development of this industry. For instance, with regard to site selection for aquaculture, the process includes wide-ranging legislation on the occupation and exploitation of land that is state owned or public coastal areas, which are described by different names depending on the country; alternatively, of state-owned coastal areas that may be used for the practice of aquaculture. This is the case for the majority of Mediterranean aquaculture regulations (Spain, Greece, France, Italy, Egypt, Algeria, Turkey, etc.), which are normally issued by a different administrative authority to that which grants aquaculture licences.

Aquaculture regulations in Mediterranean countries frequently contain aspects related to legislation on health, environmental impact and management, marketing in the field of aquaculture, and so on. To illustrate the complexity of aquaculture legal frameworks, within the European Union there are more than three hundred regulations that affect this industry. However, for the purposes of this report, we will focus on legislation concerning licences, and the spatial planning and use of public areas, monitoring and the EIA procedure, which have the greatest influence on selection of areas.

Box 2 - Aquaculture site selection at the regional Level in Spain (2009)

Particularly relevant are aquaculture laws establishing criteria for determining suitable areas for mariculture or requiring aquaculture concentration in sea farming areas. For instance, in Galicia (Spain) Law 6/1993 on Galician Fisheries and its implementing regulations, provides for the organisation of mussel farming facilities in special designated centres and the development of mussel beds in areas delimited by the regional government (articles 58 and 62 of the Galician Fishing Act). Also, Decree 406/1996 on mariculture provides for the management of the designated sea farming areas within the framework of the integral planning of coastal uses (Article 20) and the Galician Aquaculture Plan, as a sectoral territorial plan, and will be the legislation that regulates the areas delimited for practising aquaculture in aquaculture farms.

Law 2/2007 on Fishing and Aquaculture in Murcia (Spain) regulates designated sea farming sites, which it defines as areas suitable for anchoring floating cages within areas declared as being of interest for mariculture by the regional government, "after assessment of their environmental impact". This Law adds that the rules establishing said designated sites must specify both their maximum production capacity and the species that may be farmed (Article 75). Other regulations, instead of imposing mandatory regulations on planning and management, simply recommend "areas of interest for marine aquaculture", which are most appropriate for aquaculture operations. This is the case of the Spanish Mariculture Act and the laws of the Autonomous Communities (Galicia, Murcia, Asturias, etc.) - In Spain there are several autonomous departments with competencies to regulate aquaculture and fisheries.
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The Spanish decentralized model has important consequences for aquaculture in further complicating the legal regime applicable. There is a decentralisation between a) the Regional Governments (*Comunidades Autónomas*) with main competences in aquaculture and b) the Central Government where the Ministry of Environment, Rural and Marine Affairs (MARM) only have competences for designing the general policy for agriculture, fisheries and food. The MARM also has functions of coordination and representation through the General Secretary of the Sea (*Secretaría General del Mar*). Therefore aquaculture in Spain is regulated at regional level.
Autonomous Communities can develop their own aquaculture policy, granting licenses, planning the activity, capability training, organizing farmers, etc. Although if there is no regulation approved by Autonomous Communities, the State Law 23/1984, on Marine Culture, will be applicable.

Central Government has the key coordination role through the Sea Harvest Advisory Board (JACUMAR) depending on the MARM and integrated by General Secretariat of the Sea, the fisheries departments of Autonomous Communities and aquaculture organization representatives. This Advisory Board is in charge of coordinate the public administrations involved in aquaculture and manage the Aquaculture National Plans.

8.3 Licensing procedures for aquaculture

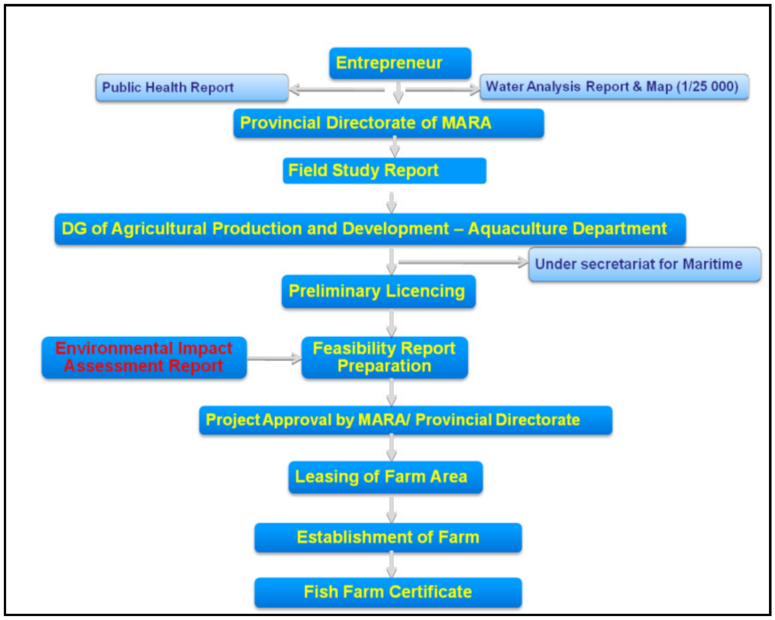
8.3.1 General principles governing the exercise of authority to issue a licence

Whenever marine culture is developed in a specific area defined as within 'coastal and maritime public domain' and owned by States, their occupation must be authorised by the competent administrative authorities in charge of managing the space. In general, the coastal zone belongs to the whole society for general use, but when a profitable or economic activity - as a private activity - is developed in such areas, a concession or permission by the responsible authority is needed.

The licensing system is a control procedure that allows the authorities to verify the viability of the installation site and the potential environmental effects of the operation in question. Licences establish aquaculture sites, the conditions and operating period, environmental requirements and the carrying capacity of each aquaculture facility, i.e. the conditions that affect the specific area where aquaculture will be practised.

There are various types of licences, depending on the type of activity or the legal status of the aquatic resource used. They have different names, such as: authorisation, concession, licence, permit or lease. Generally, in nearly all countries, the mostly commonly used terms are; *licence*, referring to the activity, and *concession*, referring to occupation of public areas. Definition depends on the legal system in each country.

Figure 7 - Licence procedure for marine aquaculture in Turkey (2009)



Source: Workshop on National Legislation on Site selection, Monitoring Programme and on Environmental Impact Assessment, 13-14 July 2009, Vigo, Spain

Analysis of the license procedures allows the drawing up of basic sets of rules for aquaculture. The follow-up of the license process defines: who can run aquaculture operations; where, how, for how long and under which conditions; which price (and taxes); which aspects of the EIA need to be considered and who has the competence to decide about all these issues.

Understanding the set of rules for aquaculture requires, beforehand, the definition of a legal term which applies in all the countries: the public domain. The concept refers to a legal principle by which "certain public lands (tidelands and coastal waters) are deemed so important to the general public, that they are held in trust by the sovereign for the benefit of the citizens […]. (Duff et al. 2003). In fact, the maritime-terrestrial public domain could be defined as a form of state intervention by which these 'goods' are destined for public purpose (public use, coastal protection and promotion of national wealth). They are public owned property, endowed with a legal regime of protection and use under the public law. Public domain refers to goods (inalienable and indefeasible) which cannot be sold nor given away, neither be acquired by repeated use over time nor be subject to any lien or mortgage. The titular or the public domain exercises the legal authority of monitoring, policing, sanctioning and protection. In most countries there are laws which determine this special character for public goods. For instance, in the Spanish case, the Constitution states that the marine-terrestrial zone, beaches, territorial waters and natural resources are public property (art. 132) and the Coastal Act has come to expand the assets of maritime-terrestrial public domain.

All the countries considered in the present review apply the doctrine of the public domain, although there are several differences in the physical spaces under it. All but Albania, Egypt and Tunisia define the maritime waters (water column) as public domain; apart from Albania, Italy, Morocco and Montenegro, some shoreline zones are considered public domain in each country. Finally, with regard to terrestrial zones (coast) Tunisia, Egypt, Greece, Morocco, and Lebanon do not ascribe the public domain protection to such areas. Jointly considered, Croatia, Cyprus, Israel, Slovenia, Turkey and

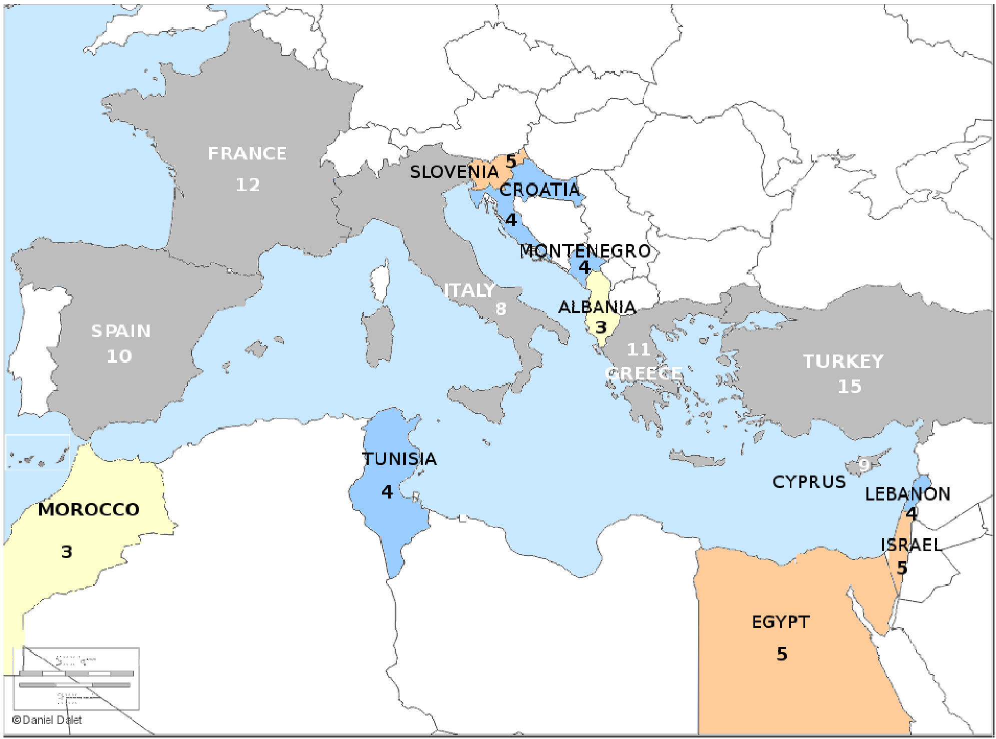
Spain are the countries which include maritime waters, terrestrial areas and the shoreline under the public domain, which implies, as explained below, a more complex process for aquaculture activities.

The more rigorous and extensive the declaration of the public domain in a legal framework, the more conflict will arise and more farmers will have less flexibility when it comes to licensing. The solution for better integration between the public domain and aquaculture is planning or zoning.

8.3.2 Authorities involved in the licensing procedure

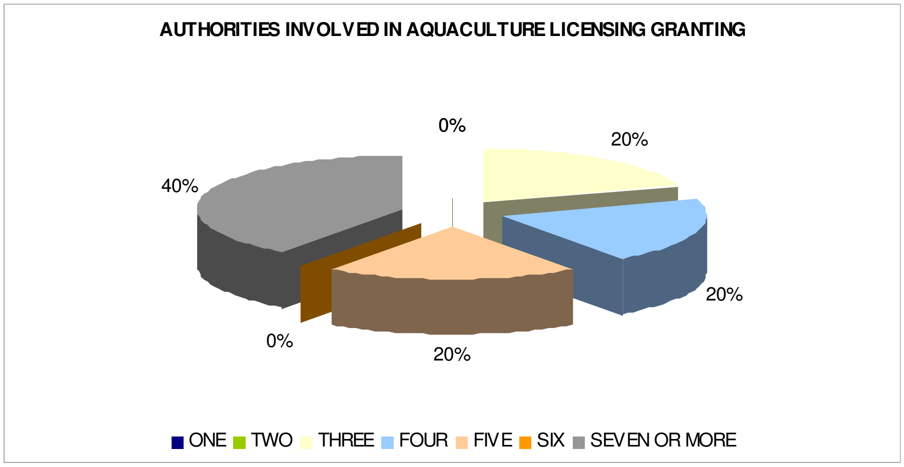
Several concepts used in this report have required accurate definitions in order to ensure a common understanding throughout countries and policy frameworks. In the licensing process, a two-step analysis have been applied: first, for the Bodies/Departments/Authorities who directly grant the licenses, those entitled with competences in the licensing process; second, for the authorities involved in the licensing process, meaning those who should be consulted or informed before granting the aquaculture license. During the surveys we made, respondents had considerable difficulties to differentiate between the two categories, what could reflect both the complexity and the lack of clarity in the aquaculture institutional settings.

Figure 8 - Licensing procedure for aquaculture: Bodies/authorities involved in granting aquaculture licences.



Legend:	(yellow)	Countries with **three** Bodies/Department/Authorities involved in aquaculture licensing (should be consulted and/or informed in the process)
	(blue)	Countries with **four** Bodies/Department/Authorities involved in aquaculture licensing (should be consulted and/or informed in the process)
	(orange)	Countries with **five** Bodies/Department/ involved in aquaculture licensing (should be consulted and/or informed in the process)
	(grey)	Countries with **seven or more** Bodies/Department/Authorities involved in aquaculture licensing (should be consulted and/or informed in the process). Total numbers are indicated for each country.

Figure 9 - Licensing procedure: bodies involved in the granting of aquaculture licenses



A major legal constraint for aquaculture development, usually remarked on by private operators, is related to **cumbersome and overlapping norms and administrative procedures**. In the Mediterranean basin, 40% of the studied countries have more than seven bodies/authorities that should be consulted or informed in the license granting process. For instance: Turkey (15), France (12), Greece (11), and Spain (10) are the leading countries in this respect. On the other hand, Albania and Morocco declare to have only 3 bodies/authorities involved. Although coordination would be at the core of effectiveness in the licensing granting procedure, it seems quite evident that the higher the number of bodies involved the more intricate the process.

In drawing some conclusions from the available data, two factors should be taken into account. The first is related to the institutional framework and the decentralization of competencies at regional and local level in each country, which have a direct impact on the number of authorities involved (as an example, in Spain or Italy aquaculture competent authorities fall under regional governments; equally, local authorities are involved in aquaculture in almost all the countries studied; Boxes 3 and 4). The second factor underlines that aquaculture activities fall under the legal and regulatory jurisdiction of multiple agencies. In this sense "it is important to recognize that criticisms of administrative overlap sometimes are inapt in that there may be no explicit 'overlap' in the strict sense of two agencies regulating the same activity. The term 'overlap' is often used in a general sense to connote the complexity of regulation and the confusion that is the predictable consequence of that complexity" (Duff et al. 2003).

Once again, a central issue for an aquaculture legal and institutional framework lies in the definition of concepts. Overlap and concurrence of competences are two different problems which call for different solutions: **overlapping** requires a clear delimitation of competences; **concurrence** of agencies and public bodies requires coordination and increase of efficiency in public management.

Box 3 - Licence procedure for marine aquaculture in Croatia (2009)

In Croatia there are four authorities/administrations involved in the aquaculture license procedure: Ministry of Agriculture, Fisheries and Rural Development (License for fish farming), Ministry of Environmental Protection, Physical Planning and Construction (EIA), Ministry of Sea, Transport and Infrastructure (concession), County (concession), Government (concession). The process starts with an aquaculture promoter submitting a request for concession of maritime area to the County. The County checks if area and usage stated in the request is in line with physical plans (site selection criteria are defined by law); if so, county starts procedure for Location permit.

The requirements for Location permit are therefore a concept design in line with the physical plan, EIA (if requested) and an agreement with Ministry of Sea, Transport and Infrastructure and Ministry of Agricultural, Fisheries and Rural Development.

The process includes a public hearing for both physical plans and EIA (if requested). After that, the County announces public tender for the award of concessions, requiring the consent with Ministry of Agriculture, Fisheries and Rural Development. The best applicant signs a Contract on concession with the County, which gives a concession for a period up to a maximum of 20 years.

Finally, the Ministry of Agriculture, Fisheries and Rural Development issues a License for fish farming. The Duration of this license is related to the duration of the concession.

Source: GFCM CAQ Workshop on National Legislation on Site selection, Monitoring Programme and on Environmental Impact Assessment, 13 -14 July 2009, Vigo, Spain

Box 4 - Aquaculture licensing in Spain (2009)

In Spain, marine aquaculture needs a number of licences from different administrations. Autonomous Communities or the regional government issues the main authorisation or concession and gives the right to develop the aquaculture activity. But the aquaculture promoter needs other types of licences depending on the site where aquaculture will be developed. In the case of marine aquaculture, as the maritime zones are considered public domain or state owned property, the promoter needs a concession to install the facilities in the public domain. And this concession is issued by the Central Government (administration in charge of coastal protection: the Ministry of Environment, according to the Law of Coast of 1988). Or even a third administration could be involved if the aquaculture facility is going to be installed in harbour areas, also considered a public domain according to the Harbour Law (27/1992).

So, when the aquaculture facility needs an area in the public domain, owned by State, the granting procedure becomes more complex and requires considerable coordination between authorities responsible for aquaculture (regional government) and authorities responsible for managing coastal areas, marine zones, etc. This double concession involves a complex and time-consuming procedure that in Spain takes 18 to 24 months for coastal domain public use and 8 months for harbour domain public uses.

Many regional governments tried to reduce the procedures and improve their efficiency by designing coastal zone planning for aquaculture. With planning as a tool for managing aquaculture, the administration defines and sets up maritime and coastal zones designated for aquaculture activities. In the last decade, some of these regional governments started to define these “interested zones for aquaculture” described by Law 23/1985, as “those zones that for its optimum conditions for aquaculture needs official protection”. The European Commission is also worried about the space limitations for aquaculture and strongly recommends the importance of technological developments and spatial planning through this useful management tool.

Besides the public bodies involved in the procedure, the concurrence of two main administrative authorities is required: one is responsible for the actual activity of aquaculture and grants the licence to begin operations, and another that manages the public owned shoreline and public coastal areas, and authorises the occupation of a public area for a specified time. It is the granting of this second authorisation that generates most problems.

Often, these two main agencies belong to different departments or ministries, which mean that they must liaise with each other in the interest of speeding up the proceedings. This makes institutional coordination and cooperation all the more necessary. For instance, in Spain a step forward has been the recent integration of responsibility for management of the coasts (public domain) and the bodies that represent Spanish marine aquaculture, through the creation of the Ministry of the Environment and Rural and Marine Affairs. However, power to authorise aquaculture operations remains in the hands of the Autonomous Communities (Regional Governments), which makes the system more complex. This analysis of the current state of play shows that the main problems that tend to characterise aquaculture in practically all countries relate to the lack of simplification of administrative procedures, the numerous authorities involved and the resulting over-bureaucratisation and lengthiness of licence granting procedures.

Generally, most common agencies involved in the license granting process are:

- Fisheries
- Merchant shipping or navigation
- Environment
- Physical planning and public Works
- Culture and heritage
- National defence
- Health and welfare is required
- Industry
- Local authorities.

The survey developed within the SHocMed project specifically addresses the main problems related to the licensing procedure. The output underlines complex, lengthy processes, multiplicity of agencies involved and lack of zones designated for aquaculture as major hurdles.

In Cyprus, problems are directly linked to the complicated and time-consuming procedures, which make it difficult to react fast enough in an environment of rapid market changes. Additionally, there is a long consultation process with different authorities, each one with its proper and divergent interest. Many of the barriers to aquaculture development are related to the lack of official aquaculture zones.

Other countries such as Tunisia and Greece consider, as main problems, the numerous authorities that are currently involved in the process of licensing. In a similar way, aquaculture promoters in Turkey affirm that obtaining an aquaculture license is “too complex”.

In the case of Spain, competency to issue a license for aquaculture falls under regional governments (as in Italy), with a variety of legal frameworks that also conflict with overarching policies at national level (for instance, environmental and coastal policies). The aquaculture sector also claims that legal uncertainty and complexity are directly translated to stagnation of aquaculture development.

Montenegro represents an example of a problem-solving approach. If the major ongoing problem relates to the complex and long lasting procedures for issuing an aquaculture permit, they hope to overcome this by procedures that will be implemented under a new law (the law on marine fishery and mariculture which is in the making[25]).

In Albania, there is a remarkable difference, as in many countries, in the ease of granting a license, depending on whether the location of the aquaculture facilities is in a public or private area. In the public zones, applicants should present complex documentation, and the administrative body will go

[25]The Law on Marine Fishery and Mariculture is still in a procedure of acceptance by the national parliament. According to this law, the Government will approve the mariculture development plan.

through numerous procedures to prepare the public notifications and necessary public information. This process appears easier for private areas, but there is a lack of monitoring of activities.

The Moroccan approach addresses directly the legal and institutional framework for aquaculture, pointing to the lack of a specific law and the absence of sensitiveness to the investment in the activity, besides other issues, such as know-how in the sector.

In Italy, the design of a participatory process has raised unintended effects which could be adverse. For example, occasional interventions by environmentalists during the phase of discussion slow down the process. In any case, the discussion with the stakeholder at different levels is mandatory through the so called '*conferenza di servizi* (CS)'. Normally this CS is requested by a private entity or by the public administration. In particular, if the CS is requested by a private entity, it is necessary to know all the requests made by the different stakeholders and authorities listed by a regional standard linked to the aquaculture license procedures, which generally includes: la *guardia di finanza (revenue guard corps)* , la *dogana (customs)*, la *regione (regional administration)*, la *sovraintendenza ai beni ambientali e culturali (environmental & cultural bureaux)*, le *associazioni dei consumatori (consumers association), i sindicati (labour unions)*, *le associazioni ambientaliste nazionali e regionali iscritte agli albi nazionali (national and/or regional environmental associations),* etc. Over and above these, the lack of national aquaculture allocation plans or zoning or site selection in the Italian regions remains a limiting aspect for aquaculture development, although several regions have developed plans for aquaculture (cf aquaculture planning).

Other countries indicated specific problems related to the EIA procedure (e.g. Slovenia), the availability of sites for coastal farms (Israel), the public inquiry linked to environmental protection (France) or the period of license validity (e.g. in Croatia, where the licenses for use of the maritime area that are under the jurisdiction of counties are usually not issued for the legal maximum period). Finally, Egypt affirms that there are no problems linked to the licensing procedure.

Box 5 - Licences procedure for marine aquaculture in Cyprus (2007)

In the FDMR, the license for the establishment and operation of a fish farm, which is issued according to the provisions of the aquaculture law and the aquaculture (general) regulations, requires information on the type of culture, the sea surface water area which is defined, the fish annual production, and its duration, which is 10 years for marine fish farms. Also, the EIA becomes an integral part of the license. Generally, the license includes terms and conditions which aim at safeguarding good management practices, collection of statistics, protection of the environment according to the EIA study, the relevant conditions imposed by the Environmental Authority and the Cypriot and EU laws, compliance with the Art. 9 of the FAO Code of Practice for Responsible Fisheries in the Mediterranean, etc. The lease of the necessary sea area is done according to the provisions of the aquaculture legislation by the Council of Ministers, and the tender procedure is followed. The tenders are assessed according to technical, economic and financial criteria stated in the aquaculture legislation. Finally the DFMR submits to the Council of Ministers a relevant proposal on the successful tender, who would had also secured all the necessary permits, including the environmental consent. The annual rent of the water surface covered by the farm installations is £ 0.10 (= 0.16 €) per square meter. The fee for the issue of an aquaculture marine fish farm license is £100.

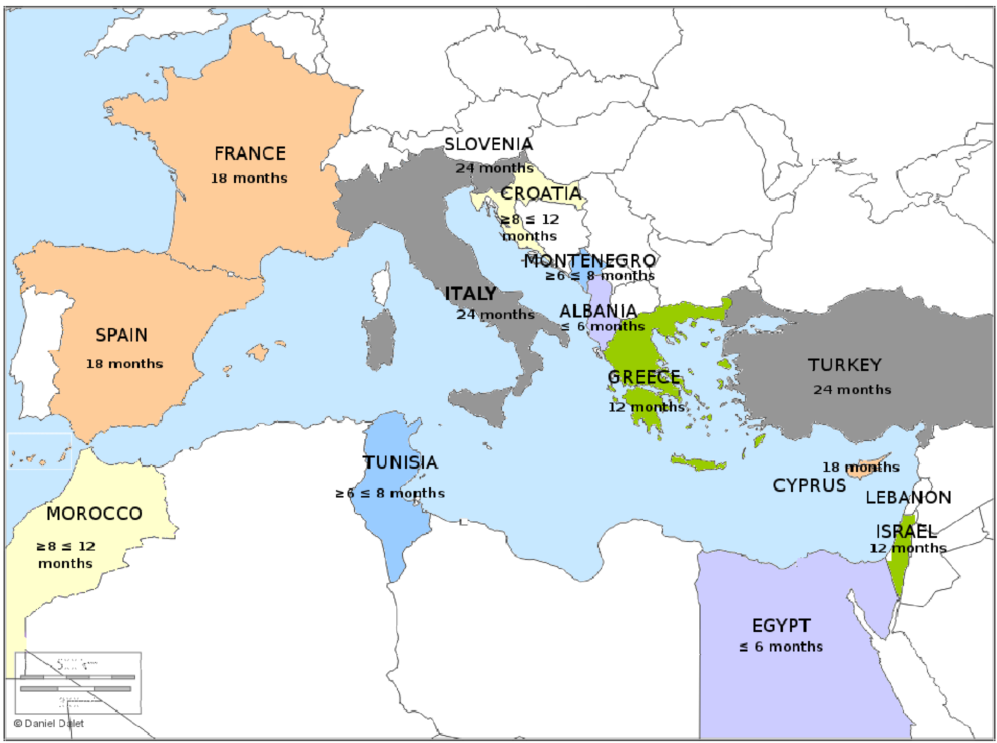
Source: D. S. (2007) Review of aquaculture development in Cyprus, MEZE (Herault) , 19 March, 2007. Ecosite du Pays de Thau, France

8.3.3 Obtaining an aquaculture license: duration of the administrative procedure

A key indicator to assess the effectiveness of the administrative procedure for license granting is related to the average time taken for a promoter or prospective aquaculture operator to obtain a license. This covers the whole process, from the application and the permits required, throughout all the revisions, public information dissemination process, etc., to the final granting of the license.

In the Mediterranean, the average time taken in the licensing process has been estimated in 14 months. Additionally, the granting of the license is just the starting point to enable initiation of building the facilities and beginning the production process; depending on the species to be cultured, the time taken from the application (average time mentioned) to the first sale of the product could take between 2.5 and 3.5 years[26]. In a global market with changing scenarios, three years is a long period of time which plays against aquaculture development.

Figure 10 - Licensing procedure for aquaculture: average period of time required to obtain a license



Legend:		
	(purple)	Countries with an average time lower that 6 months to obtain an aquaculture license
	(light blue)	Countries with an average time between 6 and 8 months to obtain an aquaculture license
	(light yellow)	Countries with an average time between 8 and 12 months to obtain an aquaculture license
	(green)	Countries with an average time of 12 months
	(orange)	Countries with an average time of 18 months
	(grey)	Countries with an average time of 24 months

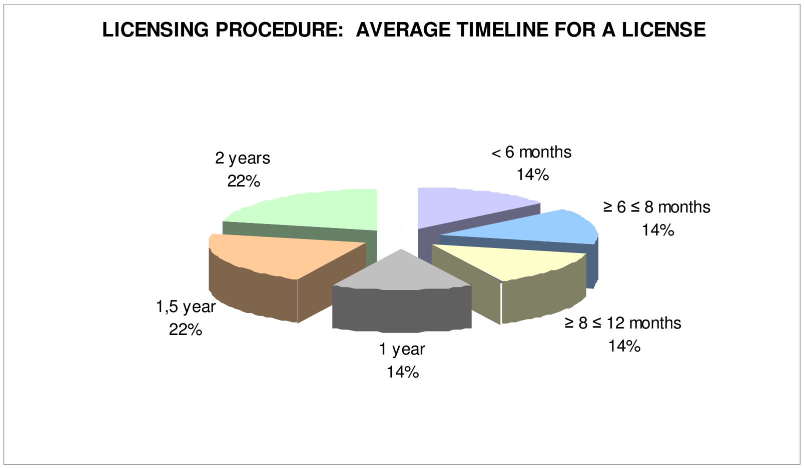
Note: For Spain, the average period is the result of the medium average taken by each regional government, which scored between 12 and 30 months[27].

Using the fourteen month period as a benchmark, 57% of the countries surveyed have shorter periods of time than the average to obtain an aquaculture license, these are: Egypt, Croatia, Israel, Albania,

[26] This period varies widely depending on the species cultured, the type of aquaculture installation, etc. The numbers presented are just estimates.
[27] Data obtained from the National Strategic Plan for the Spanish Marine Aquaculture (MARM, 2008).

Morocco, Tunisia, Greece and Montenegro. On the other hand, Cyprus, France, Slovenia, Turkey, Spain and Italy use longer time periods for the process[28].

Figure 11 - Licensing procedure for aquaculture: average period of time required to obtain a license



Of particular significance is that some countries have included in their regulation a provision for the ’legal maximum time frame for the licensing process’, as the foreseen time for the procedure. In practice, however, there is always a significant deviation between the provision regulated and the real average time taken for the whole process[29].

8.3.4 Validity of the aquaculture license

If security and stability in the medium term is a strategic issue for the development of aquaculture, the validity of the license is a good indicator to assess the scenario within which potential aquaculture operators have to decide about their investment in this activity. In the Mediterranean, aquaculture licenses are generally valid for 10 years (in 43% of the countries studied[30]), and renewable for several periods up to a maximum of 30 years depending on the country and according to different criteria. Exceptions to this are Italy[31] and Montenegro, with a validity of 4 years; Israel and Morocco (5 years), Tunisia (7 years); Croatia (20 years); and finally France (30-35 years[32]). Frequently, as for instance in Albania, the validity may vary between licensing marine aquaculture (10 years) and licensing land based aquaculture (20 years).

Figure 12 - Aquaculture licenses: validity (in years).

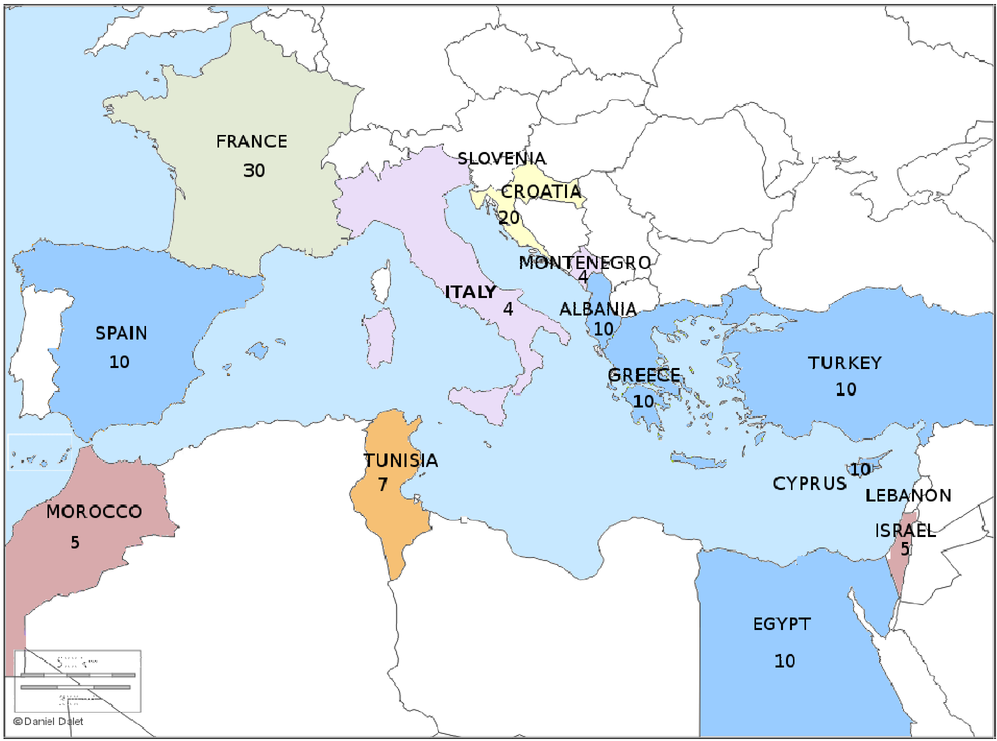
[28] There is no available data for Lebanon. According to the information obtained in the survey “Lebanon does not have legislation concerning aquaculture. There is no mariculture to date, and only one license to occupy maritime surface

[29] Regional Governments in Spain constitute a clear example: whereas provisions in regulation point to a maxim period of 6-10 months, the process delays from 18 to 30 months. In other countries such as France, the theoretical time average for obtaining an aquaculture license is 6-8 months, whereas in practices it takes an average of one year and half.

[30] No data from Slovenia were available.

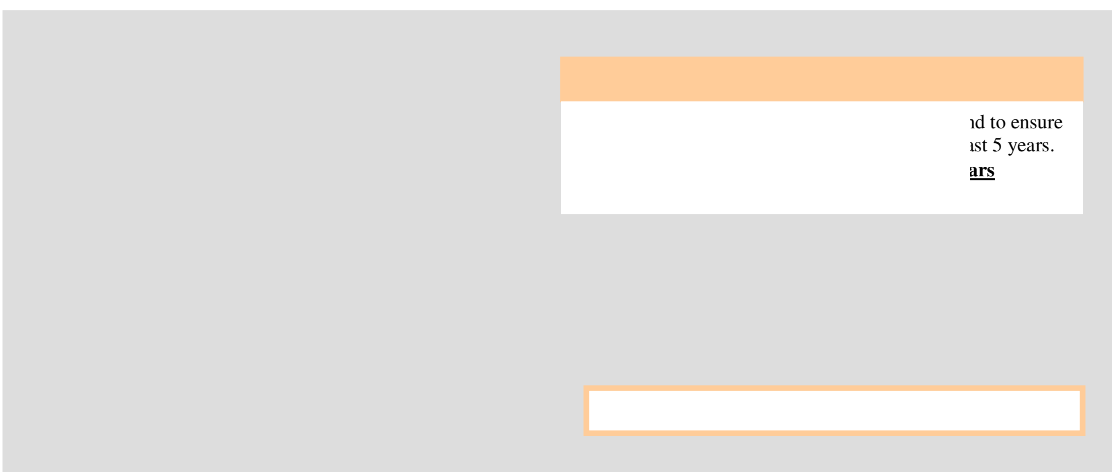
[31]. As a result of the new financial instrument for the Common Fisheries Policy of the European Union, the European Fisheries Fund (2007-2013), regional governments in Italy have shortened the validity of licenses, in order to adjust them to the financial period; see figure 4.

[32] According to the data collected from the survey, in France the duration for an aquaculture license is 30 years most of the time. Nevertheless, secondary sources pointed to a validity of 35 years (Van Houtte et al., 1989).



Sometimes, there are significant changes in the 'rules of the game' that have an impact on the medium and long term strategies of aquaculture promoters, as for instance in Italy due to the application of the EU's new financial instrument for fisheries; the European Fisheries Fund (EFF).

Figure 13 - Changes in the licensing procedure for marine aquaculture in Italy (2009)



Summarizing, the consequences of a complex and cumbersome institutional setting, combined with the long time required for obtaining a license, are evident:

1. aquaculture promoters give up viable projects;
2. potential investors search for projects with lower uncertainty in other economic activities, slowing down the development of aquaculture;

3. aquaculture projects must be redefined once the license is obtained; after an average of fourteen months in the process the project could be out of step;
4. the changes in the global market for aquaculture products are too rapid to be able to take such delays. companies already in operation could lose market shares and competitiveness due to difficulties to expand their activity through new installations;
5. development plans at the medium and long term are complex for aquaculture companies;
6. administrative cost rise;
7. coastal areas lose development capacity, especially where there is a lack of opportunities for socioeconomic growth.

Frequently, the industry expresses the negative impact of regulation in terms of difficulties for expansion, innovation (related to species and production systems), reduction of cost, attraction of new investments, etc. In this sense, private stakeholders claim that investors are searching for countries far from the Mediterranean to establish new facilities. It is evident that, in the future, aquaculture products will have a strategic role in our markets. The question is: are we the ones who will produce those products or are we going to limit ourselves to import them?

8.3.5 Assessment reports

Notices and copies of the application and the lead agency report are sent to numerous regional and national agencies including: navigation, tourism, environment, local councils as well as other government agencies. The key elements in the aquaculture procedure are these assessment reports made by different administrations involved in aquaculture licensing. Such reports should be assessed fairly and in support of the aquaculture activity. The main goal of such reports is to assess the impact of aquaculture in the area over which the authorities have competencies that are different from aquaculture. The most important issue is coordination with the lead agency that is responsible for, ultimately, granting aquaculture licences.

The lead agency, which will eventually grant the concession, should wait for referral from the other competent agencies in order to issue the permit with the approval of the other agencies and allowing the latter to have their say and give advice on the aquaculture activity. Therefore, assessment reports must be forwarded within the set deadline provided by the licence procedure. It is important, at this stage, for coordination between the different administrative agencies in order to process reports without delay. Thus, the main responsible agency - generally the Ministry of Fisheries – also has the role of resolving difficulties and facilitating the progress of applications through administrative coordinating committees of administrative officers.

For example, in Greece the authorized public administrative bodies that are involved in submitting a report are: Ministry of Agriculture, Ministry of Mercantile Marine, Ministry of Transportation and Telecommunication, Ministry of Finance, Ministry of Defence, Ministry for Environmental, Physical Planning and Public Works, Ministry of Development, Ministry of Health and Common Welfare, Hellenic Navy General Service, Hellenic Tourism Organ, Organization of Agriculture Insurance and Local authorities (Papoutsoglou, 2000).

Worldwide, some states, such as Maine in the United States of America, also take into consideration noise or visual impact that the aquaculture activity may cause, so the lead agency will request the contribution of the competent authority in these matter regarding possible impacts this respect.

8.3.6 Environmental requirements

In general, applications for aquaculture projects are submitted with an accompanying technical study, a biological study and other required documents, such as the EIA. For aquaculture licences, the EIA is an important element to ensure protection of the environment where the aquaculture activity will take place. The authority responsible for the environment usually oversees this type of assessment.

Regulations differ between different countries in terms of their content and the standards required for the EIA. Although the EC has attempted to harmonise legislation within EU Member States, the EIA requirements still differ from one country to the other. While in the EU, EIA criteria are mainly based on production criteria, in other countries such as like Egypt, they are based on the site characteristics where the facility will be located (for example, if it is a protected area).

8.4 Aquaculture planning

> *The challenge for aquaculture policy-makers, planners and managers is to fully realize the potential contribution of aquaculture in satisfying current and future human needs, while conserving and protecting natural resources.*
>
> Yong-Ja Cho, 2001

If the increasing economic pressure on the coastal zone is an issue worldwide, it is even greater issue in the Mediterranean. According to the EC, "the Mediterranean bears 30% of global sea-borne trade in volume from or into its more than 450 ports and terminals, and a quarter of worldwide sea-borne oil traffic. Its coasts are home to more than 150 million inhabitants, a figure which doubles during the tourist season" (COM, 2009).

Aquaculture is an economic activity that, like many others, exerts an influence on the littoral, hence, contributing to conflict of interest and use of space in this zone. In this context, planning policies have followed a philosophy based on partial and specific planning, generating a coastal zone management for each concrete activity: port planning, fishing, industrial, urban planning, tourism and so on. Aquaculture has not remained alien to this need for planning in order to contribute with an economically and ecologically sustainable activity.

In this sense, worldwide, public administrative entities responsible for aquaculture have initiated the implementation of public policies for the management of coastal areas identified for aquaculture activities, protecting them from the impact of other coastal activities, while improving the administrative processes and reducing the bureaucratic procedures for granting the aquaculture license.

Already, in 2002, the EU pointed out that planning and coastal management are one of the major challenges that European aquaculture will face. Recently, in its document "Building a sustainable future for aquaculture: A new impetus for the Strategy for the Sustainable Development of European Aquaculture", the Commission recalls that "area choice is crucial and spatial planning has a key role to play in providing guidance and reliable data for the location of an economic activity, giving certainty to investors, avoiding conflicts and finding synergies between activities and environments with the ultimate aim of sustainable development" and invites all Member States "to develop marine spatial planning systems, in which they fully recognise the strategic importance of aquaculture. In this context, as part of the preparation of the next reform of the Common Fisheries Policy, the Commission will consider the possibility to strengthen the linkages between Community financial instruments and the issue of access to space for maritime activities, including aquaculture" (COM 2009)

Although there is certain consensus on the need of planning for aquaculture, once again the definition of the concept and the meaning of 'planning' are multiple. In the socioeconomic and institutional context, economic policies and environmental conditions, planning goes from minimal guidelines to strategic intervention: “Planning may be orientative when priority is given to the programming of administration activities in the short to medium term, often with the purpose of demonstrating the feasibility of projects which could act as models for the private sector. Planning may largely mean encouragement, as in certain countries of the northern Mediterranean where emphasis is placed on investment aid policies to favour certain production methods and at the same time decrease short-to medium-term financial risks incurred by the businessmen. Planning can ultimately be considered as a strategy when public action is based on the combination of programmes aimed towards the private and public sectors in a sustainable perspective for the short and medium-long term. The interest of ensuring that a planning approach is adapted to the natural, economic and human constrains of the country is furthermore confirmed *a contrario* by the problems of overinvestment or depletion of natural resources, a situation found in certain Mediterranean countries” Paquotte et al. (1998).

Figure 14 - Aquaculture planning

Legend: Countries/regions with specific Planning for aquaculture
Countries without specific Planning for aquaculture

Notes:

Morocco is nowadays preparing a Planning for aquaculture. Montenegro is still in the procedure of acceptance of a new Law which includes the development of Mariculture Development Plan.Where Regional information is available it has been included in the map.

Forty percent of the countries surveyed declared to have some sort of specific ‘planning for aquaculture’. Under this we found a multiplicity of instruments that could be organized in a continuum, ranging from studies and information to regulative tools which pursue the development of aquaculture in the long and medium-term.

Whenever zoning has been developed as a study or technical scheme, in general it is not included in any official procedure or regulation; therefore, it is not mandatory and aquaculture farms could be located either in the proposed area as per plan or in other areas. Albeit not compulsory, this type of zoning provides useful information for potential aquaculture operators and public administrative bodies. On the other hand, zoning or allocation of zones for aquaculture (AZA) regulated by procedures prescribes that aquaculture can be developed only in specific areas. It seems clear that zoning areas for aquaculture simplifies the siting and allocation processes, reducing administrative procedures and enabling aquaculture development. Nevertheless, several aspects are noteworthy:

- the criteria applied for the selection of zones;
- the decision-making process, including the participation of stakeholders;
- the period of time required for the approval of the zoning.

The data from the surveys (almost half of the surveyed countries have some specific planning for aquaculture) confirm the tendency noted since the beginning of the twentieth century, i.e. an increase in the number of countries which allocate specific areas for aquaculture. The example of Montenegro is representative, since the new law includes as a tool a 'mariculture development plan' to be approved by the Government on the recommendation of the Ministry of Agriculture, Forestry and Water Management, which in turn will be based on analysis of sustainable development of mariculture, especially taking into account, biological, typological, hydro-morphological and physico-chemical characteristics of zones for mariculture defined by the spatial plan.

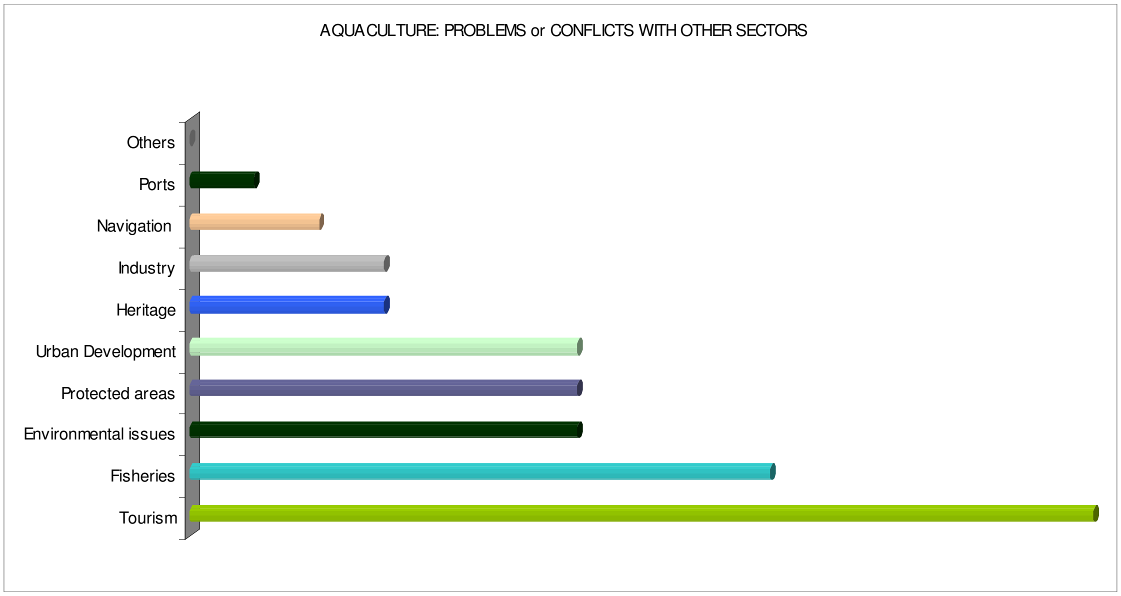
In Egypt, planning includes specific zoning for aquaculture, regulated by specific criteria; therefore aquaculture can be developed only in those areas determined by the regulations.

Noteworthy is that in some countries such as Spain and Italy, the responsibility for aquaculture falls under the regional governments. Therefore, although there is no national planning or zoning for aquaculture, several localities have developed their own planning at the regional level. For instance, in Italy the regions of Veneto (regional law n°10/1999 and the specific regional decree on EIA), Friuli V.G. (regional law n°10/1977 and legional law n°52/1991), Emilia R. (regional law 31/05/2002 n°9 before the last FIFG, regional law 16/11/2000, n°35: procedures for EIA), Tuscany (regional law 2005 n°66), Sicily (guideline for mariculture – Nov. 2008), Liguria (regional decree 30/11/2007 n°1415). In Spain, the regions of Andalusia, Galicia, Murcia and the Canary Islands have developed or are in the process of developing some type of aquaculture planning.

Undoubtedly, aquaculture planning is the basic tool to overcome the conflicts resulting from use of space and pressures on the coast. In the Mediterranean, problems and conflicts arise mainly with tourism (93% of the countries studied), and to a lesser extend with fisheries (60%), urban development (40%) and environmental issues and protected areas (40% respectively).

From the survey, it results that conflicts with the industry or navigation (14%) are a minority, and there seems to be no problem at all with ports except in Israel (although in the other countries conflicts with yachting facilities are probably under the category 'tourism').

Figure 15 - Aquaculture: problems and conflicts with others sectors



Aquaculture planning is closely linked to the set of criteria for site selection. Generally, the site selection process in the GFMC area is based on criteria or guidelines already established (79% of the studied countries), as shown in Figure 16.

Figure 16 - Aquaculture planning: procedures or guidelines for aquaculture site selection.

Legend: Countries with procedures or guidelines (indications of actions required or recommended) for aquaculture site selection.

Countries without procedures or guidelines for aquaculture site selection

Notes:

As mentioned above, according to the information obtained in the survey, Lebanon does not have legislation concerning aquaculture. There is no mariculture to date, and only one license to occupy maritime areas.

In Italy there are no guidelines at national level, but some regions such as Sicily have developed their own guidelines at regional level.

In Israel, procedures or guidelines for site selection are limited to Mediterranean cage farms.

In Cyprus, there are some criteria within the policy for aquaculture development regarding site selection. Usually the site is determined by the EIA and the policy for the establishment of any new farms is that these will not be established in depths less than 40 meters. Also, for the expansion of already existing farms, the new facilities that require expansion will be placed in the deeper parts of the existing facilities. Additionally, there is legislation by other competent authorities requiring, for example, that no farms will be sited in bathing areas or where they are an obstacle for marine traffic, or close to single point mooring stations, etc. In any case, the legislation is due to change in order to allow establishment of aquaculture zones and, in due time, the necessary criteria will be defined.

In Tunisia, there are no official standards or guidelines but the procedure for licensing encompasses some criteria in relation to occupation of a marine area, such the need to avoid sites supporting seagrass (*Posidonia oceanica*), sensitive areas, maritime routes and sheltered areas used by vessels when bad weather prevails ("zones de mouillage"). A similar situation is found in Morocco, where guidelines are based on scientific advice, local representation by administrative bodies having the necessary authority and stakeholders, include the local population. Currently, Morocco is involved in a project related to a locally integrated plan for aquaculture (developed by the Institut National de Recherche Haleutique in the area of Fnideq-Oued Laou).

Frequently the situation is akin to France, where the guidelines (*inventaire de zones d'aptitude aquacole du littoral français: un atlas numérique interactif; outil cartographique d'aide à la décision pour l'implantation des fermes aquacoles sur le littoral corse*) lack a regulatory enforcement and more information-based.

Using a systematic approach, the Croatian Ministry of Agriculture, Fisheries and Rural Development has issued 'Guidelines to marine aquaculture planning, integration and monitoring in Croatia'[33]. Moreover, there are specific regulations defining physical, chemical and biological criteria for the siting of fish, shellfish and, in particular, tuna farms.

In Turkey, the procedures and guidelines for aquaculture site selection are included in regulations, as well as in the Communiqué on 'the Closed Bay and Gulf Areas which are environmentally sensitive areas where fish farms cannot be established'[34]. Greece also regulates criteria for site selection in the legal framework, namely the ministerial directive 11014/703/F104. Montenegro has a Spatial Plan where zones suitable for aquaculture have been defined according to several criteria.

Finally, Albania and some Italian regions do not have guidelines for aquaculture site selection. In the Italian case, experts have pointed out the relevance of procedures at the regional level, and have advocated a compulsory approach to adopt 'regional planning for aquaculture site selection' to achieve effective results. Otherwise, the risk is stagnation; for instance, in regions as Campania, there have been discussions at the political level on regional zone destinations for aquaculture sites for more than three years, but without so far any official document or regulation being produced.

Within this context, many national or regional governments have tried to reduce lengthy procedures and improve efficiency by designing coastal zone planning for aquaculture. With planning as a tool for managing aquaculture, the administration defines and sets up maritime and coastal zones designated for aquaculture activities. In the last decade, some of these regional governments started to define these 'potential zones for aquaculture' described by law 23/1985, as 'those zones that for their optimal potential for aquaculture require official protection'. The EC is concerned on space limitations for aquaculture and strongly recommends the importance of technological developments and spatial planning through this useful management tool.

In Spain, four regional governments have a planning aquaculture strategy for both coastal and cage aquaculture; these are: Galicia, Canary Islands, Andalucía, and Cataluña. Galicia has established polygons for mussel aquaculture in cages (decree 406/1996; regulation for marine cage culture in Galician waters) and defines the aquaculture polygon as "the delimited area in a maritime zone for cage location". Inside the polygon, the legislation defines the 'square' or delimited area inside the polygon for cage siting". Decree 423/1993 includes rules for designing and managing these polygons.

According to the law 2/2007 on fisheries and aquaculture, the regional government of Murcia establishes the polygons for cage aquaculture in designated maritime zones reserved for aquaculture activities and overseen by different public administrative entities having responsibilities over these areas.

[33] Available online at www.ccrm.vims.edu/publications/pubs/aquaculture%20guidelines.pdf [consulted on August 09]
[34] According to the 'Communiqué' these are sensitive areas considered as prohibited for sea farming in waters that are less than 30 metres deep; closer than 0.6 sea miles to coastline; having sea currents less than 0.1 m/s; or in archeological and natural heritage areas which have been identified or are yet to be identified by the Ministry of Culture and Tourism.

In Cataluña, the coastal zone plan for aquaculture defines the locations for setting up aquaculture facilities, with provisions for proximity to the coast and excluding areas with *Posidonia*, marine protected areas, ports and harbours, touristic areas, etc. Finally, Andalusia has published, in 2006, the 'suitable zones for aquaculture development in maritime and coastal zones in Andalusia', identifying incompatibilities between aquaculture and other coastal uses in order to contribute to the sustainable development of aquaculture.

In Italy, the Sicilian region approved, in 2008, the decree on the "linee guida per la realizzazione di impianti di maricoltura in Sicilia", with the main aim of achieving integrated management of the coastal area. The objectives of the guide are to set the criteria for (i) the identification of marine areas potentially suitable to the mariculture in Sicily; (ii) the identification of land space for the construction of facilities for fry, livestock and related infrastructure; (iii) providing guidance for monitoring the activities.

Noteworthy is that the strategies of punctiform planning developed in the early eighties are no longer viable. For example, in Greece, due to the great length of the coastline and the difficulties for ICZM, concessions were provided case-by-case. However, the Supreme Court decided that this is unacceptable so the administration should provide areas for aquaculture and only in such locations should farms be established

8.4.1 Scientific basis for site selection: carrying/holding capacity

Simard et al. (2008) emphasise the capacity of a site to support aquaculture, i.e. carrying capacity, as the scientific basis for site selection. In the Mediterranean region, apparently 40% of the countries surveyed have standards for carrying/holding capacity. Nevertheless, the definition and applicability of standards related to this is quite heterogeneous. In Egypt, the government (through the GAFRD) owns three aquaculture farms as accepted models. In other countries such as Morocco, even though there are no standards, it is required to operate in an area of less than 10% of the total area of a coastal or marine ecosystem well defined and bounded physically.

In Cyprus, standards are specified and examined within the frameworks of the EIA by the environmental authorities. Similarly, Greece affirms to have standards for carrying/holding capacity of aquaculture farms.

On the other hand, Croatia, Tunisia, Turkey, Italy, Israel and Albania declare to not having any standards for carrying/holding capacity. Considering these standards as a key tool for site selection and aquaculture planning, establishment of common guidelines or criteria at the Mediterranean level seems to be much needed.

Figure 17 - Standards for carrying/holding capacity

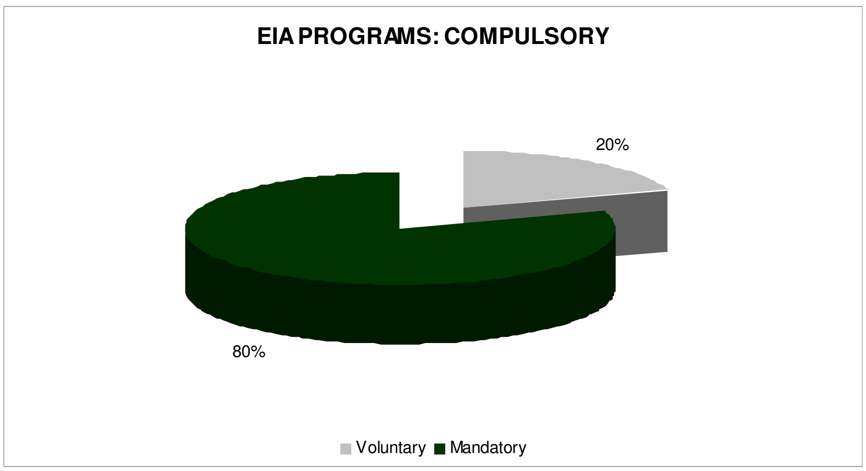
Legend:	(yellow)	Countries with standards for carrying/holding capacity for aquaculture facilities.
	(grey)	Countries without standards for carrying/holding capacity for aquaculture facilities

8.4.2 Environmental criteria for site selection: eia and monitoring

Environmental issues have increasingly become a priority on the public agenda during the last thirty years. Essentially, the greater awareness of environmental protection has been accompanied by the development of proactive tools designed to plan and guarantee such protection.

The Environmental Impact Assessment (EIA) procedure appears to be accepted and used worldwide, although it varies widely in its content, scope, implementation, etc. The EIA has been defined as “the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made” (IAIA, 1999). At the EU level, the EIA was first introduced through a Directive in 1985[35]. In the Mediterranean, the EIA process is operative in all the countries surveyed, being mandatory in 79% of them (all but Albania, Egypt and Montenegro).

Figure 18 - EIA programs in the Mediterranean



The FAO has carried out specific research on EIA and monitoring in aquaculture[36], identifying as major strengths and weaknesses: (i) the difficulty of addressing the cumulative impacts of many small-scale developments through conventional EIA; (ii) the lack of environmental objectives and standards – especially suited to the local context – against which to assess impacts and design mitigation; (iii) the excessive scope and lack of focus on key issues of much EIA and monitoring activities; (iv) the lack of institutions and capacity to coordinate, manage, implement and review EIA, monitoring and environmental management tools more generally; (v) the lack of engagement and trust between regulators and farmers; (vi) limited participation or engagement of key stakeholders; (vii) or where this does take place, poor management and inadequate conflict resolution; (viii) the lack of effective monitoring, analysis and feedback into sector management, as well as into management of individual farms, or groups/clusters of farms (FAO, 2009b).

The conclusions of the study by FAO pointed to monitoring as a key step to ensure effective environmental management of aquaculture; therefore, there is a need for integration of both EIA and monitoring within aquaculture policies.

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[35] Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment [EIA Directive (85/337/EEC], amended by Council Directive 97/11/EC of 3 March 1997 amending Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment. A Consolidated Directive is available online at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1985L0337:20030625:EN:PDF

[36] For more details see references in FAO (2009).

Currently, the lack of standards and guidelines is still evident. For example, in Cyprus the EIA is mandatory by legislation, although currently there is no specific format; according to consulted sources, a change in the legislation is due, which will provide guidelines of what should be included in the EIA as well as the format that should be used.

Box 6 - Methodological guide for the elaboration of creation of authorization classified installations for the environment protection (CIEP) in marine fish culture, France.

Sea fish farms with a production of more than 20 tons per year in France must obtain two operating licences: (i) one for sea farming (AECM), with the aim of ensuring that the granted site and use of the maritime public domain for exploitation will respect all restrictions of general interest; (ii) one for regulating facilities classified for the protection of the environment (ICPE). Although the first one requires a relatively simple licence request file, the second one demands a very complete file, which includes, beyond the notice of exploitation information, a complete impact study, as well as a hazards study and a health and safety notice. In this context, petitioners in Corsica (adjustment of status or new exploitation) are faced with the same difficulties, which highlighted the need for a methodological guide adapted to each region's specific situation, assembling in particular the necessary baseline data (legal, zootechnical, geographical, climatic, socio-economic, ecological...) as well as recognised methods for evaluating the potential effects of the farm on the environment.

Development of this guide was supported by ADEC and supervised by a steering committee composed of representatives from the administrations concerned, fish farmers and scientific bodies. The significant aspects dealt with the effects of fish farming on Posidonia herbarium, a protected species very present in Corsica and with coordinating the two AECM and ICPE procedures.

For each part of the ICPE file, the guide introduces the technical or scientific context and, depending upon the case, the state of the art, sources of available data, acquisition and methods of acquiring measurements and of assessing the potential effects, as well as practical editing recommendations.

Source: Ifremer; full text available at http://www.ifremer.fr/docelec/doc/2004/rapport-2188.pdf

Similarly, in Greece, the legislation on aquaculture requires an EIA before a licence is given, but the content of EIA is relatively unclear. In June 2009, Greece approved a new regulation (common ministerial decision by the Ministries of the Environment and the Ministry of Agriculture Development & Food) which includes the requirements for EIA studies such as: description of the production process and of the farming facilities, maps, etc. However, no models or other prediction methods are mentioned.

There are other relevant issues that could have a bearing on implementation of the EIA, such as the provision of tools to reduce its economic cost for aquaculture promoters. For instance, in Greece there are several programs of funding for the EIA by the local authorities and also by the Greek Federation of Fish Farmers.

Figure 19 - Aquaculture: monitoring systems to evaluate effects

Legend:		
	(green)	Countries with monitoring systems to evaluate the effects and impacts of aquaculture activities on the environment.
	(grey)	Countries without monitoring systems to evaluate the effects and impacts of aquaculture activities on the environment.

Formally, monitoring programs are extensively implemented in the GFCM area, since near 70% of the countries have some tools to follow the impact of aquaculture activities. Only Egypt, Montenegro, Lebanon and Albania mentioned that they lack monitoring programs for the activity, whereas Slovenia does not provide information on this matter.

Generally countries compile monitoring programs as part of the EIA. In Croatia, the Environmental Protection Act regulates monitoring of marine aquaculture, and the monitoring procedures are regulated as part of the EIA for any individual farm site.

In Cyprus, all the marine fish farms that are operating in the sea area are obliged by law to submit twice a year (in winter and summer) an environmental monitoring report based on a protocol that is issued by the DFMR. The report is evaluated by this authority and the Environmental Services and action is taken if required. In general, the report covers monitoring of nutrients in the water column, sedimentation, macrobenthos, redox potential and macroscopic analysis and, in some cases, reporting on *Posidonia oceanica* meadows.

Additionally, site inspections are made frequently in order to ensure compliance of the fish farm with the terms and conditions that accompany the relevant aquaculture permit and the environmental approval.

In Tunisia, for every project related to establishment of an aquaculture facility, the promoter has to undertake and provide to the relevant administration an impact study, with the aim of meeting the environmental quality criteria and requirements. In Turkey, the fish farms have to make an assessment using the Composite Trophic Status Index (TRIX) two times a year and report its results to the Ministry of the Environment and Forestry.

Ultimately, due to its relevance for site selection and the interactions between aquaculture and the environment, our survey included a question related to measures in place to protect benthic habitats.

In Croatia, cages have to be sited at a safe distance from all benthic habitats. In Cyprus, the fish farming permit is accompanied with several terms and conditions, as well as the environmental approval. In case that there is a problem, both directors have the right to implement any additional terms and conditions in order to mitigate problems.

In Tunisia, the impact study is a mandatory element of the application to establish fish farming facilities; the final authorization takes into account protection of the benthic habitats, especially sensitive ones, including *Posidonia oceanica*, corals and others.

In Turkey, the Authority for Special Protected Areas (SPA) was established in 1988. Special protected areas (SPA's) are designated on the basis of the presence of unique habitats and/or very productive ecosystems. A site that has been designated as SPA has the greatest protection under existing Turkish legislation from pollution and/or habitat loss. At present there are nine SPAs on the Turkish coast. Of these, seven are located on the Aegean coast and two are located on the Mediterranean coast. Within each SPA they may be inner special areas of protection, especially sensitive zones with habitats that are considered of special importance such as *P. oceanica* beds.

In Greece, the new regulation approved in 2009 establishes that no new farms will be located on *P. oceanica* meadows; no expansion will be allowed on aquaculture facilities over this habitat, and the existing ones will not be renewed after the expiry of their concession permit.

8.4.3 Main gaps in mediterranean legal frameworks for aquaculture

The identification of main gaps is the first step in establishing recommendations to improve aquaculture legislative frameworks in the Mediterranean. According to the data obtained from the SHoCMed surveys and secondary information available, the major gaps can be summarized as follows:

- The definition of aquaculture in the legal frameworks lacks a comprehensive concept, which should not only consider the activity itself but also the categories involved with respect to location (offshore, inshore, etc.) production (intensive, extensive, etc.) and other relevant criteria.

- The current cumbersome institutional settings call for simplification of both regulation and administrative procedures.

- There is a lack of coordination tools for solving overlapping and concurrence of agencies involved in aquaculture and related issues.

- There is underutilisation of soft law mechanisms (guidelines, voluntary schemes, etc.). Guidelines are intended to be flexible and adaptable to changes, depending on endogenous or exogenous factors, as well as the input from new information. The introduction of selective incentives, positive or negative, has proven useful to achieve implementation and compliance of voluntary schemes.

- There is lack of manager and decision-maker training in relation to aquaculture planning and, in some cases, to the aquaculture itself.

- Aquaculture planning in some countries is limited to technical studies or recommendations.

- Aquaculture site selection is generally focused on administrative criteria (areas where there are no conflicts of use with other activities) or environmental criteria (protected or sensitive areas), and with no consideration given to the suitability of the aquaculture site for sustainable production or income generation.

- Social and economic studies are not normally included as tools for aquaculture planning. These should include market prospective analysis (matching supply to demand) and use in conjunction biological, environmental and other technical studies to formulate aquaculture plans.

- Integrated coastal zone management is limited to regional or local areas within each country. Therefore, conflict of uses and lack of coordination and interaction among economic activities prevail.

- There is lack of stakeholder participation mechanisms that are required to ensure proactive input and accountability of the actors involved. There seems to be an inverse relationship between the participatory process and efficiency in terms of time consumption and resources that needs to be resolved.

- There is lack of common criteria and standards (monitoring, carrying capacity, EIA).

- There is lack of implementation, monitoring and compliance with aquaculture legislation.

On the last point, further work is required in relation to establishment and implementation of legislation for aquaculture. Some countries have made reference in the surveys to the lack of compliance with legal provisions already in force. In this sense, in 2004 the IUCN compiled the main actions and priorities in order to improve the sustainable development of aquaculture. Among these was the necessity of a review and comparison on legislation and policy, based on the fact that "unrespected regulation is useless and non productive, thus the aim is to present to producers and administrative officers improved and simple legal and administrative frameworks for their activity and a basis for southern Mediterranean countries developments" (IUCN, 2004).

8.5 Recommendations

The recommendations proposed in the present work are based on the following considerations:

1. Although there are no ideal models applicable to all countries, it would be useful to adopt an agenda of priority issues to ensure that the legal framework is suitable for aquaculture development and planning.

2. Undoubtedly background, tradition and existing legislation will determine future developments in each country.

3. The allocation of aquaculture administrative responsibility is linked to the design of the institutional system; these recommendations do not advocate but for the most suitable level to implement those competences, be this local, regional or national depending on the particular country.

4. It would be useful to make progress on the formulation of common concepts and standards within the Mediterranean basis. Additionally, the report includes indicators (as tools) and

recommendations for policy makers that are useful for policy design and implementation of aquaculture policies.

5. It is important to build on the research and recommendations by national and international agencies that were already available prior to undertaking the present work.

Of particular importance is the document published by FAO in 1997 within the framework of Technical Guidelines for Responsible Fisheries, which focuses on aquaculture development. The main conclusions relevant for the legislative and institutional framework are summarized in the table below[37].

[37] FAO has supported countries in order to develop and adopt appropriate legal frameworks and legislature for aquaculture through its technical assistance program.

Table 10 - Technical Guidelines for Responsible Fisheries: Aquaculture Development, FAO

		Description
LEGAL AND ADMINISTRATIVE FRAMEWORK	**General responsibilities**	In order to promote, support, and regulate an efficient and responsible aquaculture sector, States should establish, maintain and further develop an appropriate administrative and legal framework to ensure that responsible aquaculture practices are introduced and implemented within their national jurisdiction
	Designated authority	States should designate or establish an authority or authorities competent, empowered and capable to effectively promote, support and regulate aquaculture and culture-based fisheries. Appropriate institutional linkages with other authorities such as those concerned with agriculture, rural development, water resources, environment, health, education and training and many others, should also be established. These linkages may have to be expressed in legislative form.
	Legal framework	States and their aquaculture authorities should ensure that the aquaculture sector is adequately regulated and protected by legal instruments such as laws, regulations, orders, agreements, etc., which set forth the responsibilities, rights and privileges of aquaculturists in a manner which is consistent with the current and potential aquaculture practices and with those applied to comparable activities.
	Understanding and enforcement of aquaculture legislation	States and their aquaculture authorities should ensure that all applicable legal instruments including laws, regulations, orders, etc. are conceived in such form as to be readily understood by those undertaking activities within the aquaculture sector, are adequately communicated to them, and finally that these legal instruments are enforceable and enforced.
RESPONSIBLE DEVELOPMENT OF AQAUCTURE	**General responsibilities**	States should, through their competent authorities, and in partnership with all interested actors of civil society, promote development of environmentally sound and sustainable aquaculture well integrated into rural, agricultural and coastal developments, raise awareness of the general public of the benefits of aquaculture practices for enhanced food supply and income generation, and support efforts aiming at responsible actions of aquafarmers and all those concerned or associated with aquaculture.
AQUACULTURE PLANNING	**Aquaculture Development and Support Planning**	In many countries there is a continued need for aquaculture and planning authorities to produce and regularly update comprehensive plans for promoting, supporting, regulating, and reporting on the aquaculture sector. The plans should encompass all relevant aspects of support and management of the industry […] Development planning will involve, possibly in consultation with all interest groups, the setting of policies and objectives, determining and implementing of actions required, monitoring the sector's performance, and adjusting the aquaculture development plan. Good collaboration among those concerned will help identifying the type of data and information necessary for monitoring and planning.

	Description
Assuring appropriate and responsible use of land and water resources	It should be ensured by aquaculture and planning authorities as well as by aquaculturists and investors that aquaculture activities are sited in locations which: are suitable for sustainable production and income generation; are economically and socially appropriate; prevent or minimize conflicts with other users of resources, and do not create undue externalities; respect nature reserves, protected areas, and critical or especially sensitive habitats. Government authorities should also ensure that the privileges and needs of the aquaculture sector are recognized and respected by other users of land and water and, in particular, that aquafarms are not exposed to external environmental threats resulting from activities in other sectors that reduce quality and quantity of water, nutrient and biological resources required. Where applicable, zoning or site regulations should be specified to conform to the requirements of plans for regional development, river basin or coastal area management, and their respective authorities.
Institutional capacity for the support of aquaculture	Primarily for historical reasons, the institutional frameworks used by States to develop and support their aquaculture sectors have usually grown out of their fishery, forestry or other natural resource institutions and organizations. While States may continue to find such arrangements practical, especially with respect to biological, marketing, and food quality aspects, they should also consider strengthening linkages with their institutions concerned with agriculture, rural development, irrigation, engineering and other sectors with which aquaculture activities have much in common. In particular, collaboration between water development agencies and aquaculture and fishery administrations could be facilitated, which would help to identify common interests resulting in benefits to both sectors. Aquaculture and fishery experts should be involved in the formulation of economic and legal instruments relating to water management

ENVIRONMENTAL IMPACT

	Description
	Ideally, an information and management framework for the protection of inland and coastal environments and resources should be in place capable of detecting and predicting ecological changes resulting from all human activities in a given area. All environmental impact assessment and monitoring efforts should be guided by predetermined development priorities and well-formulated objectives for the management of resources and environments.
Ensuring acceptable levels of impact on the environment	However, in the interest of other farmers and water users, and the public in general, government authorities should establish procedures to undertake appropriate environmental impact assessments prior to establishing aquaculture farms, and to ensure adequate monitoring of water extraction, effluents, use of drugs and chemicals, and other farm activities that might adversely affect the surrounding lands and waters. Provisions for obtaining baseline data and for monitoring should normally be established in conjunction with the procedures used to grant and review permits to engage in aquaculture on a particular site. EIA and monitoring is an important area for collaboration by authorities, researchers and aquafarmers. Consultations among all concerned should ensure that procedures for EIA and monitoring are sufficiently flexible, taking into account that scale and cost of such efforts may well have to be adjusted to the scale of the perceived impact of a given aquaculture operation. Criteria should be defined to establish which procedures for EIA and monitoring would be required from the aquafarmers, when considered necessary. Proposed methods for EIA and monitoring should be evaluated for their applicability to local conditions and site characteristics.

Based on the results of the surveys and analysis of the legal frameworks for aquaculture, the main outputs of this report are the following recommendations:

1. Research and the results of the SHocMed surveys show heterogeneity in the legal frameworks regulating aquaculture, in particular: concepts, definitions, competence, rights, institutions, etc. Legislation regulating aquaculture must include a definition of the activity and a minimum content. It should be noted that particular laws and policies, as well as the absence of regulations, can serve as constrains for aquaculture development. It is deemed that legislative guidelines for the Mediterranean should address the following minimal aspects:

The potential of soft law

1. **Establish principles**
2. **Provide standards**
3. **Provide guidance**
4. **Foster debate and cooperation among stakeholders**

At international level:

- **Code of conduct for responsible fisheries (FAO)**
- **Code of Conduct for European aquaculture (FEAP)**
- **Guidelines for the sustainable development of marine aquaculture (IUCN)**
- **Aquaculture site selection and site management (IUCN)**

At national level:

- **Guidelines for marine aquaculture planning: integration and monitoring (Croatia)**
- **Guidelines for the minimization of waste in marine aquaculture (Spain)**
- **Codice di buona pratica di allevamento in acquacoltura (Italy)**

2. As Spreij (2003) points out, the development of a regulatory framework not only includes the adoption of legislative aquaculture texts, but also the amendment and/or enactment of related laws, including land, water and environmental legislation. For some context, it may even be sufficient to introduce changes in the existing legislation without formulating a new aquaculture law. Additionally, criteria of flexibility should be taken into account, since legislation may quickly become outdated with the rapid evolution of the industry (Spreij, 2003: 11)[38].

[38] Several countries, as for instance Australia, are involved in a proposal for de-regulation of aquaculture, based on the premise that "de-regulation in the aquaculture industry is required and overdue, as the current regulatory arrangements are too complex, disproportionate to the risk being managed and create significant regulatory duplication".

3. The aquaculture industry must have a suitable legal framework which includes all the conditions for its practice as well as guarantees of the rights and obligations of aquaculture licenses holders. Some authors consider that clearly, legal rules that establish and enforce private property rights are critical for the development of the industry both onshore and offshore (Hoagland et al. 2003). Other policies, including those that encourage research and development, curb degradation of water quality, and promote public health, must also be seen as contributing to the development of the industry (Duff et al. 2003).

4. Instruments must be established to coordinate administrative procedures for the granting of the various authorisations that will ensure the legal security of both the applicant and the granting authority itself, while also simplifying the processes for the granting of aquaculture licenses.

5. The creation of simple window or one-stop shops should be promoted, to centralize license-granting procedures, thus reducing procedure timeframes and requirements. Reports and licenses sould be processed through a single coordinating or leading agency.

6. The lack of clear, concise regulations with division of tasks between administrative authorities may generate overlap of areas of competence and delays in procedures. Overlap and concurrence of competencies are two different problems which call for different solutions: overlapping requires a clear delimitation of competencies; while the co-existence of different agencies and public bodies requires coordination and an increase of efficiency in public management.

7. The main body responsible for managing and coordinating the procedure should set the deadlines for information and responses from the other agencies or authorities that must issue opinions on different aspects: navigation, culture, heritage, ports, environmental, tourism, etc. Coordination policies should be developed through the setting up of inter-agency task groups charged with seeking the harmonisation and coordination of all competencies related to aquaculture, and regulated and under the competence of various agencies or administrative authorities.

8. There is a need for alignment between policies, especially aquaculture and environmental policies, to avoid sudden changes in the latter which have negative and unforeseen effects on the former. Moreover, it is relevant to promote consistency of policy and legislation between different levels and sectors of government; consistency should be applicable also to international laws and agreements related to this activity.

9. Site selection is one of the most important management tools for aquaculture development (minimize negative effects of/in aquaculture activities) and a clear step for Integrated Coastal Zone Management.

10. The site selection process should include provision of additional physical space for logistical and infrastructure needs on land (when the farm facilities are at sea).

11. Improving governance in order to ensure stakeholders' proactive participation in the decision making process, but also ensuring stakeholders' accountability.

12. Allocating competences at the most suitable level: "The ideal framework would allow for vertically (national to local) and horizontally (across sectors) integrated policy-making and planning with a significant role for strategic, sector or regional (integrated) environmental assessment as an input to the planning process. Such a framework should allow for adaptation in both directions, i.e. national policy should inform local planning; local planning and public involvement should inform the development or adaptation of policy at higher levels" (GESAMP 2001).

13. Aquaculture frameworks relate not only to enacting legislation but also attend to the implementation at national, regional and local levels. In particular, efforts for capacity building should be made in those countries which plan to decentralize aquaculture competencies.

14. Aquaculture has always suffered the 'burden of proof', showing that its activities are not harmful for the environment. But the impact of other activities on aquaculture has been somehow neglected. Several states in the U.S. "have revised their water quality protection laws to specifically take into account the environmental effects that state-run or state-permitted projects may have on areas that support aquaculture operations. As a consequence, proponents of a wide range of development projects must demonstrate that such projects will not significantly impact water quality for aquaculture operation (Duff et al. 2003).

15. Some countries in the Mediterranean have developed examples of best practices for aquaculture planning (e.g. Croatia - guidelines for marine aquaculture planning: integration and monitoring; and Sicily - *Linee guida per la realizzazione di impianti di maricoltura in Sicilia*)

Further steps can be taken for the development of methodological approaches to evaluate the impact of planning in aquaculture, including indicators to measure the results of policies and plans in the medium and short term. Currently, we do not have tools to assess the impact of both policies and legal frameworks on the aquaculture development.

Summarising, governments should insist on:

- Strength policy development through improved coordination among agencies.
- Identification of a lead agency in each country or region to coordinate aquaculture procedures, concepts, plans etc…
    - Interagency coordination is a critical element of effective policy planning and implementation
- Streamlining of the permitting process and developing user-friendly guidelines on:
    - ❑ Which agencies need to be contacted
    - ❑ Who to contact within those agencies to help the permitting process.
    - ❑ Adoption of best management practices
- Include aquaculture as an strategic policy
- Address the lack of indicators to assess the impact of aquaculture planning on the activity (production, value, employment)

Guidelines for an aquaculture planning procedure

1. Identification of competencies for coastal planning and aquaculture, with designation of a leading agency by law.
2. Guarantee of participation of all the agencies with competencies on issues related to the coast. A tool to ensure such participation should be provided by law.
3. Having coordination tools in place, which should include specific reference to the methods and tools for coordination of multiple and divergent interests.
4. Having a fisheries or aquaculture agency as the leader for the development of the following steps of the process:
   a) Development of technical studies:
      - Biological (including carrying capacity).
      - Oceanographical
      - Environmental
      - Institutional
      - Social
      - Economical
      - Land use

   b) Selecting parameters and criteria linked with technical studies in order to determine suitable zones for aquaculture.

   c) Mapping the suitable zones and forbidden areas for aquaculture.

   d) Internal information at government level: mandatory reports by the agencies with competencies and, if applicable, modification of site selection.

   e) Meetings with stakeholders to discuss the plan (NGOs, aquaculture and fisheries associations, consumer organizations, entrepreneur associations, etc.).

   f) Public hearing: availability of the preliminary plan to be consulted by the general public.

   g) Steering committee: lead agency and involved agencies.
      - Analysis of inputs from the public hearing and stakeholders proposals.
      - Decision to modify or not the plan (and therefore the zones).

   h) Final publication of the plan

- Aquaculture promoters apply for aquaculture licenses in the designated zones or allocated zones for aquaculture (AZA). As a result:
  - There will be suitable zones for aquaculture
  - The licensing process will be simplified
  - Monitoring and EIA will be facilitated
  - There will be an increase in legal security for aquaculture promoters
  - Overall, a huge step for integrated coastal zone management will be made

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ANNEX 1

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MEETING OF THE GFCM-CAQ WORKING GROUP ON SITE SELECTION AND CARRYING CAPACITY

21-23 OCTOBER 2008, CRETE (GREECE)

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13-14 JULY 2009, VIGO (SPAIN)

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ANNEX 2

The IUCN guide for the sustainable development of Mediterranean aquaculture: aquaculture site selection and site management[39]

Introduction

The availability of suitable areas for aquaculture in the Mediterranean is becoming a major problem for the development and expansion of the activity. There is a need for sites with appropriate environmental characteristics and good water quality. In addition to these natural limiting factors, social aspects relating to interactions with other human activities or conflicts over the use and appropriation of resources in the much-exploited coastal zone are constrains to be considered at the time of setting up aquaculture facilities.

Site selection and site management are among the most important issues for the success of the activity and need to be carried out in accordance with sustainability and best practice guidelines. This is the aim of the Marine Programme of the International Union for Conservation of Nature (IUCN). To that end, together with the Federation of European Aquaculture Producers (FEAP) and the Secretariat for Fisheries of the Ministry of Agriculture, Fisheries and Food of Spain (MAPA)[40] signed an agreement in 2004 to cooperate and generate a series of "Guides for Sustainable development of Mediterranean Aquaculture". The first of these, devoted to the *Interactions between Aquaculture and the Environment*, particularly emphasised the fact that most of the potential environmental impacts of aquaculture can be managed and minimized through an understanding of the processes involved, responsible management and the appropriate siting of farms.

The aim of the present guide "*Aquaculture site selection and site management in the Mediterranean*", the second in a series, is to promote the sustainable development of Mediterranean aquaculture by providing basic guidelines for good practice in aquaculture site selection and site management. It has been produced by the IUCN/FEAP working group on aquaculture. More than 50 experts in different areas, including socio-economists, biologists, lawyers, aquaculture farmers, and government and environmental organization representatives from most Mediterranean countries took part in a number of workshops.[41]
The principles and guidelines are the result of extensive debates during these workshops and at coordination meetings, as well as subsequent work on line through e-mail exchanges.

Executive summary

The shared use of Public Domain areas and the conservation policies for the Mediterranean Sea reduce the availability of sites. At the same time, however, demand for aquaculture products is increasing, especially because industries such as that in the Mediterranean can supply a constant stream of quality products at stable prices. Further efforts are still required to ensure the sustainable development of aquaculture in the Mediterranean; to this end, site selection and site management are important processes that need to be implemented on a sustainable way.

Most problems stem from the lack of a full appreciation of the essential elements that need to be considered in the site selection and site management processes. Wrong decisions based on incomplete information might jeopardise the sustainable development of aquaculture in the Mediterranean.

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[39] IUCN 2009. Guide for the sustainable development of Mediterranean aquaculture.n.2 Aquaculture site selection and site management. Gland, Switzerland and Malaga, Spain: IUCN, VIII+303p[39]
[40] Currently, Spanish Ministry of the Environment and Rural and Marine Affairs (MARM).
[41] Istanbul, October 2007; Alicante, February 2008; Split, March 2008. All the workshops were organized in collaboration with the GFCM and the MAP activity centres (RAC/SPA and PAP/RAC).

This guide seeks to provide the reader with a full set of parameters and ideas to think about and apply to site selection and site management. Perhaps not all the aspects might have been treated but an effort has been made to those considered as relevant enough within a sustainable framework.

The publication includes 19 guides, structured into 4 sections: concepts, frameworks, methods and tools. Each guide consists of a short summary, definitions, a development of the main theme and a justification, followed by the principle and guidelines.

Concepts

Guide A: The Importance of Knowledge
Guide B: The Participatory Approach
Guide C: Social Acceptability
Guide D: The Precautionary Principle
Guide E: The Scale Approach
Guide F: The Adaptive Approach
Guide G: Economic Aspects

Frameworks

Guide H: The Importance of Governance
Guide I: The Legal Framework
Guide J: Administrative Procedures
Guide K: Sectoral Planning
Guide L: Private Sector Organizations

Methods

Guide M: Integrated Coastal Zone Management (ICZM)
Guide N: The Site Selection Process
Guide O: The Ecosystem Approach

Tools

Guide P: Carrying Capacity; Indicators and models
Guide Q: Environmental Impact Assessment (EIA)
Guide R: Environmental Monitoring Programme (EMP)
Guide S: Geographical Information Systems (GIS)

A. The Importance of Knowledge

This guide addresses the bare essentials that must be understood and taken into account in the selection and management of aquaculture sites, so as to further the sustainable development of aquaculture in the Mediterranean.

Principle
Aquaculture site selection and site management should be based on reliable legal, environmental, technical and socio-economic knowledge to enhance the viability of the process.

Guidelines

General

- **Information on the legal and environmental aspects of the coastal strip in public ownership should be collected by the authorities and made available to the general public.**

The collection and dissemination of such information should be the responsibility of the competent authorities, given the public domain nature of most of these areas.

- **The development of aquaculture by means of site selection should be based on scientific knowledge complemented by traditional knowledge.** Research must be conducted continually in order to improve knowledge on aquaculture, which has to be made available in a way that is understandable by all.

Environmental knowledge

- **The study area should be delimited in advance.** The study area should be narrowed down without losing vital data, in order to optimize data collection in the field both technically and economically**.**

- **Environmental and cultivation conditions should be well enough matched to assure the viability of the project.** Depending on the type of aquaculture to be introduced, the most suitable environmental conditions for its development need to be assessed.

Technical knowledge

- **Decision makers should be familiar with current production and technological systems to ensure that aquaculture sites are appropriately selected.** It is important to know what kinds of aquaculture are suited to the characteristics of a particular area and to use the most up-to-date techniques to achieve the success of the project.
- **Only proven technologies should be considered in the selection of sites for aquaculture and their subsequent management, especially in offshore locations or in highly sophisticated systems such as land-based recirculation systems.** Both types of aquaculture system are complex. It is therefore essential to be familiar with the most applicable technology in order to manage the high risk of aquaculture.
- **Research into the practical implementation of sanitary fallowing of fish farm sites in the Mediterranean should be encouraged.** The consolidation of this knowledge could have important future consequences for aquaculture planning and siting, especially in view of the increase in production and site concentration.
- **Aquaculture personnel should be provided with lifelong learning.** In order to make sure aquaculture ventures run smoothly, it is important to keep personnel abreast of any new technologies or improvements which could improve site selection and site management.

Knowledge of the legal system

- **Aquaculture farmers and the authorities with jurisdiction over the coast should have clear knowledge of the legislation governing aquaculture and the relevant planning rules.** To this end, countries that want to encourage aquaculture development need to have transparent legislation on aquaculture to provide sufficient legal certainty for aquaculture farmers.
- **Aquaculture and coastal planning legislation should be familiar and accessible to all stakeholders.** In the planning of suitable sites for aquaculture, there should be a clear and comprehensive understanding of the legislation governing all interests affecting the coastline, in order to avoid conflicts of interest.

Socioeconomic knowledge

- **The process of aquaculture site selection and site management should take reliable local knowledge into consideration.** The views of the people in the area of interest should be taken into account when assessing aquaculture planning within its socioeconomic, political, cultural and legal context.

- **Regarding interactions with other activities in the area, synergies and incompatibilities should be taken into consideration.** As aquaculture is at present one of the last sectors to arrive in a specific area, it is essential that synergies and incompatibilities with other sectors are emphasised in order to ensure that aquaculture integrates into the local economy and the sites are suitably selected and managed.

B. The Participatory Approach

This guide presents a straightforward concept that is basic in its definition but complex to implement. Its connection with site selection is explained and its importance for the success of the aquaculture project shown. Models and examples are given to guide the implementation of this approach to site selection and site management and the sustainability of aquaculture.

Principle

Site selection and site management processes should involve the participation of all stakeholders that share the same coastal region, in order to achieve the sustainable development of the activity.

Guidelines

- **The participatory approach should be considered from the very beginning of the project.** It is essential for stakeholders who will be involved in any participatory process to feel involved from the outset, ensuring appropriation and therefore successful site selection for aquaculture.
- **The participatory approach should be implemented through a process of co-construction.** This process, based on each stakeholder having an equal right to speak, with decisions being made by majority or consensus, will ensure sustainable objectives and establish common goals that will benefit all the users of a given maritime region.
- **The participatory approach should take into account all stakeholders at all levels and identify their roles and abilities.** They must be properly represented and their involvement demonstrated according to the degree to which the project may affect them.
- **The participatory approach should identify a mediator or Steering Committee**. This person or group – who should be neutral and recognised by all participants – has the task of organizing the process and directing development and implementation.
- **The participatory approach should be conducted in a common language.** This will ensure that information is shared equally and that all participants can understand it, regardless of their abilities.
- **The participatory process should progress according to the ‘eddy’ model and provide periodic feedback.** The continuous evolution to which all processes are subject requires the participatory process to undergo constant revision and restructuring, correcting errors in order to reintroduce the objectives established at the beginning.

C. Social Acceptability

This guide presents the concept of social acceptability and its direct relevance and importance to site selection and site management. The concept is defined and characterized and the public perception of it is discussed, together with criteria and tools to assess it and guidelines to achieve it. Social acceptability is considered a key issue to ensure the sustainable development of aquaculture in the Mediterranean.

Principle

Social acceptability should be considered an objective of the site selection and site management process in order to ensure the establishment and permanence of the aquaculture project in the long term.

Guidelines

- **Social acceptability is an objective that should be considered from the outset in any aquaculture project.** This general rule is particularly relevant in the Mediterranean region, given the annually increasing pressures of coastline occupancy and use.
- **Communication, information and transparency should be established to foster a dialogue amongst stakeholders and ensure social acceptability.** Information exchange amongst stakeholders is vital to ensure that the consequences of the acceptance or rejection of a project are properly analysed.
- **Cultural parameters are particular to each Mediterranean region and should be considered individually when building social acceptability.** The multicultural nature of the Mediterranean adds complexity to the process of achieving social acceptability. These parameters need to be identified, analysed and integrated in the selection and management of aquaculture sites.
- **Social acceptability and the consequent sustainability of an aquaculture project should be based on the creation of a ‘quality image’ for aquaculture.** Aquaculture is still unknown to society in general. It is therefore necessary to invest in communication and education to improve people’s understanding of site selection and all other aquaculture processes through a quality scheme.

D. The Precautionary Principle

This guide presents the concept of the precautionary principle and its application to the various aspects of site selection and site management. Definitions and methods for the implementation of the concept are given and special attention is paid to the limits between benefits and drawbacks in the application of the precautionary principle.

Principle

The precautionary principle should be applied in the aquaculture site selection and site management processes.

Guidelines

- **The precautionary principle should be applied in the decision-making processes for aquaculture site selection and site management, within the framework of the ecosystem approach and in conjunction with the participatory and adaptive approaches.** It allows for the taking of decisions even though not all the relevant scientific data may be available, and it helps stakeholders to take a straightforward approach.
- **The precautionary principle should be applied within certain limits in order to avoid possible rejection.** Precaution has no defined or measurable limits, and these must be established mainly on the basis of the possible effects of any action, without crossing certain thresholds or reaching the point of no action.
- **The precautionary principle should take account of all relevant forms of information, such as scientific and traditional knowledge, on an appropriate temporal and spatial scale.** The better the decision makers are informed, the more appropriately the site selection process can be planned in view of the risks to be incurred.

E. The Scale Approach

This guide presents the concept of scale as a factor to be considered in the process of aquaculture site selection and site management, where spatial and temporal dimensions influence decision making. A definition of the concept is given and the effect of mismatches among scaling factors on site selection and site management is described.

Principle

Site selection and site management in a context of sustainable development of aquaculture should take the scale approach into account when studying interactions between several systems.

Guidelines

- **The scale approach should be applied at each step of the aquaculture site selection and site management process.** Continuous attention to sizing and identification of mismatches can help to achieve the success of aquaculture projects in a given area.
- **Research should be encouraged to understand and resolve scale mismatches in the process of site selection and site management.** The ability to identify, measure, and compare the effects caused by the different scales at which the varied systems function can help the process to succeed.
- **The potential growth of the aquaculture project should be considered at the outset of the site management process**. A long-term view of the possible future development of the aquaculture farm will enable managers to overcome further foreseeable mismatches between the activity and the surrounding systems.
- **Tools such as geographical information systems should be used to assess the spatial and temporal scales in the aquaculture site selection and site management process.** Powerful tools can help to reveal what is happening in a system at different scales so that the situation can be managed knowingly.
- **Site selection and site management should be decentralized to the lowest appropriate level.** Government structure and the level of decentralization in Mediterranean countries play an important role in the process. Institutions frequently lack the necessary multi-scale vision and associated flexibility to solve problems that occur at scales that they usually do not consider.

F. The Adaptive Approach

This guide refers to the importance of learning, anticipation and flexibility in the process of site selection and site management in view of the dynamic nature of the ecosystem in which the activity is implemented.

Principle

In aquaculture site selection and site management, the adaptive approach should be implemented to allow the activity to develop in a sustainable manner in a changing environment.

Guidelines

- **The adaptive approach should be implemented in evolving processes like aquaculture site selection and site management, on a basis of learning, anticipation and flexibility.** Reactive adaptation to change can endanger the sustainability of aquaculture. A long-term strategy is advisable instead.
- **Anticipated and unanticipated change involving risk should be addressed at the legal, ecological, socioeconomic or technological level by means of greater flexibility, in order to reduce conflict and achieve the sustainable development of aquaculture.** Long-term solutions to mismatches will depend on knowledge and the further development of flexibility to reorganize the activity in response to changes in factors influencing the aquaculture sector.
- **Research should be encouraged to allow the aquaculture sector to anticipate change.** Anticipatory research can influence and improve past and future studies on the sustainable development of aquaculture as well as help the sector to adapt more easily to a particular change.
- **Close partnerships among citizens, managers and scientists as well as cooperation among members of the same aquaculture sector should be encouraged in order to facilitate adaptation to achieve the sustainable development of aquaculture.** Through partnership and cooperation, knowledge can be shared and extended, by comparing different strategies used to cope with a given situation. This can speed up learning and adaptation in aquaculture processes.
- **Effective and rapid learning, adaptation and flexibility should be taken into consideration to cope with change.** Documentation, anticipation, flexibility, comparisons between different approaches and identification of trigger points are essential for the sustainability of aquaculture. Learning and adaptation are processes that always evolve over time.
- **Records of successful as well as failed past studies should be accessible to all stakeholders.** Much can be gained from the creation of a database of retrospective studies on Mediterranean aquaculture since the ecoregion is the same.

G. Economic aspects

This guide introduces the basic concepts and tools of environmental economics needed for site selection and site management. Economics provides meaningful indicators and decision support tools. It allows analysts, planners and entrepreneurs to compare different activities and their outcomes using a common monetary benchmark. The guide will focus on the application of cost-benefit analysis (CBA) and valuation methods since they are widely recognised and accepted by a range of decision makers, both private and public.

Principle
Economic factors and in particular the economic dimensions of aquaculture-ecosystem interactions should be considered for effective site selection and site management.

Guidelines

- **Economic tools and indicators should be used in conjunction with others (e.g. environmental impact assessments) to enable decision making based on multiple criteria reflecting a range of societal objectives.** Decision makers often have insufficient information to reach decisions aimed at avoiding biodiversity loss. This can be overcome through the integrated use of economic and other decision support tools. Economic tools are important because they reflect a range of values using widely accepted and understood monetary measures.
- **In order to capture the total economic value (TEV) of a given type of aquaculture at a given site, the application of economic tools of analysis should consider a comprehensive range of non-market and market sources of value, and direct and indirect impacts.** Economic tools should be used to value the enterprise and related businesses (e.g. packing, transport and marketing), environmental impacts (e.g. changing water quality and biodiversity), changes in employment, and similar economic aspects. This can be accomplished by using the full range of methods of economic valuation.
- **In order to understand trade-offs among candidate users of the same ecosystem, the TEV of aquaculture should be compared to the TEV of other sectors.** This will enable decision makers to prioritize activities and assess aquaculture against other uses in relation to its interaction with the ecosystem. Sustainable site selection and management should result in a higher TEV for aquaculture.
- **In order to develop appropriate regulatory incentives at the farm level, externalities should be understood and quantified.** Fish farming is an economic undertaking. If policy is to encourage or discourage certain activities, farmers must be given appropriate incentives (e.g. fees, fines, subsidies) and these incentives should reflect the externalities caused.

H. The Importance of Governance

This guide deals with the concept of governance and how it should be developed and implemented in connection with aquaculture site selection and site management. From definition to new aspects, characteristics of governance are described which are directly applicable to the sustainable development of aquaculture.

Principle

Good governance practices concerning planning and decision making should be implemented for aquaculture site selection and site management.

Guidelines

- **Governance should be flexible, dynamic and adaptive.** This ability to react to change and evolve towards greater effectiveness will give decision makers confidence and support.
- **Governance should encourage all stakeholders to participate and interact.** The inclusion of all actors and the triggering of linkages within and among them will reinforce governability, increasing success in a shared environment where site selection has to be made.
- **Governance should be applied at all levels.** Because globalization is becoming a strong driver of change, new forms of governance should be developed at all scales, from local to global.
- **Aquaculture planning should be developed under the best applicable governance.** As governance influences the processes of site selection and site management, the rules and their implementation should underline guidelines of sustainability.
- **Governance should be considered and implemented on a long-term basis.** Unlike fisheries, where daily decisions may be subject to uncertainties, aquaculture planning has a steadier, more long-term course that should be taken into account in governance arrangements.

I. The Legal Framework

This guide offers a series of guidelines for the establishment of appropriate legal frameworks for the practice of aquaculture, particularly with regard to site selection. The aim is to highlight the benefits of adequate regulations for aquaculture. An overview of the current situation is given for the Mediterranean.

Principle

An adequate and favourable legal framework should be in place to ensure appropriate site selection and site management.

Guidelines

- **A suitable legal framework should be in place, guaranteeing the rights and stating the obligations of holders of aquaculture licences**. That will ensure legal security for both aquaculture operators and the activity itself.
- **Coordination and agreements on the legal framework for aquaculture site selection and site management should be built among the various administrative authorities**. A lack of clear, concise regulations that specify the division of tasks between administrative authorities may result in the overlap of areas of competence and delays in procedures.
- **The legal framework should be available and understandable to all stakeholders.** Comprehensive aquaculture legislation will provide guarantees of success, in terms of both environmental protection and the development of the aquaculture industry. Furthermore, such a legal framework will be a way of informing society about the aquaculture industry.

- **The legal framework for aquaculture should establish the basic programmes and conditions necessary for the selection of suitable areas for aquaculture.** The designation of appropriate areas for aquaculture in both maritime and coastal areas should be reflected in regulations. This will ensure the legal security of aquaculture activities, their future stability and their success and competitiveness.
- **Aquaculture legislation should be integrated with all forms of jurisdiction over the coastal zone.** Regulations should be established for the management of coastal areas, covering planning, conservation conditions, protection of coastal resources, and planning of areas to be used for marine aquaculture.
- **The legal system should include requirements that ensure compatibility with other uses.** To achieve this there must be coordination between the competent administrative authorities and agencies, the industry and the general public, as well as legislative action.
- **Aquaculture legislation should address the social and economic aspects of the area in which aquaculture activities take place.** The lack of regulation may cause the rejection of aquaculture by society or administrative authorities that prioritize other interests.

J. Administrative Procedures

This guide gives an overview of the existing administrative procedures in different countries. The main problematic topics of bureaucracy, timing, requirements, rights and duties are explained and possible solutions proposed.

Principle

Adequate administrative procedures should be established in order to facilitate the appropriate selection and management of sites for aquaculture.

Guidelines

- **Regulations should be drafted that set out the procedures for granting aquaculture licences**. It is important to have regulations that clearly inform aquaculture operators of the requirements for obtaining a licence, the timeframe of the application process as well as the rights and obligations attached to the licence.
- **Instruments should be prepared to coordinate the administrative authorities and agencies involved and the procedures for granting the various authorizations.** This will ensure the legal security of both the applicant and the granting authority itself, while also simplifying the aquaculture licensing process.
- **Administrative authorities with responsibilities in aquaculture should develop guidelines for the submission of applications, containing legal and institutional information**. These guidelines would be useful for establishing aquaculture policies, not only for the competent administrative authorities, but also for aquaculture operators and society in general. A simple form should be produced, accompanied by a checklist to help the applicant ensure that all documents are submitted.
- **The establishment of technical offices that centralize aquaculture procedures in a region or country is recommended**. The creation of one-stop shops should be promoted to centralize licence-granting procedures, thus reducing procedure timeframes and requirements.

- **Common administrative licensing procedures should be enforced at a Mediterranean level.** Efforts should be made to set up a basis for minimum common requirements, to facilitate capital movement within the Mediterranean.
- **The criteria used to calculate the aquaculture fee should be reasonable, transparent and uniform for each type of aquaculture, in order to ensure legal certainty.** The fee for occupation of an area in the public domain must be proportional to the use thereof, and take into account the specific character of the aquaculture activity in question. Alternatives to purely economic fees should be proposed.
- **The capabilities and human resources of the administrative authorities responsible for aquaculture should be increased,** backed up by a political commitment to coordinate the institutions and agencies involved in the regulation and management of aquaculture.

K. Sectoral Planning

This guide presents sectoral planning as a means for achieving the sustainable development of the aquaculture sector and describes the direct links between planning and site selection and site management. A definition of sectoral planning and the components of the sector is given, followed by the role of the authorities and key aspects needed for the development of a sectoral plan. Finally, examples of sectoral planning procedures are described.

Principle

The selection and management of areas for aquaculture should take into account a sectoral approach and sectoral planning.

Guidelines

- **The potential for growth of the aquaculture sector in a particular geographical area should be taken into account as the starting point for the selection of sites.** The prospect of growth is an essential factor to ensure that the activity appears and/or remains in a specific geographical area.
- **The growth of the sector should be balanced with respect to other sectors sharing the same public domain areas**. It is important to find a balance between the development of aquaculture and other activities that interact with it in public domain areas, which is why growth of the former must be planned and orderly.
- **Sectoral planning should balance the sector's needs and the authorities' objectives.** As principal actors in the process, both parties should interact and develop a co-construction process supported by other actors such as associations, research bodies and other organizations.
- **Effective sectoral planning should be based on prospective studies.** Empirical knowledge is needed to lay the foundations for sectoral plans. This in turn requires sufficient economic, material and human resources to obtain the information needed and make it available to the actors involved in the sector's development.
- **Sectoral planning should be carried out with the help of instruments and tools that make appropriate spatial and temporal analysis possible**. Geographical information systems are tools that facilitate the reading, representation and analysis of information.

L. Private Sector Organizations

This guide defines professional organizations and associations as organizational structures developed by the private sector. Their role and commitments are explained as well as their importance in the site selection and site management process. With reference to Mediterranean organizations, the scale factor is considered together with observed trends due to globalization. Finally some examples are given as well as guidelines on how private sector organizations can contribute to the sustainable development of aquaculture.

Principle

Professional associations and sectoral organizations should be promoted in order to defend the feasibility of private initiatives in the selection and management of aquacultures sites.

Guidelines

- **Aquaculture companies and professionals should organize themselves in order to defend common interests.** By associating they gain greater social presence and a greater ability to reach top administrative and political levels, which otherwise would remain inaccessible for most companies.
- **Professional associations should establish and implement codes of conduct and better management practices for all their members.** Implementing these initiatives, even if they are voluntary, contributes to improving both productive practices and social acceptability.
- **Public authorities should support professional associations.** Since the weak spot of structures such as professional associations is usually their limited financial capacity, administrative authorities should have public grants at their disposal.
- **Professional associations should be created at a local level, with the intention of joining organizations at a higher level.** The birth of a professional association at the local level provides an immediate basis for the identification of common topics and problems. However, there also exist common problems and challenges at higher territorial levels, such as the Mediterranean region, that can only be dealt with effectively through higher ranking organizations such as federations.
- **All producers should have the opportunity to join and participate in an association.** Membership of a professional association must be open to all producers, regardless of their production volume, type of farming or location, and all members must have the right to participate and vote.

M. Integrated Coastal Zone Management (ICZM)

This guide highlights the need to take all the stakeholders involved in a particular coastal area into consideration in order to ensure that the diverse frameworks and processes occurring in the zone are properly implemented. In this sense, integrated coastal zone management can facilitate aquaculture site selection and site management and its further sustainable development.

Principle

In the process of site selection and site management for aquaculture, Integrated Coastal Zone Management (ICZM) represents a new form of governance that should be implemented.

Guidelines

- **A preliminary study exploring each sector's needs in a given area should be implemented.** Aquaculture must be seen as one of several activities that use the same marine ecosystem, the development of which requires a search for new sites.
- **A thorough understanding of existing and potential interactions that affect the different activities and resources in the area and how they are likely to develop over time is needed in order to integrate aquaculture with the others.** Management efforts can no longer be carried out individually by different sectors using the same marine ecosystem. It is necessary to encourage benefits from complementary interactions and to find ways of limiting antagonistic ones.
- **The costs and benefits of all activities, including aquaculture, should be identified in order to take into account their beneficial as well as harmful effects on other activities.** It is important from an economic point of view to be aware of the direct and/or indirect impacts that may result from such coexistence. Integrated Coastal Zone Management is an adaptive, never-ending process.
- **Relevant ICZM elements in the legal framework should be identified and improved.** Traditionally, pieces of legislation may be produced for individual sectors. To integrate the various sectors using the same marine ecosystem as aquaculture, it is necessary to give the existing legal framework a broader outlook to allow them to coexist on a legal basis.
- **National experiences with such an experimental process as ICZM applied to aquaculture site selection and site management should be shared globally.** This information may be helpful on the one hand to countries whose ICZM capabilities are just emerging and on the other to countries which already apply ICZM yet require further information about the process.
- **ICZM activities should be well financed in order to uphold and allow further sustainable development of sectors such as aquaculture.** Effective coastal zone management requires regular financing in order to support its ongoing ICZM process, the objective of which is to take all the stakeholders into account, including the aquaculture sector.

N. The Site Selection Process

This guide provides a method for site selection, taking into account all the aspects needed to achieve the sustainable development of Mediterranean aquaculture. Key aspects, concepts and terminology are explained and special attention is given to the sequence of the process itself. The guide includes a basic list of parameters to be studied and mapped as well as a practical example from southern Spain.

Principle

A clear and sequential site selection process should be put in place in order to ensure sustainable aquaculture.

Guidelines

- **Site selection should depend on the aquaculture activity planned and the existing environmental conditions.** In designing a process, all limiting factors or priorities that could interfere with the proposed objective of selecting sites for the sustainable development of aquaculture must be taken into account.

- **The scale factor should be applied in order to size the project, taking into account the degree of detail required and the budget available for the process.** The material and financial resources required to carry out a site selection process should be considered in terms of balancing investment against expected results.
- **The methodology to be used in a site selection process should begin with a sectoral analysis and the identification of needs.** The sectoral analysis must provide information on the type and size of aquaculture planned. This information will be essential in order to identify the best parameters for the study, the agents involved and the project's scope.
- **The study methodology should preferably be selective and dynamic.** Administrative factors should be addressed first due to possible incompatibilities with other uses and to select and focus on the environmental factors to study. The process should be dynamic, so that information obtained is progressively interpreted and added to allow for feedback and updating.
- **The choice of parameters should directly relate to the statutory context in force for the aquatic activity in the study area.** The parameters selected for the study constitute the main basis for determining the suitability of the area and should include those that interfere directly or indirectly with the planned activity.
- **The site selection method should include the chronological sequence of actions required to carry out the study within the expected timeframe.** A schedule should be established for the collection of information, map development, consultation and validation by agents, final results and mapping.
- **The results of site selection processes should be mapped at a scale and in a format that can be easily read and interpreted.** The information obtained and its interpretation must be represented graphically and be intelligible to the general public.

O. The Ecosystem Approach

This guide promotes the application of the ecosystem approach for managing the impacts of human activities on the ecosystem, with the aim of optimizing its use without damaging it. It would therefore be more accurate to call it an ecosystem-based approach to integrated management (EBM). It is a step-by-step management tool based on the best available scientific, traditional and local knowledge on the ecosystem and complies with the 12 principles recommended by the Conference of the Parties to the Convention on Biological Diversity.

Principle

Site selection and site management should be addressed from an ecosystem-based approach to integrated management.

Guidelines

- **In an ecosystem-based approach to integrated management (EBM), site selection and site management should be based on cause-and-effect relationships between stressors, namely the activity, and impacts, so as to provide information on the state of the ecosystem.** Assessment tools, such as Pathways of Effects or Cumulative Effects, can help managers to propose mitigation measures or modifications to activities that have a negative impact on the ecosystem conservation objectives.
- **EBM is a management tool which should be implemented at all scales, from local to international, without undergoing changes.** The ecosystem approach is a space-based strategy

taking into consideration environmental and socioeconomic aspects, with the aim of promoting the conservation and sustainable use of the ecosystem in an equitable way.

- **Aquaculture site selection and site management should be addressed with EBM, once the top-down process has been carried out.** This will secure the ecosystem attributes and objectives relating to biodiversity, productivity, health and resilience and therefore the sustainable development of any activity depending on them.

P. Carrying Capacity, indicators and models

This guide provides definitions and tools for measuring carrying capacity. Different dimensions and meanings of carrying capacity are given, as well as criteria and variables to be used. Examples and models are proposed and guidelines are provided relating to site selection and site management for the sustainability of aquaculture.

Principle

Operational measurements of carrying capacity should be taken into account for aquaculture site selection and site management in order to allow for the sustainable use of marine resources.

Guidelines

- **The carrying capacity of all measurable parameters should be considered in site selection and site management.** In order to achieve the sustainable development of aquaculture it is important to consider the environmental, social, physical, production and economic aspects of the activity.
- **Areas with evidence of limited carrying capacity should be avoided.** Aquaculture requires good water quality for its implementation; polluted sites or areas with frequent harmful algal blooms or oxygen deficits should therefore be avoided**.**
- **Aquaculture facilities should adjust their production to the carrying capacity of the local environment.** Each ecosystem has a different capacity to absorb and assimilate excess loading of organic compounds and nutrients. Therefore low production should be in shallow, inshore, sheltered areas and increased production in deep, offshore, exposed sites.
- **Even in the case of the most favourable environmental conditions, an upper limit of production per farm should be established.** Any revision of limits should be supported by intensive and regular monitoring, providing sufficient evidence that this maximum production level does not cause irreversible adverse impacts.
- **An assessment should be made of the maximal allowable proportion of space that may be used for aquaculture in each water body, taking into account other uses and local wildlife.** Ecological and socioeconomic indicators as well as models and standards must be used to obtain the best possible integrated assessment of space allocation.
- **Consultation and dialogue should be encouraged among regulators, producers, scientists and relevant stakeholders in order to arrive at generally acceptable terms.** The establishment of common environmental quality standards and regulations among the Mediterranean countries and regions will lead not only to fair competition but also to a higher degree of environmental protection and an enhanced environmental profile of the aquaculture industry.

Q. Environmental Impact Assessment (EIA)

This guide outlines the environmental impact assessment as an essential tool to be implemented before a site is approved for aquaculture. It ensures that proper decision-making processes are in place, supported by accurate data on the impacts of the activity, and it takes into account the socio-environmental acceptability of the project. It should be consistent with both sustainability criteria and best practice.

Principle

For appropriate aquaculture site selection and installation, the environmental impact assessment (EIA) procedures should be mandatory and implemented.

Guidelines

- **An environmental impact assessment should be mandatory for all projects, including aquaculture site selection, and incorporated in legislation.** The sea is an area in the public domain and specific laws have to be implemented in order to ensure the appropriate and sustainable use of the ecosystem, thereby promoting the sustainable development of aquaculture. The responsibility for bearing the costs of the EIA should be discussed.
- **To facilitate the process of aquaculture site selection, the current environmental impact assessment protocols, standards and models should be simplified and harmonized throughout the Mediterranean and a regular review of the statements should be carried out.** Proper indicators for environmental quality standards (EQS) and impacts must be developed in the Mediterranean for the various types of production (shellfish and finfish).
- **The environmental impact assessment should be based on the best and most appropriate scientific knowledge, covering technical, socioeconomic and environmental aspects, as well as on the precautionary principle.** Scientific facts, assumptions and expert judgements, and the consequences of the range of error for the assessment have to be discussed. In this context, the precautionary principle or approach is an important element for an EIA.
- **The decision-making authorities must keep abreast of innovations affecting environmental impact assessments by means of regular training, while the private sector must also be given easy access to such information.** Stakeholders are not always aware of recent developments or reasons for changes. Therefore, regular updating is required to facilitate proper aquaculture site selection.
- **Research on current issues, such as cumulative effects or mitigation measures, as well as future topics should be promoted and developed in order to achieve the sustainable development of aquaculture.** Innovative techniques, such as those involving distance between cages or limits on diseases, as in examples of prevention from Norway, or any activities that take advantage of the nutrient enrichment of the environment caused by aquaculture have to be more extensively studied and exploited.
- **Stronger socioeconomic compensation measures should be introduced in the environmental impact assessment.** This would allow for aquaculture projects to be more effectively integrated into the local environment and for synergies to be observed and developed.

R. Environmental Monitoring Programme (EMP)

This guide deals with the environmental monitoring programme (EMP), which has to be consistent with sustainability criteria. This tool, used after the environmental impact assessment (EIA), uses sampling to highlight the extent to which aquaculture management affects the ecosystem over time, by comparing current data collected at various points in time with data obtained before development as well as with other existing data.

Principle

Environmental monitoring programmes need to be implemented and should be compulsory for sustainable aquaculture site management.

Guidelines

- **A baseline study should be implemented prior to the environmental monitoring programme.** Thorough, in-depth knowledge of the surrounding environment and aquaculture practices is needed to define the best possible specific environmental monitoring programme.
- **Reliable monitoring should be used to detect environmental responses to changes in the scale of production and to readjust the thresholds of environmental quality standards.** Due to the continuous development of the industry, monitoring must be adaptive to assess the dynamic linkages between aquaculture and the ecosystem within which it operates.
- **Standardization and harmonization of EMP should be imposed by law in all Mediterranean countries**. Supported by research programmes, the same EMP procedures should be followed, so as to make aquaculture sustainable throughout the Mediterranean.
- **The EMP, together with environmental quality standards, should be regularly revised and harmonized by reliable multidisciplinary bodies and the results disseminated in an easily understandable way.** A well conceived EMP is a highly effective method that links environmental changes with activity inputs. However, there are no set ways of monitoring or interpreting the data obtained. These are dependent on the aims of the study, the size (in the case of development), the site characteristics and existing scientific knowledge.
- **The sampling frequency used in the EMP should be determined in the environmental impact assessment.** Sampling of the sediment and water column should be done at least during the period of greatest impact, in summer. The EMP could be adaptive, so that negative effects would increase the level of monitoring, whereas positive effects would reduce it.
- **A regular socioeconomic analysis in the EMP should be developed and revised at least every 5 years.** This is in order to monitor the socioeconomic impact and review what was expected in the Environmental Impact Assessment.

S. Geographic Information Systems (GIS)

This guide defines what geographical information systems are and their application to site selection and site management. A brief description of the tool is given, and the features that GIS should have in order to make it useful and effective. An example of a GIS produced in Andalusia (southern Spain) is presented.

Principle

Geographical information systems (GIS) should be used as a tool for site selection and site management.

Guidelines

- **Geographical information systems (GIS) should be used as a tool in participatory and construction processes:** This will help people's understanding and focus the discussion on the real problems, balancing power among all stakeholders.
- **The information contained in a GIS should be objective and based on reliable sources.** Since these are tools for decision makers, the information must be based on good authority and only be open to question by means of empirical demonstration.
- **The information stored in a GIS should be maintained and kept up to date.** A GIS should be considered a live system in which the information it contains varies over time; it should therefore prevent decision-making errors resulting from the use of obsolete data.
- **Information on the characteristics of the data contained in the GIS (metadata) should be made available.** The metadata must conform as far as possible to internationally recognised standards, providing reliability.

Introduction to the Guides

Due to the complexity of the subject and the amount of information treated, the Guide has been structured in four sections:

- CONCEPTS

  Guides A to G address fundamental concepts to apply, including the importance of knowledge, the participatory approach, social acceptability, the precautionary principle, the scale approach, the adaptive approach and economic aspects. They were chosen to provide a broad overview of the situation.

- FRAMEWORKS

  Guides H to L mention frameworks that must be taken into account, like the importance of governance, legal issues, administrative procedures, sectoral planning and private sector organizations. They help to establish the aims and guide the process of site selection and site management.

- METHODS

  Guides M to O cover methods to consider, such as integrated coastal zone management (ICZM), the site selection process, and the ecosystem approach that IUCN has made operational through many initiatives.

- TOOLS

  Guides P to S describe tools to use throughout the process, including carrying capacity, indicators and models, the environmental impact assessment (EIA), the environmental monitoring programme (EMP) and geographical information systems (GIS).

Each guide consists of a short summary, definitions, a development of the main theme and a justification, followed by the principle and guidelines. Moreover, a series of Mediterranean examples gives an insight into the current situation in the region.

ANNEX 3

List of key works on aquaculture-environment interactions from the Mediterranean

AN	Reference	cultured species	Descriptors
1	Forchino A., Borja A., Brambilla F., Rodriguez J.G., Muxika I., Terova G., Saroglia M. Evaluating the influence of off-shore cage aquaculture on the benthic ecosystem in Alghero Bay (Sardinia, Italy) using AMBI and M-AMBI. Ecological Indicators. Article in Press.	fish	benthic ecosystem
2	Garcia-Sanz T., Ruiz J.M., Perez M., Ruiz M., (2011). Assessment of dissolved nutrients dispersal derived from offshore fish-farm using nitrogen stable isotope ratios (δ¹⁵N) in macroalgal bioassays. Estuarine, Coastal and Shelf Science, 91: 361-370.	fish	nutrients isotopes
3	Sanz-Lazaro C., Belando M.D., Marin-Guirao L., Navarrete-Mier F., Marin A., (2011). Relationship between sedimentation rates and benthic impact on Maerl beds derived from fish farming in the Mediterranean. Marine Environmental Research, 71: 22-30.	fish	sedimentation rates Maerl beds
4	Sanz-Lazaro C., Belando M.D., Navarrete-Mier F., Marin A., (2011). Effects of wild fish and motile epibenthic invertebrates on the benthos below an open water fish farm. Estuarine, Coastal and Shelf Science, 91: 216-223.	fish	benthic communities
5	Sanz-Lazaro C., Navarrete-Mier F., Marin A., (2011). Biofilm responses to marine fish farm wastes. Environmental Pollution, 159: 825-832.	fish	dissolved wastes
6	Segvic Bubic T., Grubisic L., Ticina V., Katavic I., (2011). Temporal and spatial variability of pelagic wild fish assemblages around Atlantic bluefin tuna *Thunnus thynnus* farms in the eastern Adriatic Sea. Journal of Fish Biology, 78: 78-97.	tuna	wild fish
7	Tsagaraki T.M., Petihakis G., Tsiaras K., Triantafyllou G., Tsapakis M., Korres G., Kakagiannis G., Frangoulis C., Karakassis, I. Beyond the cage: Ecosystem modelling for impact evaluation in aquaculture. Ecological Modelling, Article in Press.	fish	
8	Yucel-Gier G., Pazi I., Kucuksezgin F., Kocak F., (2011). The composite trophic status index (TRIX) as a potential tool for the regulation of Turkish marine aquaculture as applied to the eastern Aegean coast (Izmir Bay). Journal of Applied Ichthyology, 27: 39-45.	fish	TRIX index
9	Aksu M., KaymakcI-Basaran A., Egemen, O., (2010). Long-term monitoring of the impact of a capture-based bluefin tuna aquaculture on water column nutrient levels in the Eastern Aegean Sea, Turkey. Environmental Monitoring and Assessment, 171: 681-688.	tuna	water column nutrient levels
10	Akyol O., Ertosluk O., (2010). Fishing near sea-cage farms along the coast of the Turkish Aegean Sea. Journal of Applied Ichthyology, 26: 11-15.	fish	
11	Apostolaki E.T., Holmer M., Marba N., Karakassis I., (2010). Degrading seagrass (Posidonia oceanica) ecosystems: A source of dissolved matter in the Mediterranean. Hydrobiologia, 649: 13-23.	fish	nutrients flux oxygen flux *Posidonia oceanica*
12	Apostolaki E.T., Holmer M., Marba N., Karakassis I., (2010). Metabolic imbalance in coastal vegetated (*Posidonia oceanica*) and unvegetated benthic ecosystems. Ecosystems, 13: 459-471.	fish	nutrients *Posidonia oceanica*
13	Arechavala Lopez P., Uglem I., Sanchez Jerez P., Fernandez Jover D., Bayle Sempere J.T., Nilsen R., (2010). Movements of grey mullet *Liza aurata* and *Chelon labrosus* associated with coastal fish farms in the western Mediterranean Sea. Aquacult. Environ. Interact. 1: 127–136.	fish	aggregation wild fish behaviour
14	Basaran A.K., Aksu M., Egemen O., (2010). Impacts of the fish farms on the water column nutrient concentrations and accumulation of heavy metals in the sediments in the eastern Aegean Sea (Turkey). Environmental Monitoring and Assessment, 162: 439-451.	fish	nutrient concentrations sediments
15	Brigolin D., Marchi G., Porrello S., Tomassetti P., Pastres R., (2010). Modelling the biomass yield and the impact of seabream *Sparus aurata* mariculture in the Adriatic and Tyrrhenian sea (Italy). Aquaculture	fish	environmental impact assessment

	International, 10: 149-163.		
16	Carvalho S., Barata M., Pereira F., Pousao-Ferreira P., Cancela Da Fonseca L., Gaspar M.B., (2010). Can macrobenthic communities be used in the assessment of environmental quality of fish earthen ponds? Journal of the Marine Biological Association of the United Kingdom, 90: 135-144.	fish	macrobenthos
17	Dupon-Nivet M., Karahan-Nomm B., Vergnet A., Merdy O., Haffray P., Chavanne H., Chatain B., Vandeputte M., (2010). Genotype by environment interactions for growth in European seabass (*Dicentrarchus labrax*) are large when growth rate rather than weight is considered. Aquaculture 306: 365-368.	fish	genotypes environmental conditions growth rate
18	Fernandez Jover D., Faliex E., Sanchez Jerez P., Sasal P., Bayle Sempere J.T., (2010). Coastal fish farming does not affect the total parasite communities of wild fish in SW Mediterranean. Aquaculture 300: 10–16.	fish	macroparasites
19	Garcia-Sanz T., Ruiz-Fernandez J.M., Ruiz M., Garcia R., Gonzalez M.N., Perez M., (2010). An evaluation of a macroalgal bioassay tool for assessing the spatial extent of nutrient release from offshore fish farms. Marine Environmental Research, 70: 189-200.	fish	nutrient release
20	Lassauque J., Lepoint G., Thibaut T., Francour P., Meinesz A., (2010). Tracing sewage and natural freshwater input in a Northwest Mediterranean bay: Evidence obtained from isotopic ratios in marine organisms. Marine Pollution Bulletin, 60: 843-851.	fish	nutrient input
21	Mavraganis T., Telfor T., Nathanailides C., (2010). A combination of selected indexes for assessing the environmental impact of marine fish farms using long term metadata analysis. Int. Aquat. Res. 2: 167-171.	fish	Long term metadata analysis
22	Mirto S., Bianchelli S., Gambi C., Krzelj M., Pusceddu A., Scopa M., Holmer M., Danovaro R., (2010). Fish-farm impact on metazoan meiofauna in the Mediterranean Sea: Analysis of regional vs. habitat effects. Marine Environmental Research, 69: 38-47.	fish	meiofauna
23	Navarrete-Mier F., Sanz-Lazaro C., Marin A., (2010). Does bivalve mollusc polyculture reduce marine fin fish farming environmental impact? Aquaculture 306: 101-107.	shellfish fish	nitrogen isotopes metal accumulation
24	Neofitou N., Vafidis D., Klaoudatos S., (2010). Spatial and temporal effects of fish farming on benthic community structure in a semi-enclosed gulf of the Eastern Mediterranean. Aquacult. Environ. Interact. 1: 95–105.	fish	macrobenthos
25	Papageorgiou N., Kalantzi I., Karakassis I., (2010). Effects of fish farming on the biological and geochemical properties of muddy and sandy sediments in the Mediterranean Sea. Mar. Environ. Res. 69: 326-336.	fish	sediments
26	Ruiz J.M., Marco-Mendez C., Sanchez-Lizaso J.L., (2010). Remote influence of off-shore fish farm waste on Mediterranean seagrass (*Posidonia oceanica*) meadows. Marine Environmental Research, 69: 118-126.	fish	*Posidonia oceanica*
27	Sangulin J., Babin A., Skrgatic Z., (2010). Physical, chemical and biological properties of water column and sediment at the fish farms in the middle adriatic, Zadar County. Fresenius Environmental Bulletin, 19: 1869-1877.	fish	water column
28	Sliskovic M., Jelic-Mrcelic G., Antolic B., Anicic I., (2010). The fouling of fish farm cage nets as bioindicator of aquaculture pollution in the Adriatic Sea (Croatia). Environmental Monitoring and Assessment, pp. 1-14. Article in Press.	fish	
29	Srut M., Stambuk A., Pavlica M., Klobucar G.I.V., (2010). Cage exposure of European sea bass (*Dicentrarchus Labrax*) for in situ assessment of pollution-related genotoxicity. Arhiv za Higijenu Rada i Toksikologiju, 61: 29-36.	fish	DNA
30	Stabili L., Schirosi R., Licciano M., Mola E., Giangrande, A., (2010). Bioremediation of bacteria in aquaculture waste using the polychaete *Sabella spallanzanii*. New Biotechnology, 27: 774-781.	shellfish fish	bacterial pathogens
31	Terlizzi A., de Falco G., Felline S., Fiorentino D., Gambi M.C., Cancemi G., (2010). Effects of marine cage aquaculture on macrofauna assemblages associated with *Posidonia oceanica* meadows. Italian Journal of Zoology, 77: 362-371.	fish	*Posidonia oceanica* benthic macrofauna
32	Tsapakis M., Dakanali E., Stephanou E.G., Karakassis I., (2010). PAHs and n-alkanes in Mediterranean coastal marine sediments: aquaculture as a significant point source. J. Environ. Monit. 12: 958-963.	fish	monitoring sediment pollution
33	Apostolaki E.T., Marba N., Holmer M., Karakassis I., (2009) Fish farming enhances biomass and nutrient loss in *Posidonia oceanica* (L.) Delile (2009).	fish	*Posidonia oceanica*

	Estuar. Coast. Shelf Sci. 81: 390-400.		nitrogen phosphorus
34	Apostolaki E.T., Marba N., Holmer M., Karakassis I., (2009) Fish farming impact on decomposition of *Posidonia oceanica* litter. J. Exp. Mar. Biol. Ecol. 369: 58-64.	fish	*Posidonia oceanica* nitrogen phosphorus
35	Aubin J., Papatryphon E., van der Werf H.M.G., Chatzifotis S., (2009). Assessment of the environmental impact of carnivorous finfish production systems using life cycle assessment. Journal of Cleaner Production, 17: 354-361.	fish	environmental impact
36	Aubin J., Van der Werf H.M.G., (2009). Fish farming and the environment: A life cycle assessment approach [Pisciculture et environnement: Apports de l'analyse du cycle de vie]. Cahiers Agricultures, 18: 220-226.	fish	environmental impact
37	Bartoli M., Vezzulli L., Nizzoli D., Azioni R., Porrello S. Moreno M., Fabiano M., Viaroli P. (2009). Short-term effect of oxic to anoxic transition on benthic microbial activity and solute fluxes in organic-rich phytotreatment ponds. Hydrobiologia: 629: 123-136.l	fish	benthic microbial activity
38	Borja A., Rodriguez J.G., Black K., Bodoy A., Emblow C., Fernandes T.F., Forte J., Karakassis I., Muxika I., Nickell T.D., Papageorgiou N., Pranovi F., Sevastou K., Tomassetti P., Angel D., (2009). Assessing the suitability of a range of benthic indices in the evaluation of environmental impact of fin and shellfish aquaculture located in sites across Europe. Aquaculture 293: 231-240.	shellfish fish	benthic macrofauna
39	Bueno M.J.M., Hernando M.D., Aquera A., Fernandez-Alba A.R., (2009). Application of passive sampling devices for screening of micro-pollutants in marine aquaculture using LC-MS/MS. Talanta 77: 1518-1527.	fish	pollution effects
40	Carvalho S., Falcao M., Curdia J., Moura A., Serpa D., Gaspar M.B., Dinis M.T., Pousao-Ferreira P., Cancela Da Fonseca L., (2009). Benthic dynamics within a land-based semi-intensive aquaculture fish farm: The importance of settlement ponds. Aquaculture International, 17: 571-587.	fish	macrobenthic communities
41	Fabi G., Manoukian S., Spagnolo A., (2009). Impact of an open sea suspended mussels culture on macrobenthic community (Western Adriatic Sea). Aquaculture 289: 54-63.	shellfish	macrobenthic communities
42	Fernandez-Jover D., Sanchez-Jerez P., Bayle-Sempere J.T., Arechavala-Lopez P., Martinez-Rubio L., Jimenez J.A.L., Lopez F.J.M., (2009). Coastal fish farms are settlement sites for juvenile fish. Marine Environmental Research, 68: 89-96.	fish	juvenile fish aquaculture impact
43	Ferreira J.G., Sequeira A., Hawkins A.J.S., Newton A., Nickell T.D., Pastres R., Forte J., Bodoy A., Bricker S.B., (2009). Analysis of coastal and offshore aquaculture: Application of the FARM model to multiple systems and shellfish species. Aquaculture 292: 129-138.	shellfish	molluscs water quality standards
44	Forrest B.M., Keeley N.B., Hopkins G.A., Webb S.C., Clement D.M., (2009). Bivalve aquaculture in estuaries: Review and synthesis of oyster cultivation effects. Aquaculture, 298: 1-15.	shellfish oyster	aquaculture impact Suspended culture
45	Grego M., De Troch M., Forte J., Malej A., (2009). Main meiofauna taxa as an indicator for assessing the spatial and seasonal impact of fish farming. Marine Pollution Bullettin, 58: 1178-1186	fish	meiofauna
46	Jusup M., Klanjscek J., Petricioli D., Legovic T. (2009). Predicting aquaculture-derived benthic organic enrichment: Model validation. Ecological Modelling, 220: 2407-2414.	fish	environmental impact
47	Lenzi M., Gennaro P., Mastroianni A., Mercatali I., Persia E., Roffilli R., Solari D., Tomassetti P. and Porrello S., (2009). Improvement of a system for treating land-based fish-farm effluents. Chemistry and Ecology, 25: 247-256.	fish	chemistry
48	Magni P., Tagliapietra D., Lardicci C., Balthis L., Castelli A., Como S., Frangipane G., Giordani G., Hyland J., Maltagliati F., Pessa G., Rismondo A., Tataranni M., Tomassetti P., Viaroli P., (2009). Animal-sediment relationship: evaluating the "Pearson-Rosenberg paradigm" in Mediterranenan coastal lagoon. Marine Pollution Bulletin, 58: 478-486.	fish	benthic communities
49	Matijevic S., Kuspilic G., Morovic M., Grbec B., Bogner D., Skejic S., Veza J., (2009). Physical and chemical properties of the water column and sediments at sea bass/sea bream farm in the middle Adriatic (Maslinova bay).	fish	water column sediments

	Acta Adriatica, 50: 59-76.		impact
50	Papageorgiou N., Sigala K., Karakassis I., (2009). Changes of macrofaunal functional composition at sedimentary habitats in the vicinity of fish farms. Estuar. Coast. Shelf Sci. 83: 561-568.	fish	sediment chemistry
51	Pitta P., Tsapakis M., Apostolaki E.T., Tsagaraki T., Holmer M., Karakassis I., (2009). 'Ghost nutrients' from fish farms are transferred up the food web by phytoplankton grazers. Marine Ecology Progress Series, 374: 1-6.	fish	nutrients
52	Sara G., Zenone A., Tomasello A., (2009). Growth of Mytilus galloprovincialis (mollusca, bivalvia) close to fish farms: a case of integrated multi-trophic aquaculture within the Tyrrhenian Sea. Hydrobiologia, Article in Press.	fish	
53	Stamou A.I., Karamanoli M., Vassiliadou N., Douka E., Bergamasco A., Cenobese L., (2009). Mathematical modeling of the interactions between aquacultures and the sea environment. Desalination 248: 826-835.	fish	nitrogen phosphorus mathematical models
54	Tomassetti P., Persia E., Mercatali I., Vani D., Marusso V., Porrello S., (2009). Effects of mariculture on macrobenthic assemblages in a western Mediterranean site. Marine Pollution Bulletin 58: 533-541.	fish	sediments benthic fauna
55	Vidovic J., Cosovic V., Juracic M., Petricioli D., (2009). Impact of fish farming on foraminiferal community, Drvenik Veliki Island, Adriatic Sea, Croatia. Marine Pollution Bulletin, 58: 1297-1309	fish	foraminifera
56	Vizzini S., (2009). Analysis of the trophic role of Mediterranean seagrasses in marine coastal ecosystems: A review. Botanica Marina, 52: 383-393.	fish	marine phanerogams
57	Yabanli M., Egemen Oe., (2009). Monitoring the environmental impacts of marine aquaculture activities on the water column and the sediment in vicinity of the Karaburun Peninsula (Turkey – Eastern Aegean Sea). J. FisheriesSciences.com 3: 207-213.	fish	sediments water column
58	Yucel-Gier G., Uslu O., Kucuksezgin F., (2009). Regulating and monitoring marine finfish aquaculture in Turkey. Journal of Applied Ichthyology, 25: 686-694.	fish	monitoring
59	Balata D., Bertocci I., Piazzi L., Nesti U., (2008). Comparison between epiphyte assemblages of leaves and rhizomes of the seagrass *Posidonia oceanica* subjected to different levels of anthropogenic eutrophication. Estuar. Coast. Shelf Sci 79: 533-540.	fish	*Posidonia oceanica*
60	Canadas A., Hammond P.S., (2008). Abundance and habitat preferences of the short-beaked common dolphin *Delphinus delphis* in the southwestern Mediterranean: Implications for conservation. Endangered Species Res 4: 309-331.	fish	biodiversity
61	De Gaetano P., Doglioli A.M., Magaldi M.G., Vassallo P., Fabiano M., (2008). FOAM- a new simple benthic degradative module for the LAMP3D model: An application to a Mediterranean fish farm. Aquac Res 39: 1229-1242.	fish	benthic chemistry model biodegradation
62	Diaz Lopez B., Bunke M., Bernal Shirai J.A., (2008). Marine aquaculture off Sardinia Island (Italy): Ecosystem effects evaluated through a trophic mass-balance model. Ecol Model 212: 292-303.	fish	ecosystem mass balance
63	Diaz-Almela E., Marba N., Alvarez E., Santiago R, Holmer M., Grau A., Mirto S., Danovaro R., Petrou A., Argyrou M., Karakassis I., Duarte C.M., (2008). Benthic input rates predict seagrass (*Posidonia oceanica*) fish farm-induced decline. Mar. Pollut. Bull 56: 1332-1342.	fish	*Posidonia oceanica*
64	Dimitriadis C., Koutsoubas D., (2008). Community properties of benthic molluscs as indicators of environmental stress induced by organic enrichment. J Nat Hist 42: 559-574.	fish	benthic macrofauna
65	Fernandez-Jover D., Sanchez-Jerez P., Bayle-Sempere J.T., Valle C., Dempster T., (2008). Seasonal patterns and diets of wild fish assemblages associated with Mediterranean coastal fish farms. ICES Journal of Marine Science, 65: 1153-1160.	fish	wild fish
66	Giles H., (2008). Using Bayesian networks to examine consistent trends in fish farm benthic impact studies. Aquaculture 274: 181–195.	fish	sediments monitoring benthic macrofauna

67	Holmer M., Argyrou M., Dalsgaard T., Danovaro R., Diaz-Almela E., Duarte C.M., Frederiksen M., Grau A., Karakassis I., Marba N., Mirto S., Perez M., Pusceddu A., Tsapakis M., (2008). Effects of fish farm waste on *Posidonia oceanica* meadows: Synthesis and provision of monitoring and management tools. Mar. Pollut. Bull 56:1618-1629.	fish	*Posidonia oceanica*
68	Kruzic P., (2008). Variations in Posidonia oceanica meadow structure along the coast of the Dugi Otok Island (eastern Adriatic Sea). J Mar Biol Assoc UK 88: 883-892.	fish	*Posidonia oceanica*
69	Lampadariou N., Akoumianaki I., Karakassis I., (2008). Use of the size fractionation of the macrobenthic biomass for the rapid assessment of benthic organic enrichment. Ecol Indic 8: 729-742.	fish	benthic macrofauna monitoring
70	Mahmoudi E., Essid N., Beyrem H., Hedfi A., Boufahja F., Aissa P., Vitiello P., (2008). Mussel-farming effects on Mediterranean benthic nematode communities. Nematology 10: 323-333.	shellfish mussels	benthic meiofauna
71	Mannino A.M., Sara G., (2008). Effects of fish-farm biodeposition on periphyton assemblages on artificial substrates in the southern Tyrrhenian Sea (Gulf of Castellammare, Sicily). Aquatic Ecology, 42: 575-581.	fish	dissolved nutrients Fish-farm waste Algal assemblage
72	Matijevic S., Kuspilic G., Kljakovic-Gaspic Z., Bogner D., (2008). Impact of fish farming on the distribution of phosphorus in sediments in the middle Adriatic area. Mar. Pollut. Bull 56: 535-548.	fish	benthic chemistry phosphorus
73	Neofitou N., Klaoudatos S., (2008). Effect of fish farming on the water column nutrient concentration in a semi-enclosed gulf of the Eastern Mediterranean. Aquac Res 39: 482-490.	fish	nutrients
74	Perez M., Garcia T., Invers O., Ruiz J.M., (2008). Physiological responses of the seagrass *Posidonia oceanica* as indicators of fish farm impact. Mar. Pollut. Bull 56: 869-879.	fish	*Posidonia oceanica*
75	Sanchez-Jerez P., Fernandez-Jover D., Bayle-Sempere J., Valle C., Dempster T., Tuya F., Juanes F., (2008). Interactions between bluefish *Pomatomus saltatrix* (L.) and coastal sea-cage farms in the Mediterranean Sea. Aquaculture 282: 61-67.	fish	wild fish
76	Sequeira A., Ferreira J.G., Hawkins A.J.S., Nobre A., Lourenco P., Zhang X.L., Yan X., Nickell T., (2008). Trade-offs between shellfish aquaculture and benthic biodiversity: A modelling approach for sustainable management. Aquaculture 274: 313-328.	shellfish	benthic biodiversity
77	Vezzulli L., Moreno M., Marin V., Pezzati E., Bartoli M., Fabiano M., (2008). Organic waste impact of capture-based Atlantic bluefin tuna aquaculture at an exposed site in the Mediterranean Sea. Estuar. Coast. Shelf Sci 78: 369-384.	tuna	benthic
78	Yucel-Gier G., Uslu O., Bizsel N., (2008). Effects of marine fish farming on nutrient composition and plankton communities in the Eastern Aegean Sea (Turkey). Aquac Res 39:181-194	fish	nutrients-plankton
79	Aguado-Gimenez F., Marin A., Montoya S., Marin-Guirao L., Piedecausa A., Garcia-Garcia B., (2007). Comparison between some procedures for monitoring offshore cage culture in western Mediterranean Sea: Sampling methods and impact indicators in soft substrata. Aquaculture 271: 357-370.	fish	benthic monitoring
80	Apostolaki E.T., Tsagaraki T., Tsapakis M., Karakassis I., (2007). Fish farming impact on sediments and macrofauna associated with seagrass meadows in the Mediterranean. Estuar. Coast. Shelf Sci 75: 408-416.	fish	benthic macrofauna *Posidonia oceanica*
81	Belias C., Dassenakis M., Scoullos M., (2007). Study of the N P and Si fluxes between fish farm sediment and seawater. Results of simulation experiments employing a benthic chamber under various redox conditions. Mar. Chem. 103: 266-275.	fish	benthic chemistry fluxes
82	Brambilla F., Lalumera G., Terova G., Crosa G., Saroglia M., (2007). Inflow and outflow water quality control in coastal aquaculture systems: A case study. Aquac Res 38: 1654-1663.	fish	water quality
83	Carubelli G., Fanelli R., Mariani G., Nichetti S., Crosa G., Calamari D., Fattore E., (2007). PCB contamination in farmed and wild sea bass (*Dicentrarchus labrax* L.) from a coastal wetland area in central Italy. Chemosphere 68: 1630-1635.	fish	wild fish PCBs
84	Dedieu K., Rabouille C., Thouzeau G., Jean F., Chauvaud L., Clavier J.,	shellfish	benthic chemistry

	Mesnage V., Ogier S., (2007). Benthic O sub(2) distribution and dynamics in a Mediterranean lagoon (Thau France): An in situ microelectrode study. Estuar. Coast. Shelf Sci 72: 393-405.	oysters	
85	Diaz-Almela E., Arnaud-Haond S., Vliet M.S., Alvarez E., Marba N., Duarte C.M., Serrao E.A., (2007). Feed-backs between genetic structure and perturbation-driven decline in seagrass (*Posidonia oceanica*) meadows. Conserv Genet: 1377-1391.	fish	*Posidonia oceanica*
86	Dimitriou E., Katselis G., Moutopoulos D.K., Akovitiotis C., Koutsikopoulos C., (2007). Possible influence of reared gilthead sea bream (*Sparus aurata*-L.) on wild stocks in the area of the Messolonghi lagoon (Ionian Sea- Greece). Aquac Res 38: 398-408.	fish	wild fish
87	Dolenec T., Lojen S., Kniewald G., Dolenec M., Rogan N., (2007). Nitrogen stable isotope composition as a tracer of fish farming in invertebrates *Aplysina aerophoba*, *Balanus perforatus* and *Anemonia sulcata* in central Adriatic. Aquaculture 262: 237-249.	fish	benthic macrofauna
88	Fernandez-Jover D., Sanchez-Jerez P., Bayle-Sempere J., Carratala A., Leon V.M., (2007). Addition of dissolved nitrogen and dissolved organic carbon from wild fish faeces and food around Mediterranean fish farms: Implications for waste- dispersal models. J. Exp. Mar. Biol. Ecol 340: 160-168.	fish	wild fish
89	Fernandez-Jover D., Jimenez J.A.L., Sanchez-Jerez P., Bayle-Sempere J., Casalduero F.G., Lopez F.J.M., Dempster T., (2007). Changes in body condition and fatty acid composition of wild Mediterranean horse mackerel (Trachurus mediterraneus, Steindachner, 1868) associated to sea cage fish farms. Mar. Environ. Res 63: 1-18.	fish	wild fish
90	Frederiksen M.S., Holmer M., Diaz-Almela E., Marba N., Duarte C.M., (2007). Sulfide invasion in the seagrass *Posidonia oceanica* at Mediterranean fish farms: Assessment using stable sulfur isotopes. Mar. Ecol. Prog. Ser 345: 93-104.	fish	*Posidonia oceanica*
91	Holmer M., Frederiksen M.S., (2007). Stimulation of sulfate reduction rates in Mediterranean fish farm sediments inhabited by the seagrass *Posidonia oceanica*. Biogeochemistry 85: 169-184.	fish	*Posidonia oceanica*
92	Holmer M., Marba N., Diaz-Almela E., Duarte C.M., Tsapakis M., Danovaro R., (2007). Sedimentation of organic matter from fish farms in oligotrophic Mediterranean assessed through bulk and stable isotope delta super(1) super(3)C and delta super(1) super(5)N) analyses. Aquaculture 262: 268-280.	fish	benthic chemistry isotopes
93	Kornaros M., Lyberatos G., Kaspiris P. (2007). Impacts of a marine fish farm in Argolikos Gulf (Greece) on the water column and the sediment. Desalination, 210(1-3), 110-124.	fish	
94	Mantzavrakos E., Kornaros M., Lyberatos G., Kaspiris P., (2007). Impacts of a marine fish farm in Argolikos Gulf (Greece) on the water column and the sediment. Desalination 210: 110-124.	fish	benthic chemistry
95	Marin A., Montoya S., Vita R., Marin-Guirao L., Lloret J., Aguado F., (2007). Utility of sea urchin embryo-larval bioassays for assessing the environmental impact of marine fishcage farming. Aquaculture 271: 286-297.	fish tuna	benthic sediments bioassay
96	Matijevic S., Kuspilic G., Kljakovic-Gaspic Z., (2007). The redox potential of sediment from the Middle Adriatic region. Acta Adriat 48: 191-204.	fish	benthic chemistry redox
97	Mazon M.J., Piedecausa M.A, Hernandez M.D., Garcia Garcia B., (2007). Evaluation of environmental nitrogen and phosphorus contributions as a result of intensive ongrowing of common octopus (*Octopus vulgaris*). Aquaculture 266: 226-235.	shellfish octopus	nutrients
98	Mesnage V., Ogier S., Bally G., Disnar J.R., Lottier N., Dedieu K., Rabouille C., Copard Y., (2007). Nutrient dynamics at the sediment-water interface in a Mediterranean lagoon (Thau, France): Influence of biodeposition by shellfish farming activities. Mar. Environ. Res 63: 257-277.	shellfish	nutrients
99	Metzger E., Simonucci C., Viollier E., Sarazin G., Prevot F., Elbaz-Poulichet F., Seidel J.L., Jezequel D., (2007). Influence of diagenetic processes in Thau lagoon on cadmium behavior and benthic fluxes. Estuar. Coast. Shelf Sci 72: 497-510.	shellfish	benthic chemistry
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207	Lojen S., Angel D., Kats T., Tsapakis M., Kovac N., Malej A., (2003). Super(15)N enrichment in fouling communities influenced by organic waste deriving from fish farms. Ann. An. Istrske Mediter. Stud. (Hist. Nat.) 13: 9-12.	fish	fouling
208	Melia P., Nizzoli D., Bartoli M., Naldi M., Viaroli P., (2003). Assessing the potential impact of clam rearing in dystrophic lagoons: an integrated oxygen	shellfish clams	anoxia

	balance. Chem. Ecol. 19: 129-146.		
209	Mercurio M., Longo C., Nonnis Marzano C., Scalera Liaci L., Corriero G., (2003). Commercial sponge farming in the marine reserve 'Isola di Ustica'. Biol. Mar. Mediterr. 10: 462-464.	shellfish sponges	environmental impacts
210	Mistri M., Modungo S., Rossi R., (2003). Sediment organic matter and its nutritional quality: a short-term experiment with two exotic bivalve species. Chem. Ecol 19: 225-231.	shellfish	benthic chemistry
211	Munari C., Modugno S., Ghion F., Castaldelli G., Fano E.A., Rossi R., Mistri M., (2003). Recovery of the macrobenthic community in the Valli di Comacchio- northern Adriatic Sea- Italy. Oceanol. Acta 26: 67-75.	fish	benthic macrofauna recovery
212	Porrello S., Ferrari G., Lenzi M., Persia E., (2003). Ammonia variations in phytotreatment ponds of land-based fish farm wastewater. Aquaculture 219: 485-494.	fish	nutrients mitigation
213	Porrello S., Lenzi M., Persia E., Tomassetti P., Finoia M.G. (2003). Reduction of aquaculture wastewater eutrophication by phytotreatment ponds system. I. Dissolved and particulate nitrogen and phosphorus. Aquaculture 219: 515-529.	fish	nutrients mitigation
214	Porrello S., Lenzi M., Tomassetti P., Persia E., Finoia M.G., Mercatali I., (2003). Reduction of aquaculture wastewater eutrophication by phytotreatment ponds system. II. Nitrogen and phosphorus content in macroalgae and sediment. Aquaculture 219: 531-544.	fish	macroalgae
215	Pujalte M.J., Sitja-Bobadilla A., Alvarez-Pellitero P., Garay E., (2003) Carriage of potentially fish-pathogenic bacteria in *Sparus aurata* cultured in Mediterranean fish farms. Diseases Aquat. Organisms 54: 119-126.	fish	disease-parasites
216	Ramos M., Marin A., Barbera R.V., Guirao L.M., Cesar A., Lloret J., (2003). Evolution of benthic communities in El Hornillo Bay (AM guilas- Murcia) (southeast Spain) after cessation of floating-cage seabream *Sparus auratus* L 1758 and seabass *Dicentrarchus labrax* (L 1758) culture. Bol Inst Esp Oceanogr 19:379-389.	fish	benthic macrofauna recovery
217	Santulli A., Bertolino F., Asaro E., Lombardo S., Modica A., Porrello S., Mistretta G., Arena R., Messina C., (2003). Environmental impact of a commercial farm of Mediterranean bluefin tuna (*Thunnus thynnus*) located in the Gulf of Castellammare (Trapani Italy): preliminary results. Biol. Mar. Mediterr 10: 477-481.	fish tuna	benthic macrofauna benthic chemistry
218	Sara G., Vizzini S., Caruso M., Mazzola A., (2003). Origin of sedimentary organic carbon in a fish-farming impacted area (Gaeta Gulf central Tyrrhenian MED). Biol. Mar. Mediterr 10: 482-484.	fish	benthic chemistry stable isotopes
219	Turk V., Malej A., (2003). The influence of fish cage aquaculture on bacterioplankton in the Bay of Piran (Gulf of Trieste Adriatic Sea). Ann. An. Istrske Mediter. Stud. (Hist. Nat.) 13: 37-42.	fish	bacterioplankton
220	Vega Fernandez T., D'Anna G., Badalamenti F., Pipitone C., Coppola M., Rivas G., Modica A., (2003). Fish fauna associated to an off-shore aquaculture system in the Gulf of Castellammare (NW Sicily). Biol. Mar. Mediterr 10: 755-759.	fish	wild fish
221	Vezzuli L., Marrale D.,, Moreno M., Fabiano M., (2003). Sediment organic matter and meiofauna community response to long-term fish-farm impact in the Ligurian Sea (western Mediterranean). Chem. Ecol 19: 431-440.	fish	benthic meiofauna
222	Viaroli P., Bartoli M., Giordani G., Azzoni R., Nizzoli D., (2003). Short-term changes of benthic fluxes during clam harvesting in a coastal lagoon (Sacca di Goro Po River delta). Chem. Ecol 19: 189-206.	shellfish clams	benthic chemistry
223	Black K.D., MacDougall N., (2002). Hydrography of four mediterranean marine cage sites. J. Appl. Ichthyol. 18: 129-133.	fish	hydrography
224	Cornello M., Giovanardi O., (2002). Structure of macrozoobenthic communities in the marine district of Chioggia (northern Adriatic Sea Italy) in relationship to offshore mussel culture. Biol. Mar. Mediterr 9: 609-612.	shellfish mussels	benthic macrofauna
225	Delepee R., Gaillard S., Pouliquen H., Le Bris H., (2002). The freshwater moss Fontinalis antipyretica bioaccumulates oxolinic acid. Rev. Med. Vet 153: 679-680.	fish	disease control drugs bioaccumulation
226	Dempster T., Sanchez-Jerez P., Bayle-Sempere J.T., Gimenez-Casalduero F., Valle C., (2002). Attraction of wild fish to sea-cage fish farms in the south-	fish	wild fish

	western Mediterranean Sea: Spatial and short-term temporal variability. Mar. Ecol. Prog. Ser 242: 237-252.		
227	Dimech M., Borg J.A., Schembri P.J., (2002). Changes in the structure of a *Posidonia oceanica* meadow and in the diversity of associated decapod mollusc and echinoderm assemblages resulting from inputs of waste from a marine fish farm (Malta Central Mediterranean). Bull. Mar. Sci 71:1309-1321.	fish	*Posidonia oceanica*
228	Karakassis I., Tsapakis M., Smith C.J., Rumohr H., (2002). Fish farming impacts in the Mediterranean studied through sediment profiling imagery. Mar. Ecol. Prog. Ser 227: 125-133.	fish	benthic macrofauna SPI
229	La Rosa T., Mirto S., Favaloro E., Savona B., Sara G., Danovaro R., Mazzola A., (2002). Impact on the water column biogeochemistry of a Mediterranean mussel and fish farm. Water Res 36:713-721.	fish	nutrients-plankton
230	Mirto S., La Rosa T., Gambi C., Danovaro R., Mazzola A., (2002).,Nematode community response to fish-farm impact in the western Mediterranean. Environ. Pollut 116: 203-214.	fish	benthic meiofauna
231	Verlaque M, Belsher T, Deslous-Paoli JM (2002) Morphology and reproduction of Asiatic *Ulva pertusa* (Ulvales Chlorophyta) in Thau Lagoon (France Mediterranean Sea). Cryptogamie: Algol 23: 301-310	shellfish oysters	alien spp.
232	Vezzulli L., Chelossi E., Riccardi G., Fabiano M., (2002). Bacterial community structure and activity in fish farm sediments of the Ligurian Sea (Western Mediterranean). Aquacult. Int 10:123-141.	fish	benthic microbial
233	Bartoli M., Nizzoli D., Viaroli P., Turolla E., Castaldelli G., Fano E.A., Rossi R., (2001). Impact of Tapes philippinarum farming on nutrient dynamics and benthic respiration in the Sacca di Goro. Hydrobiologia 455: 203-212.	shellfish clams	nutrients sediment
234	Breuil G., Mouchel O., Fauvel C., Pepin J.F., (2001). Sea bass *Dicentrarchus labrax* nervous necrosis virus isolates with distinct pathogenicity to sea bass larvae. Diseases Aquat. Organisms 45: 25-31.	fish	disease-parasites
235	Chapelle A., Lazure P., Souchu P., (2001). Modelling anoxia in the Thau Lagoon (France). Oceanol. Acta 24 S: S87-S97.	shellfish	anoxia
236	Karakassis I., Tsapakis M., Hatziyanni E., Pitta P., (2001). Diel variation of nutrients and chlorophyll in sea bream and sea bass cages in the Mediterranean. Fresenius Environ. Bull. 10: 278-283.	fish	nutrients plankton
237	Kovac N., Vriser B., Cermelj B., (2001). Impact of net cage fish farm on sedimentary biogeochemical and meiofaunal properties of the Gulf of Trieste. Ann. An. Istrske Mediter. Stud. (Hist. Nat.) 11: 65-74.	fish	benthic meiofauna
238	La Rosa T., Mirto S., Marino A., Alonzo V., Maugeri T.L., Mazzola A., (2001). Heterotrophic bacteria community and pollution indicators of mussel - farm impact in the Gulf of Gaeta (Tyrrhenian Sea). Mar. Environ. Res 52: 301-321.	shellfish mussels	nutrients bacteria
239	La Rosa T., Mirto S., Mazzola A., Danovaro R., (2001). Differential responses of benthic microbes and meiofauna to fish-farm disturbance in coastal sediments. Environ. Pollut. 112: 427-434.	fish	benthic meiofauna
240	Mazzola A., Sara G., (2001). The effect of fish farming organic waste on food availability for bivalve molluscs (Gaeta Gulf Central Tyrrhenian MED): stable carbon isotopic analysis. Aquaculture 192: 361-379.	fish	biogeochemistry food availability stable isotopes
241	Padros F., Palenzuela O., Hispano C., Tosas O., Zarza C., Crespo S., Alvarez-Pellitero P., (2001). Myxidium leei (Myxozoa) infections in aquarium-reared Mediterranean fish species. Diseases Aquat Organisms 47: 57-62.	fish	disease parasites
242	Papapanagiotou E.P., Trilles J.P., (2001). Cymothoid parasite Ceratothoa parallela inflicts great losses on cultured gilthead sea bream *Sparus aurata* in Greece. Diseases Aquat Organisms 45:237-239.	fish	disease; parasites
243	Ruiz J.M., Perez M., Romero J., (2001). Effects of fish farm loadings on seagrass (*Posidonia oceanica*) distribution, growth and photosynthesis. Mar. Pollut. Bull 42: 749-760.	fish	*Posidonia oceanica*
244	Sandulli R., Carriglio D., Mei M.L., (2001). Preliminary investigations on the effects of off-shore fish farming on the meiofauna and sediments in the Porto Cesareo area (Lecce Italy). Biol. Mar. Mediterr 8: 626-629.	fish	benthic meiofauna
245	Souchu P., Vaquer A., Collos Y., Landrein S., Deslous-Paoli J.M., Bibent B.,	shellfish	nutrients

	(2001). Influence of shellfish farming activities on the biogeochemical composition of the water column in Thau lagoon. Mar. Ecol. Prog. Ser 218: 141-152.	oysters	plankton
246	Barbato F., Massini G., Creo C., De Angelis N., Imperatrice M., Signorini A., Allegro A., Reno M.G., (2000). Mitigation of the impact of fish rearing in floating cages using a device for waste collection and recovery. Biol. Mar. Mediterr 7: 603-606.	fish	nutrients sulphides mitigation
247	Cancemi G., De Falco G., Pergent G., (2000). Impact of a fish farming facility on a *Posidonia oceanica* meadow. Biol. Mar. Mediterr 7: 341-344.	fish	*Posidonia oceanica*
248	Chapelle A., Menesguen A., Deslous-Paoli J.M., Souchu P., Mazouni N., Vaquer A., Millet B., (2000). Modelling nitrogen primary production and oxygen in a Mediterranean lagoon. Impact of oysters farming and inputs from the watershed. Ecol. Model 127: 161-181.	shellfish oysters	nutrients
249	Crema R., Prevedelli D., Valentini A., Castelli A., (2000). Recovery of the macrozoobenthic community of the Comacchio Lagoon system (Northern Adriatic sea). Ophelia 52: 143-152.	fish	benthic macrofauna
250	De Vittor C., Falconi C., Predonzani S., Fonda Umani S., (2000). Mussel culture impact on sea floor sediments in the Gulf of Trieste. Biol. Mar. Mediterr 7: 85-92.	shellfish mussels	benthic macrofauna
251	Dimech M., Borg J.A., Schembri P.J., (2000). The effects of a marine fish-farm on the species richness and abundance of molluscs decapods and echinoderms associated with a *Posidonia oceanica* meadow in Malta (Central Mediterranean). Biol. Mar. Mediterr 7: 357-360.	fish	*Posidonia oceanica*
252	Dimech M., Borg J.A., Schembri P.J., (2000). Structural changes in a *Posidonia oceanica* meadow exposed to a pollution gradient from a marine fish-farm in Malta (Central Mediterranean). Biol. Mar. Mediterr 7: 361-364.	fish	*Posidonia oceanica*
253	Galil B.S., (2000). A sea under siege - alien species in the Mediterranean. Biol. Invasions 2: 177-186.	general	alien spp.
254	Karakassis I., Hatziyanni E., (2000). Benthic disturbance due to fish farming analyzed under different levels of taxonomic resolution. Mar. Ecol. Prog. Ser 203: 247-253.	fish	benthic macrofauna
255	Karakassis I., Tsapakis M., Hatziyanni E., Papadopoulou K., Plaiti W., (2000), Impact of cage farming of fish on the seabed in three Mediterranean coastal areas. ICES J. Mar. Sci 57: 1462-1471.	fish	benthic macrofauna
256	La Rosa T., Mirto S., Danovaro R., Fabiano M., Manganaro A., Maugeri T., Mazzola A., (2000). Meiofauna and benthic microbial biomass in relation to organic matter content in a strong biodepositional system. Biol. Mar. Mediterr 7: 239-246.	fish	benthic meiofauna
257	Martin D., Pinedo S., Sarda R., (2000). Distribution patterns and trophic structure of soft-bottom polychaete assemblages in a north-western Mediterranean shallow-water bay. Ophelia 53: 1-17.		benthic macrofauna
258	Mazzola A., Mirto S., La rosa T., Fabiano M., Danovaro R., (2000). Fish-farming effects on benthic community structure in coastal sediments: analysis of meiofaunal recovery. ICES J. Mar. Sci 57: 1454-1461.	fish	benthic meiofauna recovery
259	Mirto S., La Rosa T., Danovaro R., Mazzola A., (2000). Microbial and Meiofaunal Response to Intensive Mussel-Farm Biodeposition in Coastal Sediments of the Western Mediterranean. Mar. Pollut. Bull 40: 244-252.	shellfish mussels	benthic meiofauna
260	Barbato F., De Angelis N., Imperatrice M., Cannas A., (1999). A device for collection and recover of solid waste generated by cage fish rearing. Biol. Mar. Mediterr 6: 281-283.	fish	sedimentation wastes mitigation
261	Ceccarelli R., Saluzzi A., Fiore V., Salerno A., Barbera G., (1999). The environmental impact of an offshore aquaculture system in the Gulf of Gaeta: a first approach. Biol. Mar. Mediterr 6: 294-297.	fish	nutrients offshore
262	Delgado O., Ruiz J., Perez M., Romero J., Ballesteros E., (1999). Effects of fish farming on seagrass (*Posidonia oceanica*) in a Mediterranean bay: seagrass decline after organic loading cessation. Oceanol. Acta 22: 109-117.	fish	*Posidonia oceanica*
263	Di Bitetto M., Congestri R., Massini G., Colloca F., Cerasi S., Ciattaglia A., Ugolini R., (1999). Preliminary results of the environmental monitoring below submersible offshore fish-cages in the Policastro Gulf (Italy). Biol. Mar.	fish	oyster culture offshore

	Mediterr 6: 316-318.		
264	Diamant A., Banet A., Paperna I., Westernhagen Hvon Broeg K, Kruener G., Koerting W., Zander S., (1999). The use of fish metabolic pathological and parasitological indices in pollution monitoring. 2. The Red Sea and Mediterranean. Helgol. Mar. Res 53: 195-208.	fish	parasites
265	Dougall N.M., Black K.D., (1999). Determining sediment properties around a marine cage farm using acoustic ground discrimination: RoxAnn super™. Aquacult. Res 30: 451-458.	fish	benthic sediments RoxAnn
266	Karakassis I., Hatziyanni E., Tsapakis M., Plaiti W., (1999). Benthic recovery following cessation of fish farming: A series of successes and catastrophes. Mar. Ecol. Prog. Ser 184: 205-218.	fish	benthic macrofauna recovery
267	Katavic I., Antolic B., (1999). On the impact of a sea bass (*Dicentrarchus labrax* L.) cage farm on water quality and macrobenthic communities. Acta Adriat 40:19-32.	fish	benthic macrofauna *Posidonia oceanica*
268	Kress N., Herut B., Shefer E., Hornung H., (1999). Trace element levels in fish from clean and polluted coastal marine sites in the Mediterranean Sea Red Sea and North Sea. Helgol. Mar. Res 53: 163-170.	fish	trace matels PCBs
269	Lubrano Lavadera S., Fabbrocini A., Rispoli S., Sansone G., (1999). Growth tests of *Ostrea edulis* near off-shore cage aquaculture. Biol. Mar. Mediter. 6: 325-327.	fish	fish impact on oyster growth offshore
270	Mazzola A., Mirto S., Danovaro R., (1999). Initial fish-farm impact on meiofaunal assemblages in coastal sediments of the Western Mediterranean. Mar. Pollut. Bull 38:1126-1133.	fish	benthic meiofauna
271	Mirto S., Fabiano M., Danovaro R., Manganaro A., Mazzola A., (1999). Use of meiofauna for detecting fish farming disturbance in coastal sediments: preliminary results. Biol. Mar. Mediterr 6: 331-334.	fish	benthic meiofauna
272	Pergent G., Mendez S., Pergent-Martini C., Pasqualini V., (1999). Preliminary data on the impact of fish farming facilities on *Posidonia oceanica* meadows in the Mediterranean. Oceanol. Acta 22: 95-107.	fish	*Posidonia oceanica*
273	Sorokin II, Giovanardi O., Pranovi F., Sorokin P.I., (1999). Need for restricting bivalve culture in the southern basin of the Lagoon of Venice. Hydrobiologia 400: 141-148.	shellfish	nutrients plankton
274	Sorokin Y., Sorokin P., Ravagnan G., (1999). Analysis of Lagoonal Ecosystems in the Po River Delta Associated with Intensive Aquaculture. Estuar. Coast. Shelf Sci 48: 325-341.	fish	nutrients sediment
275	Karakassis I., (1998). Aquaculture and coastal marine biodiversity. Oceanis 24: 271-286.	fish	biodiversity
276	Pitta P., Karakassis I., Tsapakis M., Zivanovic S., (1998). Natural vs. mariculture induced variability in nutrients and plankton in the eastern Mediterranean. Hydrobiologia 391: 181-194.	fish	nutrients plankton
277	Rossi R., (1998). (Under the magnifying glass: Valliculture). Il Pesce 15: 72-73.		aquatic birds
278	De Casabianca M.L., Laugier T., Marinho-Soriano E., (1997). Seasonal changes of nutrients in water and sediment in a Mediterranean lagoon with shellfish farming activity (Thau Lagoon France). ICES J. Mar. Sci 54: 905-916.	shellfish	nutrients plankton macroalgae
279	Brahim M., Mastouri A., Akrout F., (1996). Boughrara lagoon : annual hydrobiological parameters monitoring. Bull. Inst. Natl. Sci. Technol. Mer 23: 83-106.		HABs fish kill
280	Mazouni N., Gaertner J.C., Deslous-Paoli J.M., Landrein S., Geringer d'Oedenberg M., (1996). Nutrient and oxygen exchanges at the water-sediment interface in a shellfish farming lagoon (Thau France). J. Exp. Mar. Biol. Ecol 205: 91-113.	shellfish oysters	benthic macrofauna benthic chemistry
281	Brizzi G., Aleffi F., Goriup F., Landri P., Orel G., (1995). Modifications in benthos under mussel culture in the Gulf of Trieste (North Adriatic Sea). Ann. An. Istrske Mediter. Stud. (Hist. Nat.) 6: 17-26.	shellfish mussels	benthic macrofauna

ANNEX 4

Questionnaire used in the surveys on aquaculture legal issues (see Chapter 8)

QUESTIONNAIRE

Project: "Developing sitting and carrying capacity guidelines for Mediterranean aquaculture within aquaculture appropriate areas (SHOCMED)"

AQUACULTURE LEGAL ISSUES

Identification

Name:

Occupation:

Organization:

Email:

Country:

1. Is there any specific law [a law regulating exclusively aquaculture issues] for aquaculture regulation in your country?

☐ *Yes, there is an aquaculture law* [a law regulating exclusively aquaculture issues]

☐ *No, there is no specific law; but we have a law for fisheries and aquaculture* [a law regulating both fisheries and aquaculture issues]

☐ *No, but we have other regulatory norms for aquaculture* [legally binding commands with a lower rank in the normative system than a Law, for instance Decrees, Regulations, Orders, etc.].

☐ *No, we have no legislation for aquaculture*

Licensing procedure

2.1. Which are the Public Bodies/Departments/Authorities with **competences** [legal authority or capability in aquaculture; those who directly give the licenses, as for instance Ministry of Fisheries or Ministry or Environment] in aquaculture licensing?
Please, list them.

2.2 How many authorities/administrations are **involved** [those who should be consulted or informed –as for instance, Defence or Tourism departments] in aquaculture activities or licensing procedures?

3. What is the official name of the aquaculture licence in your country?
   - Concession for aquaculture
   - Permit for aquaculture
   - Authorisation
   - Other, please indicate the appropriate name

4. What is the average time-consuming to obtaining an aquaculture licence? [How long it takes to get a license; the question is related not to the legal timeframe foreseen in the regulation, but to the normal time that takes for an applicant to get his/her License for fish farming]

☐ < 6 months ☐ ≥ 6 and < 8 months ☐ ≥ 8 and < 12 months ☐ 1 year

☐ 1 year and a half ☐ 2 years ☐ 2 years and a half ☐ 3 years ☐ >3 years

5. What is the duration [validity] for an aquaculture licence once it is granted?

☐ 5 years ☐ 10 years ☐ 30 years ☐ other (please, indicate it)

6. Some countries require two different licences for aquaculture: one for the aquaculture activity and other one for occupying the coastal-maritime area. Does this two licences system apply to your country?

☐ Yes
☐ No
☐ Other (please, indicate it)

7. In you opinion, what is the main problem regarding the licensing process for aquaculture [problems related to the procedure, not to the aquaculture activity]?

Aquaculture planning

8.1 Do you have a specific planning for aquaculture? [a plan focused in the promotion and development of the marine aquaculture, including strategic plans, development plans and other planning tools]

☐ Yes ☐ No

8.2 Do you have a specific zoning for aquaculture? [Selected areas marked out exclusively for aquaculture activities]

☐ Yes ☐ No

If the answer is yes, please indicate:

- the zoning has been developed as an study, but it is not include in any official norm or regulation and therefore it is not mandatory and aquaculture farms could be located in other zones. ☐
- the zoning is regulated by norms, and aquaculture can be developed only in those areas determined by the regulation. ☐

9. Are you involved in any integrated coastal zone management plan [ICZM: the integrated planning and management of coastal resources and environments in a manner that is based on the physical, socioeconomic, and political interconnections both within and among the dynamic coastal systems, which when aggregated together define a coastal zone]?

☐ Yes. Please, provide a short description ☐ No

10. 1. Is the coastal zone considered as *public domain* [state's owned land] in your country?

☐ Yes ☐ No

Which spaces?

☐ Maritime waters
☐ Terrestrial zone (Coast)
☐ The shoreline zone

10.2. What are the main incompatibility problems in coastal areas related to aquaculture site selection?
☐ fisheries ☐ tourism ☐ protected areas ☐ industry ☐ heritage

☐ navigation ☐ ports ☐ urban development ☐ environmental issues ☐ others

11. Is there any working group or task group in order to solve aquaculture site selection problems [choosing the right place to locate aquaculture facilities]?
☐ Yes . Please, provide a short description ☐ No

12. Is there any advisory group or task force integrated by public and private stakeholders and focused on coordinating the competences in coastal and maritime zones?
☐ Yes . Please, provide a short description ☐ No

Environmental protection and site selection

11. Do you have any procedures or guidelines [indications of actions required or recommended] for aquaculture site selection?
☐ Yes . Please, provide a short description ☐ No

12. Is there any kind of criteria and regulatory systems [mandatory requirements applicable to the definition of zones for aquaculture] applied on site selection?
☐ Yes . Please, provide a short description ☐ No

13. Do you have any standards [an established or accepted model, either legally required or scientifically accepted] for carrying/holding capacity of aquaculture farms?
☐ Yes . Please, provide a short description ☐ No

14. Do you apply any monitoring system to evaluate the effects and impacts of aquaculture on the environment?,
☐ Yes . Please, provide a short description ☐ No

15.1 Do you have a program for Environmental Impact Assessment EIA?
☐ Yes . Please, provide a reference ☐ No

15.2. The EIA program is
☐ Voluntary ☐ Mandatory

16.Do you have any measures and tools for protecting benthic habitats?
☐ Yes . Please, provide a short description ☐ No

17. COMMENTS. Please, comment any other issue that you consider relevant for the aquaculture site selection.

Please, send this questionnaire to rchapela@cetmar.org
Thank you very much for your cooperation