1. INTRODUCTION

These technical guidelines on the ecosystem approach to aquaculture (EEA) are developed to support mainly Articles 9 and 10 of the FAO Code of Conduct for Responsible Fisheries (CCRF).

The main objective of the guidelines is to assist countries, institutions and policy-makers in the development and implementation of a strategy to ensure the sustainability of the aquaculture sector, integration of aquaculture with other sectors and its contribution to social and economic development.

1.1 The ecosystem approach to aquaculture

Aquaculture growth worldwide invariably involves (with differences among regions and economies) the expansion of cultivated areas, larger aquaculture farms, higher density of farmed individuals and the use of feed resources often produced outside of the immediate area. Worldwide, aquaculture has increasing social and economic impact through the production of food, contribution to livelihoods and generation of income. Other positive effects on the ecosystem include, for example, the provision of seeds for restocking of endangered or overexploited aquatic populations. However, when badly managed, aquaculture can affect ecosystems functions and services, with negative environmental, social and economic consequences. Aquaculture usually also faces risks from other human activities such as contamination of waterways by agriculture and industrial activities.

There have been important advances regarding the formulation of instruments and codes to facilitate sustainable development of the aquaculture sector. These include the provisions in Articles 9 and 10 in the CCRF, the development of technical guidelines expanding on the scope and meaning of these articles (e.g. FAO, 1997) and other numerous guiding documents. Countries worldwide are also attempting to implement a diverse array of aquaculture regulations to control inadequate development of the sector.

Yet some relevant constraints persist, often including:

- lack of awareness and understanding of ecosystem processes;
- lack of appropriate connection between ecological and social processes;
- lack of local institutions to agree upon appropriate standards and mechanisms to uphold them for aquatic systems or farm groups;
- lack of institutions capable of implementing more strategic approaches;
- the priority afforded to short-term interests by many business enterprises and by the poor;
- lack of consideration of relevant boundaries and a multiple-scales approach, when appropriate; and
- lack of integrated multisectoral planning and management.

To address these issues, the FAO workshop *Building an Ecosystem Approach to Aquaculture* (Soto, Aguilar-Manjarrez and Hishamunda, 2008)[1] laid the foundations for the development of the present guidelines and proposed the following definition:

> ***"An ecosystem approach to aquaculture (EAA) is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity and resilience of interlinked social-ecological systems."***

Being a *strategy*, the EAA is not *what* we do but *how* we do it; and the participation of relevant stakeholders is at the base of the formulation and implementation of the "strategy". Figure 1 and Box 1 depict the changing approach from the conventional to an ecosystem approach to aquaculture emphasizing "the way we do things".

The premise of the ecosystem approach (EA) is in the Convention on Biological Diversity (UNCBD, 1993), which defines EA as a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.

Indeed, most of the principles and practical steps of EAA are not new. The EAA builds on the conceptual work carried out to develop the ecosystem approach to fisheries (EAF) (FAO, 2003, 2005), including the guidelines on human dimensions of the ecosystem approach to fisheries (FAO, 2008a), as well as initiatives related to integrated natural resource management such as integrated coastal zone management (ICZM) and integrated watershed management (IWSM) and the planning and management for sustainable coastal aquaculture development (e.g. GESAMP, 2001).

The requirements and criteria presented below on the implementation of an EAA are to be based on, and interpreted in accordance with, the current suite of agreed international instruments that pertain to aquaculture (Box 2).

The EAA also echoes the development principles stated in the formulation of the EAF. Both the EAA and EAF have three main objectives within a hierarchical tree framework:

1. ensuring human well-being;
2. ensuring ecological well-being; and
3. facilitating the achievement of both, i.e. effective governance of the sector/areas where aquaculture occurs and has potential for development.

The EAA is based on the principles of sustainable development, where "sustainable" is not restricted to ecological considerations, but includes economic and social considerations and their interaction with ecological

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[1] This publication contains extensive background material and case studies related to EAA (available at www.fao.org/docrep/011/i0339e/i0339e00.htm).

Box 1
The core ideas underlying the ecosystem approach

The ecosystem approach (EA) recognizes that

- humans are an integral part of important ecosystems, and people should be at the center of biodiversity management. This implies the need for integrated, participatory approaches in the identification of issues and further in to "ecosystem" management.
- ecosystems provide services that underpin most human activity, and that we need to ensure that we do not threaten the sustained delivery of these services through damage to ecosystem functions.
- given our ignorance of the functioning of these highly complex systems, there is a need for a precautionary and adaptive approach.
- some activities threaten or reduce the quality of ecosystem services available to society at large and therefore represent a cost that should be accounted or internalized.
- waste products from one activity or sector may serve as inputs to another, thus enhancing productivity and reducing pressure on ecosystem functions and services.
- ecosystems function at a range of scales from highly local to global, and we therefore need a "nested" approach with different approaches to management according to scale.
- there is a need for analysis and understanding of the broader social, economic and environmental implications of meeting targets and for transparency of decision-making in relation to trade-offs between social, economic and environmental objectives.

Modified from Hambrey, Edwards and Belton (2008).

ones. Both the social and biophysical or ecological dimensions of ecosystems are tightly linked, so that disruption in one is likely to cause a disruption or change in the other.

The present EAA guidelines provide a common, coherent and practical framework for policy-making and promote a process of enhanced sectoral management at different scales, taking full account of environmental limits and the interests of other resource users and stakeholders. Although the guidelines have a sectoral perspective, which is needed for practical purposes related to the implementation of the approach, they are congruent with more general guidelines for integrated natural resources management,

Box 2
Principles, instruments, global and national agreements, regulations and codes of practice related to the sustainable development of the aquaculture sector

Aquaculture should:

- Recognize the sovereign rights of States and comply with all relevant local, national and international laws and regulations.
- Be consistent with relevant international agreements and conventions, in particular:
  - The United Nations Convention on the Law of the Sea (UNCLOS, 1982)[2]
  - The Convention on Biological Diversity (UNCBD, 1993)
  - The FAO Code of Conduct for Responsible Fisheries (CCRF), especially Articles 9 and 10 (FAO, 1995)
  - The rules of the World Trade Organization (WTO), notably the Agreement on the Application of Sanitary and Phytosanitary (SPS)[3] Measures and the Agreement on Technical Barriers to Trade (TBT)
  - The FAO/World Health Organization (WHO) *Codex Alimentarius* (FAO/WHO)[4]
  - World Organisation for Animal Health (OIE) Aquatic Animal Health Code 12th edition (OIE, 2009)
  - The labour standards of the International Labour Organization (ILO)
  - The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)
  - Agenda 21 (Rio Earth Summit, 1992)
- Be consistent with the following documents
  - Aquaculture development; FAO Technical Guidelines for Responsible Fisheries. No. 5 (FAO, 1997)
  - Aquaculture Development Beyond 2000: The Bangkok Declaration and Strategy (NACA/FAO, 2000)
  - The International Principles for Responsible Shrimp Farming (FAO/NACA/UNEP/WB/WWF, 2006)
  - Expert consultation on improving planning and policy development in aquaculture (FAO, 2008b)

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2 See www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm

3 See www.wto.org/english/tratop_e/sps_e/spsagr_e.htm

4 Available at ftp://ftp.fao.org/codex/Publications/understanding/Understanding_EN.pdf

integrated watershed and river basin management, and integrated coastal zone management. Practitioners are encouraged to select, modify and continuously adapt their own approaches and tools to specific circumstances.

1.2 Aim

The prime goal of EAA is to overcome the sectoral and intergovernmental fragmentation of resources management efforts and to develop institutional mechanisms for effective coordination among various sectors active in the ecosystems in which aquaculture operates and between the various levels of government.

The two outcomes of this should be:

(i) a "truly" sustainable aquaculture sector (environmentally, economically, socially); and

(ii) change in the public's (understood as broadly as possible) attitude and perception of aquaculture.

1.3 Key principles

As "the" strategy to ensure aquaculture contributes positively to sustainable development, the EAA should be guided by three main interlinked principles:

Principle 1

Aquaculture development and management should take account of the full range of ecosystem functions and services, and should not threaten the sustained delivery of these to society.

Developing aquaculture in the context of ecosystem functions and services is a challenge that involves defining ecosystem boundaries (at least operationally), estimating some assimilative and production carrying capacities, and adapting farming practices accordingly. The mix of ecosystem services will depend on wider management practices and the trade-off among different services must be acknowledged. This is especially important in the case of ecosystem functions that are unique, essential or threatened to ensure their preservation.

Principle 2

Aquaculture should improve human well-being and equity for all relevant stakeholders.

This principle seeks to ensure that aquaculture provides equitable opportunities for development and equitable sharing of its benefits. This includes ensuring that it does not result in any undue detriment for any groups within society, especially the most vulnerable. Both food security and safety are to be promoted as key components of well-being.

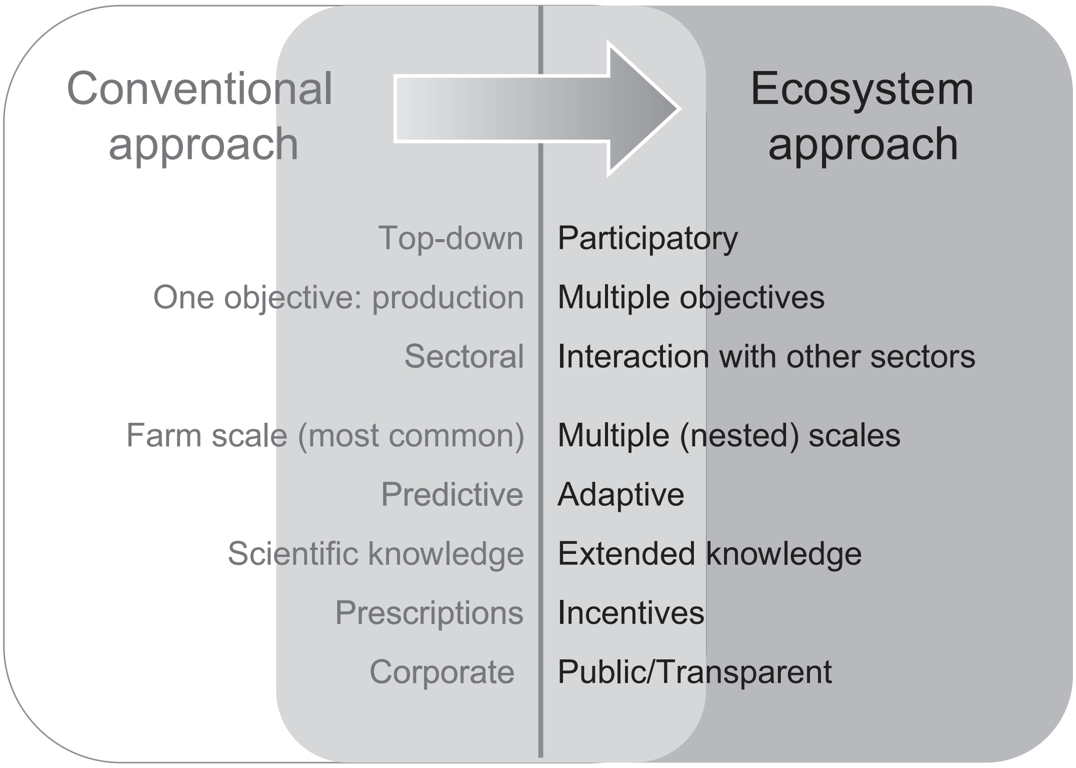
Principle 3

Aquaculture should be developed in the context of other sectors, policies and goals.

This principle recognizes the interactions between aquaculture and the larger system, in particular, the influence of the surrounding natural and social environments on aquaculture practices and results. This principle also acknowledges the opportunity of coupling aquaculture activities with other production sectors to promote materials and energy recycling and better use of resources in general.

Principle 3 is a call for the development of multisectoral or integrated planning and management systems. However, we should make clear that this principle mostly applies to those aspects that are within the ability of the aquaculture sector to change or modify.

Figure 1
The transition from a conventional approach to an ecosystems approach to aquaculture



Modified from FAO (2005).

2. THE EAA IN PRACTICE: PREPARATION AND INITIATION

2.1 Where does EAA fit in a typical aquaculture development planning process and when should it start?

The ecosystem approach to aquaculture as a "strategy" should be the means to achieve or fulfill a higher policy level (see Box 3) that reflects relevant national, regional and international development goals and agreements.

The agreed policy could state something like "Aquaculture should promote sustainable development, equity and resilience of interlinked social-ecological systems" (as described in Section 1.1). Achieving social and economic well-being through aquaculture may have environmental costs (as does any other food production system), and it is necessary to consider such trade-offs.

The policy also defines the roles of the government, the private sector and of producers' organizations in achieving these goals.

A ***strategy*** is usually built around practical objective axes of development, chosen by relevant authorities and stakeholders. These axes usually consist of "technical" objectives (e.g. related to specific forms of aquaculture) and cross-cutting objectives (e.g. related to institutional strengthening, capacity building, research enhancement, etc.) as deemed appropriate to achieve the policy goals.

Box 3
Planning and policy concepts

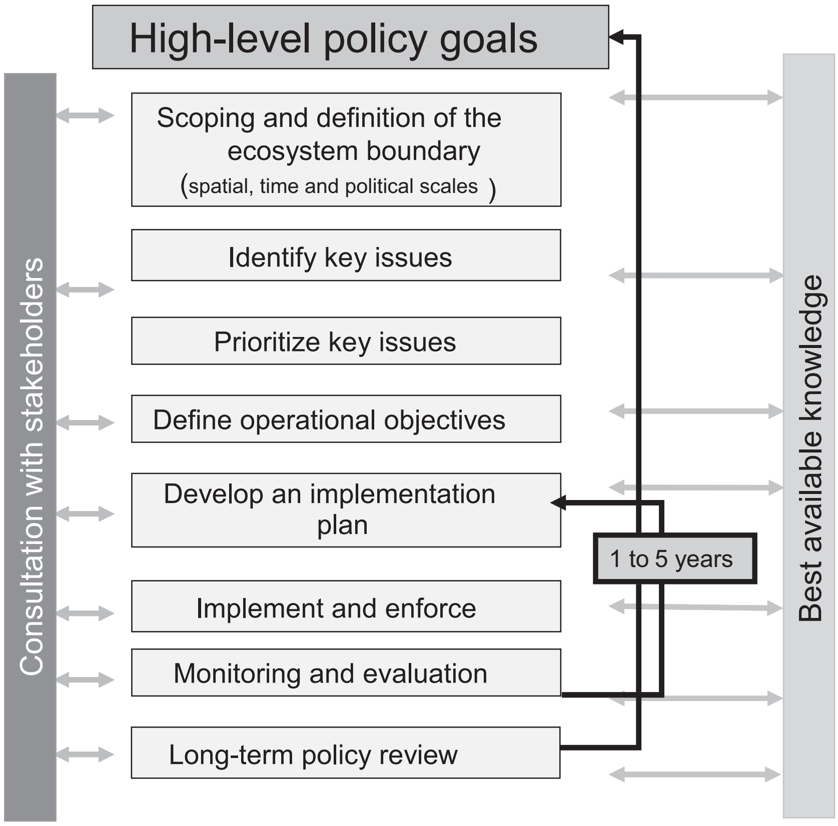
The expert consultation on planning and policy development for aquaculture proposed that:

- An ***aquaculture policy*** consists of a broad vision for the sector, reflecting its directions, priorities and development goals at various levels including provincial, national, regional and international.
- A ***strategy*** represents a road map for the implementation of a policy and contains specific objectives, targets and instruments to address issues which might stimulate or impede the comparative advantage of the sector and obstruct its development. The EAA fits here. Implementing an EAA can be an objective under a country's strategy to achieve a desired (higher level) policy goal (e.g. to develop environmentally sustainable coastal aquaculture).
- An ***action plan*** represents a road map for the implementation of a strategy, that is, to achieve its objectives and implement strategy instruments. It is time-bound, contains specific programmes and activities, and details the resources required to achieve them.

Source: FAO, 2008b.

To implement the strategy successfully, it is necessary to translate the relevant policy goals into operational objectives and actions. Two elements are fundamental throughout the process: (i) to collect and use the best available information; and (ii) to have broad stakeholder participation. The process, steps and potential starting point for EAA are described in Figures 2 and 3.

Figure 2
EAA planning and implementation process



Source: APFIC, 2009.

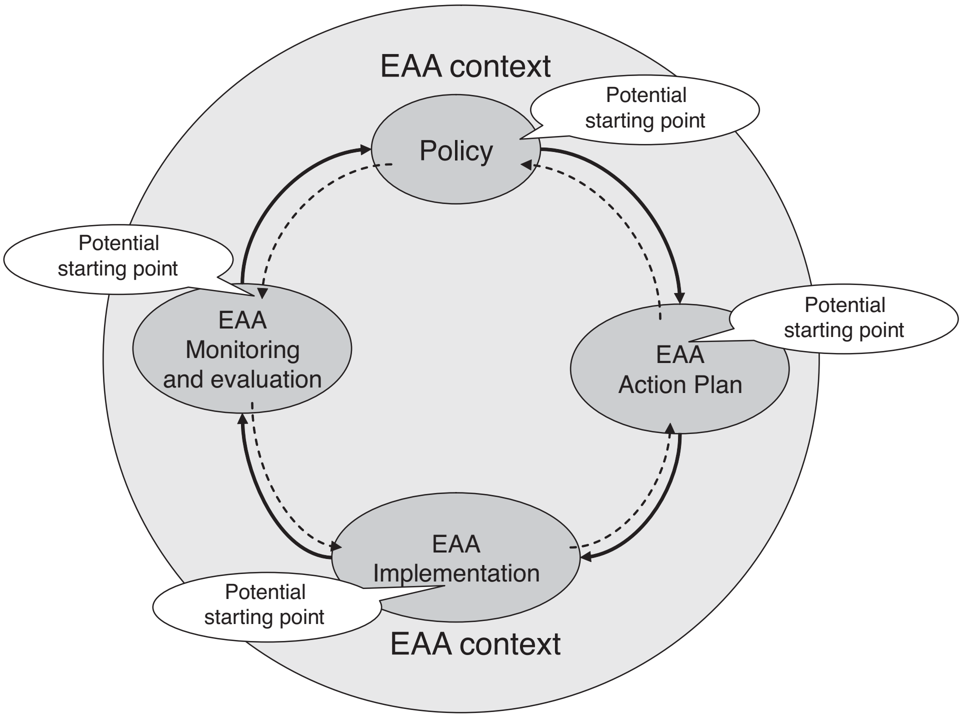
2.2 Scoping

2.2.1 Definition of system boundaries and relevant stakeholders

There is a need to define the ecosystem boundaries in space and time when attempting to implement the EAA. This is a necessary exercise, including the decision on whether planning and implementation of the strategy will cover the whole aquaculture sector of a country/region, or (more typically) will address an aquaculture system or aquaculture area in a country/subregion. Therefore, there should also be a **general objective** or purpose to be addressed at the defined scale.

The ecosystem boundaries are delineated on geological, physico-chemical, biological and ecological grounds, while socio-economic and administrative

Figure 3
When should EAA start? This can happen ... at any point



boundaries outline the management area. The closer the correspondence between the ecosystem limits and management areas, the more likely it is that there will be a high level of harmonization across planning structures. However, these boundaries do not usually coincide. For this reason, a clear mapping of areas of correspondence and gaps is needed. The definition of the ecosystem boundaries is also needed to identify the relevant stakeholders and to address the different issues (Aguilar-Manjarrez, Kapetsky and Soto, 2010).

2.2.2 Spatial scales

Farm scale

The individual farm is easy to locate and identify, and local effects are often easy to assess, although in cage aquaculture, especially in open ecosystems such as open seas, it may be challenging to establish the boundary of potential effects. Most management practices are developed for this scale and most top-down regulation measures, such as the environmental impact assessment (EIA), worldwide apply at this scale. Also better management practices (BMPs) are implemented and can be assessed at this level.

Escapees and diseases originating from aquaculture operations can be prevented/controlled at the farm scale, although their effects usually occur at the next spatial scale, the watershed.

The farm level is also the focal point for ecosystem impacts on aquaculture. Cultured species are sensitive to water quality and are vulnerable to damage inflicted by other users of the waterbody. Thus, issues such as pollution from urban areas, agricultural runoff and industry; predation; and damage from boats, capture fishing and other waterborne gear are highly relevant at the farm level, and protective measures, including pollution regulation, spatial planning and insurance, are important.

Stakeholders at this scale are usually farm owners, workers, family members and local inhabitants.

The watershed/aquaculture zone and geographic region

This geographical scale includes a cluster of farms more or less aggregated (an aquaculture zone) that share a common waterbody and that need a coordinated management.

While the environmental and social impacts of a single farm might be marginal, more attention needs to be paid to the potentially cumulative ecosystem effects of collectives or clusters of farms and their aggregates at watershed/zone scale, for example, eutrophication as a consequence of excessive nutrient outputs.

Escape of alien species or alien genotypes takes place at the farm level. However, relevant impacts on biodiversity often occur throughout entire watersheds. Similarly, disease outbreaks take place first at the farm level, but often need control, management and mitigation at the watershed scale. Similarly, if the direction of pathogen transfer is from the watershed to the farm, detection and management must include the watershed scale.

Stakeholders and relevant institutions include clusters of farms/farmers; watershed management bodies; fishers; commercial fishing representatives; agriculture associations; agriculture, industry and other interacting sectors; aquaculturists; local communities; local authorities; servicing entities (transport, local dealers etc); research and training institutions; etc. The scale at which these entities operate will depend on the nature of the issues.

When the watershed boundaries go beyond political boundaries, different authorities (or, in some cases, even different countries) will need to be involved. The FAO Regional Fishery Bodies[5] can play an important role in this respect, as they can provide the political platform for the implementation of the EAA. Examples of large common waterbodies/ecosystems where

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[5] FAO Regional Fishery Bodies can be found at www.fao.org/fishery/rfb/search/en

aquaculture is expanding are the Mediterranean Sea, the Mekong Delta in Asia, the Volta Basin in Africa and the Amazon Basin in South America.

Large marine ecosystems (LMEs) and marine protected areas (MPAs) are also relevant ecosystem scales.

Global scale

The global scale refers to the global industry for certain commodity products (e.g. salmon, shrimp, catfish) and also to global issues such as production, trade of fishmeal and fish oil for feeds, trade of aquaculture products, certification, technological advances, research and education of global relevance, etc. Of particular importance is the supply of fishmeal and fish oil in some areas of the world that are feed ingredients for fish and shrimp production in other areas. This means that resources and energy are moving between different regions of the world with unexpected consequences. The sustainability of these resources is particularly important for the long-term sustainability of aquaculture.

Global issues can be better tackled by organizations such as FAO, the World Organisation for Animal Health (OIE) and the World Trade Organization (WTO) via seeking action and coordination between governments.

Consumers worldwide are the main stakeholders at this scale.

The most common spatial scales are descibed in Figure 4.

2.2.3 Temporal scales

Aquaculture is affected by external forcing factors or drivers such as population growth and development, global trade and climate change, and these affect the interactions of aquaculture and the ecosystem at all the scales and with a temporal dimension adding to uncertainty. It is therefore necessary to apply a precautionary approach due to unknown ecosystem threshold or resilience, including the human components. Therefore, time scales are relevant in strategy and planning.

2.2.4 Political scales

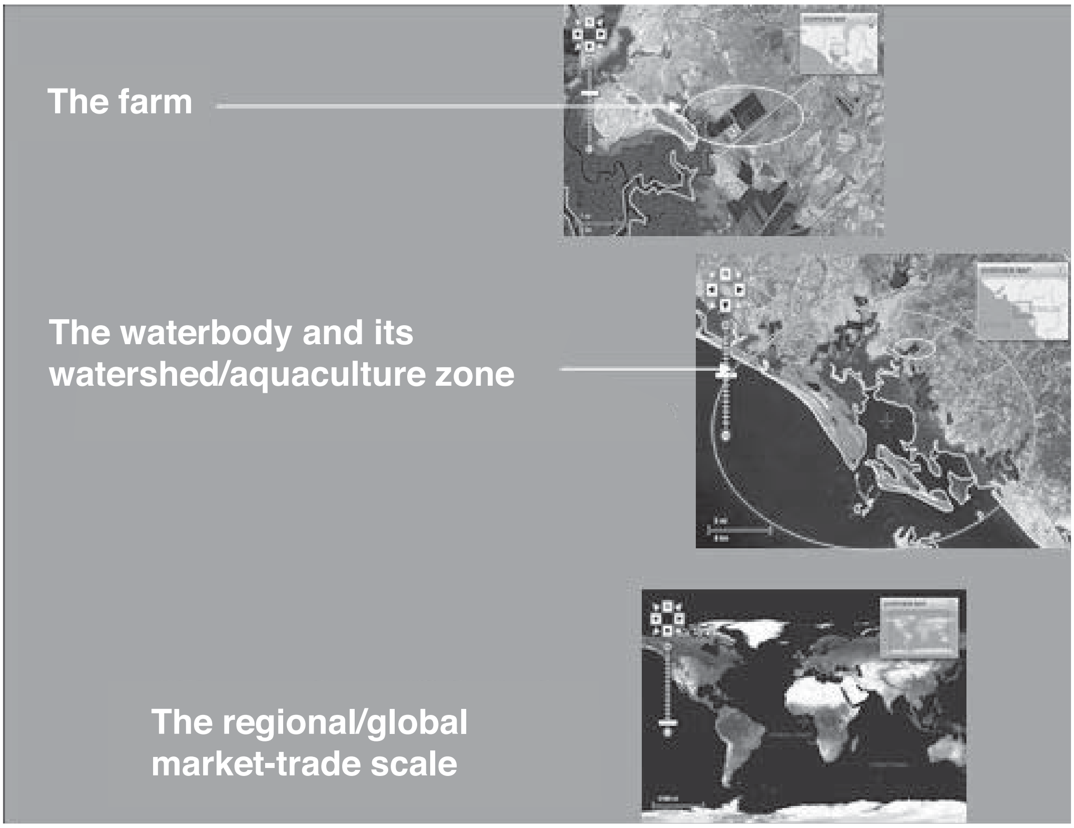
An aquaculture zone or aquaculture regional level is a scale that may go beyond national boundaries and require transboundary political will to implement the EAA. The concepts of coastal zone, offshore and open-seas aquaculture, and watershed management may require creative approaches and political willingness of different administrative entities where water-bodies are shared and the physical boundaries do not coincide with the administrative boundaries within a country or region.

2.3 Stakeholder and issue identification analysis

2.3.1 Stakeholder identification

Once the system boundary has been defined, it is possible to start identifying all the relevant stakeholders. There are basic guidelines for the identification

Figure 4
Relevant geographical scales for an EAA



of stakeholders.[6] For example, stakeholders related to aquaculture in coastal mangrove areas may include: local aquaculture farmers and their communities, local fishers, fisheries and aquaculture authorities, environmental non-governmental organizations (NGOs), environmental institutions, tourism agencies and institutions, organizations associated with the use of coastal infrastructure, research institutions, etc. (see Box 4 for a simple guide).

2.3.2 Identification of issues

Proper identification of issues requires:

(a) involving the relevant stakeholders for the selected system, within the geographical scale and boundaries defined in the scoping process;
(b) having adequate background information available to all these relevant stakeholders; and
(c) establishing a facilitation process that includes a "neutral facilitator" or facilitation system.

6 See www.canari.org/docs/guidelines5.pdf

Box 4
A guide to stakeholder identification in aquaculture activities

Criteria for selection of stakeholders:

- those who have sufficient political clout to draw in officials with the public authority to make the decision;
- those who have legal standing and therefore the potential to block a decision;
- those who control resources (or property rights) necessary for implementation of a decision;
- those who may not be sufficiently organized to pose a relevant threat today, but who may in the near future; and
- those who hold necessary information. 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. Including parties who may have access to such information may be essential to developing wise and stable decisions.

According to the above criteria, stakeholders could include:

- fish farmers and aquaculturists in general;
- capture fishers;
- 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);
- environmentalists;
- scientists;
- homeowners;
- recreational users;
- other enterprises directly using the river, lake or reservoir, coast or marine body (e.g. marinas, ports, shipping, wind farms);
- other enterprises indirectly using the coast or marine body (urban and industrial consumers of waters, polluters, etc.); and
- food and health authorities.

Modified from Shmueli (2009).

Box 5 provides a set of questions that can be used in the identification of issues with stakeholders.

Box 5
Identification of issues with relevant stakeholders

A stakeholder analysis to identify issues in the context of the EAA will aim at answering questions such as:
- What are the current and future interests of the various stakeholders in the use and management of the resource (coastal area, freshwater use, etc.)?
- What are their needs and expectations?
- How do they use the resource and what benefits do they derive from it?
- What are their past and current power, rights and responsibilities (both formal and informal)?
- What are the networks and institutions of which they are part?
- What are the social and environmental impacts, both positive and negative, of their past and current uses of and relationships with the resource?
- How is this relationship changing or being modified due to the aquaculture practices?
- How ready and willing are they to participate in and contribute to an integrated management approach?
- What are the potential areas of agreement and shared interest upon which consensus and collaboration can be developed?
- What are the human, technical and financial resources that they are prepared to contribute to an integrated management process?

Modified from the Caribbean Natural Resources Institute (2004).

2.3.3 Gathering/preparation of complementary information on the socio-economic context of aquaculture development

Gathering relevant information both from the stakeholders' analysis and from relevant documents (formal publications, institutional documents, etc.) is essential to ensure that issues are clearly identified.

The socio-economic dimensions of aquaculture can be classified as:
(a) those accruing directly to the enterprise;
(b) those accruing to the wider economy; and
(c) those that include a range of environmental and social effects.

Geographical scale

At the enterprise and farm level, the main contributions to human well-being include the financial returns to the aquaculture farmer or investor, employment benefits to the farming household or to those working on the farm, and benefits related to food supply and safety for direct consumers of the farm's products. Aquaculture contributes towards the nutritional needs of a wide cross-section of human populations.

However, in general, the major contributions of aquaculture towards the improvement of human well-being are found in the wider economy and the sector as a whole. Here, job creation and investment opportunities involve firms/entities that supply the fish farms and that are involved in processing, marketing, sales and transport.

Food security

Reliability of supply and product quality gain impetus at the aquaculture zone scale because the magnitude of operations needed to sustain the upstream and downstream sectors is beyond the capacity of a single farm. The extent to which the benefits from the farm, sector or multiple sectors benefit local people (including poor and vulnerable communities) depends on the extent to which local interests are involved. In general, when investors are not local, many benefits are exported.

Diversification of livelihoods

One of the most important benefits of aquaculture development lies in its potential to diversify economic activities at the household, community, national and regional levels. This includes on-farm activities as well as off-farm employment, e.g. labour on aquaculture farms and non-farm employment in input supply and marketing chains, processing facilities and management. Such information must be included.

Small-scale aquaculture involves family labour, allowing for fuller utilization of available human resources within the household. The impact on social resilience within a community will depend on whether hired workers are local residents or outsiders.

Interactions with other sectors and opportunity costs

Interaction of aquaculture with stakeholders from other sectors can be synergistic, neutral or conflictual. For example, poorly managed aquaculture that pollutes a waterbody imposes costs in terms of human health, restoration or finding an alternative source of clean water. Similarly, if aquaculture and other sectors are in conflict, there will be trade-offs, the nature of which will depend on existing local priorities and governance structures.

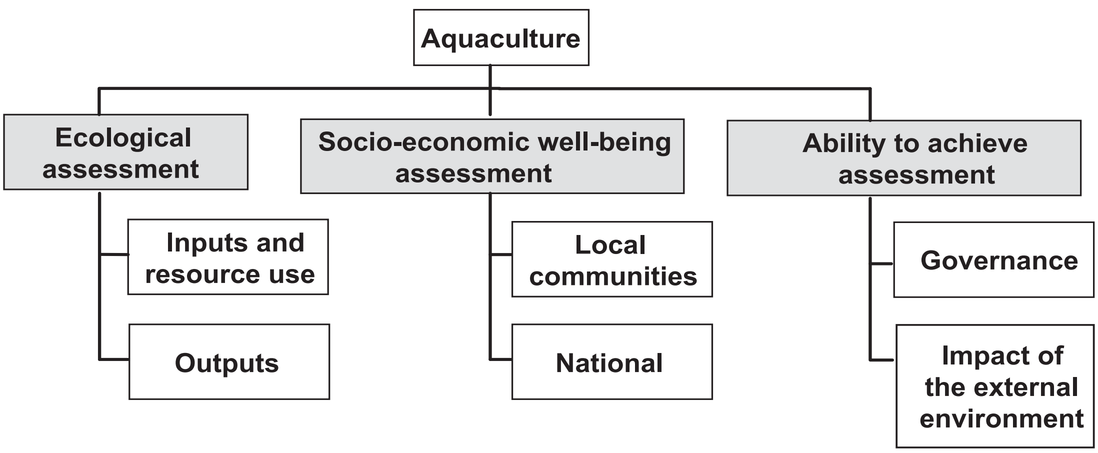
The EAA requires that all the social costs and benefits be assessed as comprehensively as possible, taking into consideration the costs and benefits of other alternative activities. An EAA implies looking at the economics of aquaculture production from a broader social and environmental perspective in order to identify production situations that bring a positive net benefit to society.

2.3.4 Aquaculture issues – effects on the ecosystem and effects of other ecosystem components and external drivers on aquaculture

It is advisable to distinguish *ecological, socio-economic* and "*ability to achieve*" type of issues (Figure 5). An ecological assessment can provide information on ecological issues related to the aquaculture process, considering inputs, resource use and outputs (Figure 6). Often these issues have a related social problem. This could be a cause or a consequence, and most of the time affects local communities, although it could also have national consequences; therefore, a parallel assessment of the socio-economic well-being is advisable.

Also in most cases, ecological and socio-economic issues have a root cause in the "ability to achieve", which includes governance and institutional factors. Typical "ability to achieve" or root causes include lack of adequate knowledge, lack of training, insufficient legislation frameworks, lack of enforcement, problems with user rights, etc. Examples of detailed "tree-issues", as shown in Figure 5, can be found for EAF in FAO (2003) and for EAF/EAA in APFIC (2009).

Figure 5
Assessing ecological, socio-economic and "ability to achieve" issues

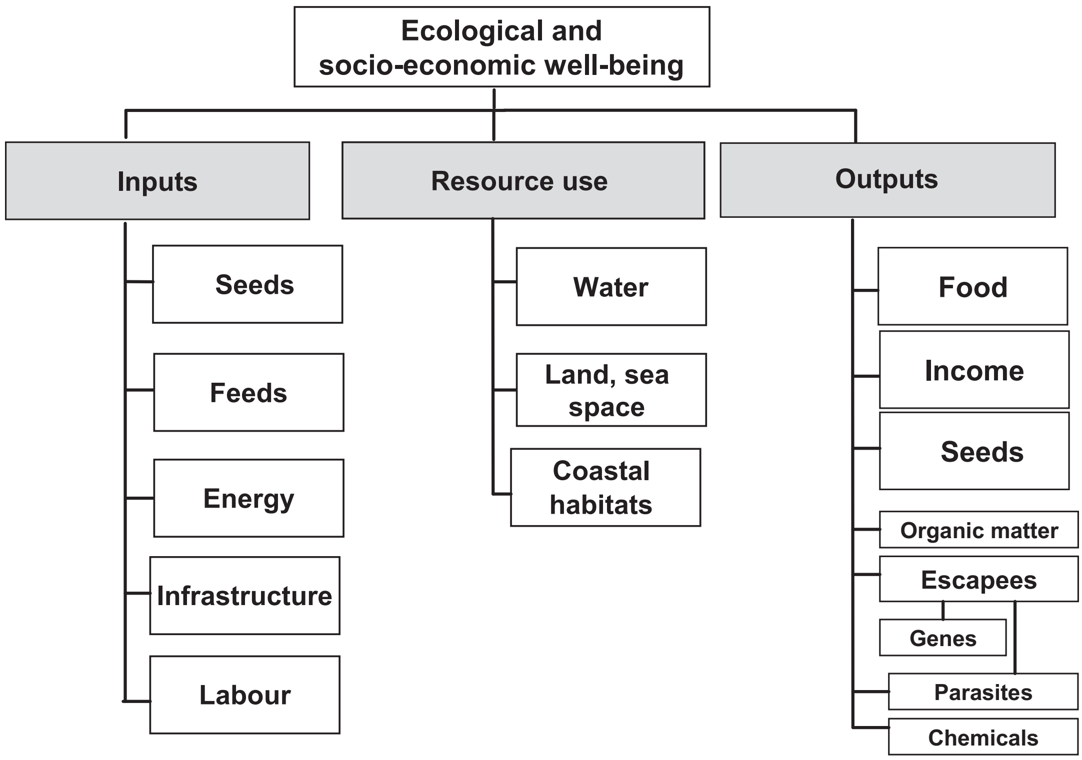


2.3.4.1 Ecological and socio-economic well-being issues

External forcing factors should also be considered under "ability to achieve", for example, catastrophic events, climate change impacts, sudden changes in international markets, etc. Within the external forcing factors, we include the effects of other users of aquatic ecosystems on aquaculture, for example, agriculture and urban pollution of aquatic environments with damaging effects on aquaculture.

A good approach to identify aquaculture issues is to focus on the different steps in the production process, including upstream and downstream (such as post-harvest) aspects, and attempt to find the root causes as explained above. Aquaculture as a production process may require land/sea area as well as water and specific inputs, including labour, to produce expected outputs such as food and income, together with unwanted outputs such as nutrients or chemicals. Issues affecting ecological and socio-economic well-being can be associated with the main parts of the process as shown in Figure 6. As explained earlier, issues are identified within a specific scale and ecosystem boundary.

Figure 6
Schematic tree to identify issues of the ecological and socio-economic nature related to different parts of the aquaculture production process



Negative effects of aquaculture

As summarized in Figure 5, the negative effects of aquaculture often include (first-order impacts):

- increasing demands on fisheries for fish meal/oil, major constituents of carnivorous/omnivorous species feeds;
- unsustainable demand for wild seed or juveniles for fattening (e.g. shrimp and tuna respectively);
- alteration of inland and coastal habitats for the construction of ponds and aquaculture systems (e.g. shrimp farming in mangrove areas);
- nutrient and organic enrichment of recipient waters resulting in build-up of anoxic sediments and modifying benthic communities;
- eutrophication of waterways, lakes and coastal zones;
- release of chemicals used to control water conditions and diseases;
- competition for and, in some cases, depletion of resources (e.g. water);
- negative effects from escaped farmed organisms (often more relevant when exotics are involved);
- restructuring of biological and/or social environments; and
- unfair distribution of income to small farmers and/or to labourers.

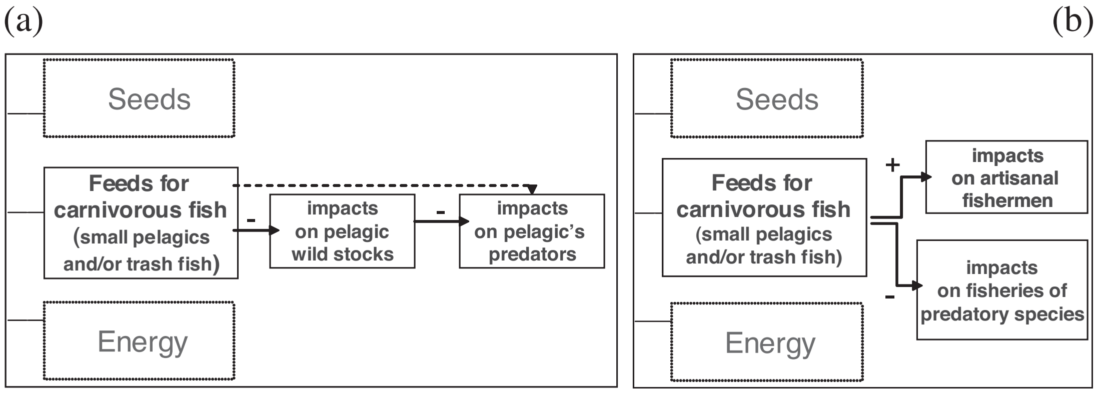
Second-order impacts should also be considered, especially as they can negatively alter the livelihoods of downstream stakeholders, for example, when the construction of shrimp ponds alter habitats, thereby modifying the ecosystem and with it the local fisheries it supports and the livelihoods of local fishers.

Usually direct impacts are of greater concern; nevertheless, indirect impacts can also be relevant and could also have opposing effects. For example, looking at the inputs and at the "Feeds" box in Figure 6, a common issue in some regions is the use of trash fish and/or small pelagics to feed freshwater and marine carnivorous species, which could have a negative impact on the small pelagic stocks (Figure 7a), an ecological issue. However, many small-scale artisanal fishermen live on these fisheries and benefit from the price paid for this feed, and so there is a positive livelihood effect when they do not have other choices (Figure 7b). On the other hand, an indirect negative effect of such an aquaculture-driven fishery could be impacts on wild predator species that live on these pelagic fish. Therefore, the EAA must consider such events within agreed time scales, particularly at the watershed scale.

Positive effects of aquaculture

The most important socio-economic positive effects of aquaculture fall into the categories of food, income and livelihood diversification. An ecosystem approach to the sector should ensure that such positive effects are not overridden by negative impacts in the short, medium and long term.

Figure 7
Expansion of the box "Feeds" in Figure 6 to explain (a) ecological and (b) social issues



Note: Negative (-) and positive (+) effects.

Figures 8 and 9 describe the most common aquaculture issues as impacts related to the production process and affecting environmental and social well-being; positive and negative effects are included. The appendix contains a list of the most common aquaculture issues related to inputs, resource use and outputs at the farm, the waterbody and the global scales.

2.3.4.2 Effects of external components on aquaculture

As explained above, "root causes" and "ability to achieve" issues can be outside the sector.

Pollution

Aquaculture relies on the productivity of a given waterbody as well as on artificial rearing facilities with adequate and sufficient fertilization and/or feeding, so yields are ultimately determined by environmental conditions as well as culture techniques. Increasing levels of pollution of aquatic resources have a negative effect on aquaculture productivity, product safety and profitability. Pollution can be in the form of increased nutrient output (e.g. domestic sewage, agricultural and livestock runoff) leading to eutrophication and possibly to algal blooms or red tides, heavy metals, polychlorinated biphenyls (PCBs), etc.

Climate change

Climate change can affect aquaculture production through changes in seasonality of weather patterns, increasing sea level, warming and increased extreme events leading to unpredictable production. Most aquaculture is undertaken either in freshwater or in the marine coastal fringe, both of which are susceptible to climate change.

Unlike most terrestrial animals, all cultured aquatic species are poikilothermic, meaning their body temperatures vary with the ambient temperature. Therefore, climate change-induced temperature variations will have a much stronger impact on aquaculture activities and on their productivity and yields than on livestock.

Climate change could also alter wild fisheries upon which aquaculture is particularly dependent for production of fishmeal and fish oil and for capture-based aquaculture.

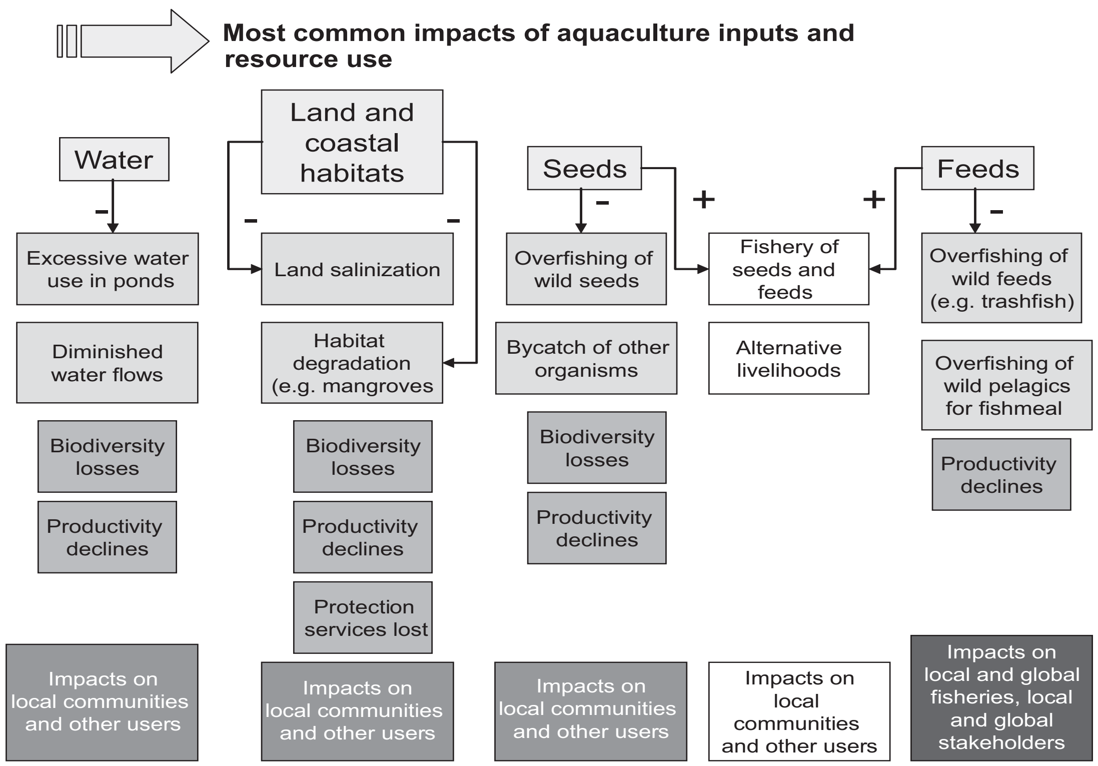
Thus climate change must be considered as a potentially relevant external element affecting aquaculture sector performance and development (Cochrane *et al*., 2009); therefore, preparedness and adaptive measures must be in place.

2.4 Prioritization of issues

A large number of issues can be identified for aquaculture but their importance varies greatly. Consequently, it is necessary to have some way of prioritizing them so that those that require imminent management receive more immediate attention within a plan of action.

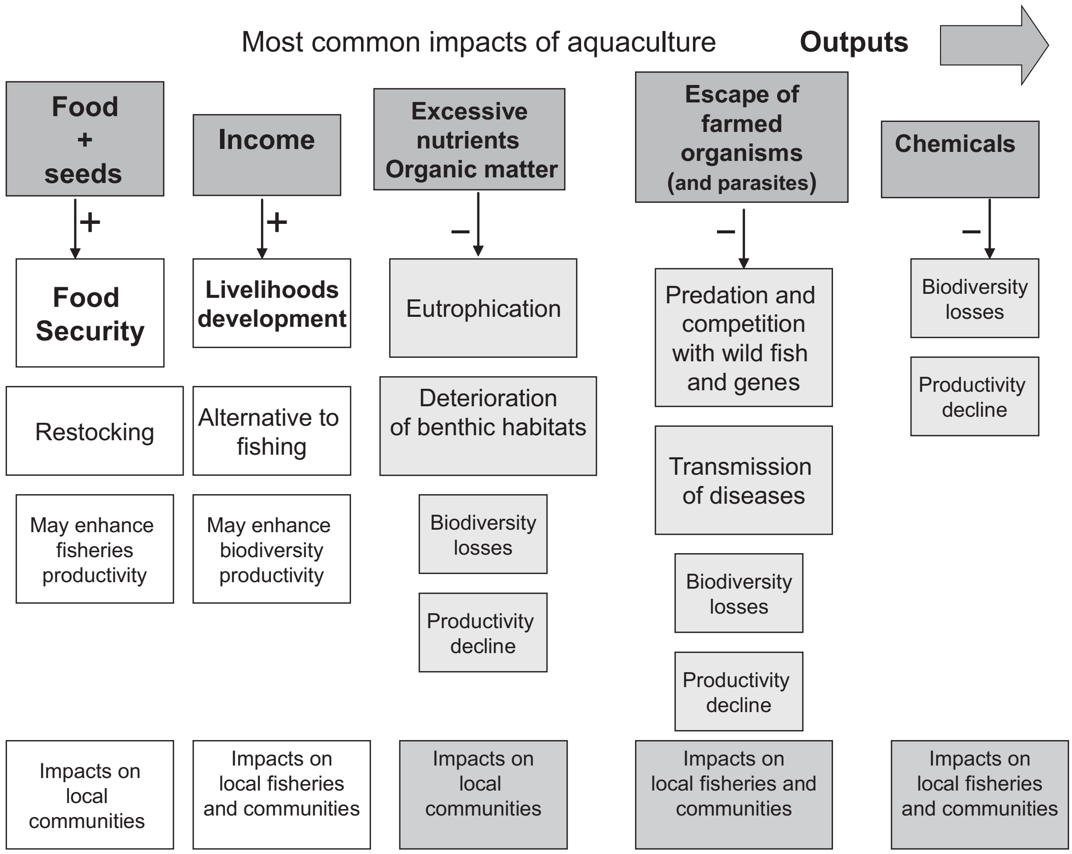
Figure 8

Examples of common issues and impacts related to aquaculture inputs and resource use



Note: Positive (+) and negative impacts (-).

Figure 9
Examples of common issues and impacts related to aquaculture outputs and resource use



Note: Positive (+) and negative impacts (-).

To determine the priority of issues and therefore the appropriate level of management response, the process should use some kind of risk analysis method.

Defining hazards and estimating risks

It is important to define the concept of hazard in aquaculture. This would be a physical agent or event having the potential to cause harm or to impair the ability to achieve a higher level objective. These often include: a biological pathogen (pathogen risk); an escaped aquatic farmed organism (genetic risk, ecological risk, invasive alien species risk); a chemical, heavy metal or biological contaminant (food safety risk); excess organic matter (environmental or ecological risk); the loss of a captive market (financial or social risk).

All risk assessment methods work by assessing the probability of not meeting the developmental objectives (see Section 2.5 below).

A risk analysis typically seeks answers to four questions:

- What can go wrong?
- How likely is it to go wrong?
- What would be the consequences of its going wrong?
- What can be done to reduce either the likelihood or the consequences of its going wrong?

Whichever risk assessment method is used, it must include appropriately detailed justifications as to the levels of risk chosen (high, medium, low, etc.). Often, when there is not enough information or expertise on risk assessment, stakeholders' qualitative local knowledge-based assessments can be used.

This allows other parties who were not part of the process to be able to see the logic and assumptions behind the decisions that were made. It also helps when reviewing the issue sometime in the future – unless we know why we chose the levels, it will be hard to know if anything has changed that may require a shift in the risk levels and therefore management actions. This also assists in understanding the knowledge "gap" analyses/uncertainties. Bondad-Reantaso, Arthur and Subasinghe (2008) and Arthur *et al*. (2009) provide extensive information on risk analysis in aquaculture. GESAMP (2008) also provides good guidance on environmental risk and communication in aquaculture.

The precautionary principle should be used whenever information is not available to make a fully informed decision.

2.5 Establish/define overall objectives and operational objectives

On the basis of the defined objectives, a plan to achieve them can be established (this enables the implementation of the EAA).

The overall objective (= goal) of the EAA is to make the aquaculture sector more sustainable. The EAA should promote ecologically and socially responsible planning and management of aquaculture as an integral part of a community and a region. It should allow integration of aquaculture (and reduce conflict) with other sectors and users sharing the same resources. The means to achieve this should involve a participatory process for planning and management with local communities and other stakeholders.

Operational objectives will depend on the chosen priorities and will be context and situation specific. However, the targets to be achieved should be consistent with the overall objective and should stem from a thorough understanding of the developmental context and developmental options, and an exchange of informed opinion between all stakeholders. However, reaching a consensus may prove difficult and may require resorting to "hard choices" (Brugère *et al*., 2010).

It is essential that objectives are achievable, and that progress toward them is measurable. This implies, for each objective:

- agreed criteria (e.g. nutrient concentration, eutrophication level, new livelihood opportunities) for measuring progress or assessing impact; and
- specific targets or standards (social, economic, environmental) to aim for over a specified time frame.

These targets and standards will serve as the agreed basis for:

- rational and consistent social, economic and environmental assessment of alternative activities to aquaculture;
- appraisal and design of possible planning interventions; and
- monitoring and performance evaluation, and specifically State of the Environment Reporting.

Targets would normally include economic indicators (e.g. per capita gross domestic product [GDP], disposable income, trade surplus); social targets (e.g. related to health [life expectancy], education, equality); and environmental targets (such as a specific level of water quality; presence of an indicator species; an area of coral reef or mangrove forest to be conserved, etc.).

3. IMPLEMENTING THE EAA: THE PLAN

The key steps of the EAA implementation are adapted from those for the EAF (FAO, 2007; APFIC, 2009).

Once there has been a clear and participatory identification of issues and agreement on the operational objectives, implementation of the EAA can begin.

Developing a plan for implementation is the first step. This process should be transparent and participatory, with all stakeholders and local communities consulted during the formulation of the plan of activities and the implementation of management measures, etc., that will allow achievement of the objectives under the umbrella of current aquaculture policy. Developing clear and realistic timelines and estimates of human resources and budgets required for the different activities is essential.

The objectives of the EAA should be in line with the contents of the national aquaculture development policy (and strategy) of the country where the EAA is to be implemented. The implementation of the EAA may be an opportunity to revisit or revise an out-of-date aquaculture policy – or to formulate one if it does not exist.

3.1 Minimum requirements to support the implementation of the EAA

Legal, policy and institutional analysis is an essential part of any new planning and management initiative, especially where a greater degree of integration is sought. The legislation and regulations for aquaculture and the environment or the nature and functioning of institutions and their mode of decision-making will have major implications for the implementation of an EAA. Developing human capacity to be better equipped for the requirements of new approaches such as the EAA is also of crucial importance. All these requirements are also described in detail in Brugère *et.al.* (2010).

3.1.1 Create/enhance enabling legal frameworks

Policy development and implementation should be supported by an appropriate legal framework. It may be necessary to conduct periodic reviews of legislation to assess relevance, effectiveness and conflicts of aquaculture and other relevant legislation relative to policy goals.

The principles of EAA could be represented to a certain extent in general policies and legislation that support sustainable development as environmental consciousness, socio-economic equity and interaction of sectors. One central question therefore is to analyze the extent to which EAA-relevant issues are considered in general policies and legislation for industrial activity (e.g. animal health standards, zoning) or whether they should be handled specifically for aquaculture.

Comprehensive national aquaculture legislation must cover a variety of issues, such as siting, EIA, production control, waste management, product safety and traceability, and diseases and parasites. Thus, many aspects are covered by different areas of law, such as environmental protection, public health, trade, property, land use, planning and animal health. Countries with significant aquaculture production have more sophisticated legislation on aquaculture than countries where aquaculture is less developed.

3.1.2 Strengthen, modify or create new institutional arrangements

The nature of the existing institutions should be assessed, and new institutions or frameworks for institutional collaboration and joint decision-making should be proposed and, if needed, reformed or established. However, it should be recognized that this is not easy (see Section 3.1.3), especially if it involves interdisciplinarity and different sectors. Institutional analysis covers both formal (e.g. a government agency) and informal institutions (e.g. socially transmitted conventions and codes of behaviour).

Sectoral agencies responsible for managing activities impacting aquatic ecosystems (e.g. capture fisheries, coastal zone development, watershed management organizations, agriculture, forestry, industrial developments) must develop new ways (i.e. institutional arrangements) of interacting to regularly communicate, cooperate and collaborate. The need for innovative governance to implement an ecosystem-based approach to aquaculture can be seen as an obstacle, but it also represents an opportunity to increase the social benefits that are likely to arise through synergies among food production and other sectors.

The key is to strengthen existing institutions (or, in their absence, develop new ones) capable of integration, especially in terms of shared objectives and standards. One should, however, be aware that institutional "quick fixes" in reaction to evolving contexts may not be as effective as institutional arrangements modified or created in anticipation of new requirements placed on institutions by new situations.

3.1.3 Integrate aquaculture with other sectors to deal with external and internal issues

3.1.3.1 Zoning

Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation (Box 6). It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture.

The strength of zoning lies in its simplicity, clarity and potential to streamline procedures (Aguilar-Manjarrez, Kapetsky and Soto, 2010). Once a zone has been established and its objectives defined, then developments that meet the objectives and general conditions for the zone may need no further assessment, as what is allowed and what is not allowed should be clear and developers can plan accordingly.

Box 6
Various functions of zoning of land and water for aquaculture development

- help to prevent and control environmental deterioration at the farm and watershed scale;
- help to implement biosecurity measures and disaster risk management;
- reduce adverse social and environmental interactions;
- serve as a focus for estimates of environmental capacity; and
- serve as a framework for the provision or improvement of water supply/drainage infrastructure to small-scale farmers

Modified from GESAMP (2001).

3.1.3.2 Cross-integration

As aquaculture is mostly relatively new and expanding rapidly, it can result in conflicts with other more mature sectors. Principle 3 (Section 1.3) is essentially a call for more integrated planning and management systems, as has been advocated for many years through integrated coastal zone management (ICZM) and integrated watershed management (IWSM).

Aquaculture development affects and is affected by other human activities such as fisheries, agriculture, irrigation and industry, as well as increasing urbanization, so their relative contribution to environmental degradation needs to be assessed and controlled.

Thus, there is a need for sectoral integration of various types (see Box 7).

Awareness-raising is needed within the aquaculture sector and among other sectors at the watershed/zone scale. Integration between different sectors should be facilitated with the ecosystem perspective, especially where mutual benefits are likely to arise, for example, rice and fish farming in areas where the freshwater resource is scarce.

3.1.4 Creating and enhancing human capacity

The development of human and institutional capacity should reflect sectoral needs (e.g. producer, research, management, trade development, regulatory

Box 7
Various types of sectoral integration

- Policy (institutional) integration – minimizing intersectoral conflict; coordinating policy and management measures to ensure consistency and a level playing field.
- Operational (or enterprise level) integration – ensuring that the various activities pursued by a particular enterprise are coordinated and mutually reinforcing. This may include recycling of wastes.
- Waterbody integration – promoting a balance between different activities or sectors within an aquatic system in order to maximize the reuse of nutrients or other materials, thereby increasing efficiency and reducing pressure on the environment.
- Provision of “green infrastructure” – maximizing the delivery of ecosystem services, including waste assimilation, by ensuring that areas or corridors of a range of habitat types are conserved or re-created and managed appropriately.

Modified from Hambrey, Edwards and Belton (2008).

Box 8
Examples of cross-sector integration

- Converting rice fields to aquaculture in areas that are marginal in terms of suitability for rice cultivation.
- Banning the farming of shrimp in traditional rice-producing areas to avoid salinization and obstruction of irrigation canals, to conserve a traditional resource/sector in the face of a lucrative but risky and possibly short-term activity.
- Banning the use of small fish to feed carnivorous fish when small fish are a major human dietary item locally.
- Implementing water framework directives for a more integrated approach to river basin planning and management.
- Facilitating access to fisheries in aquaculture areas to enhance nutrient flow through the harvest of wild fish resources.
- Promoting aquaculture water use for agriculture irrigation (and vice versa).

and associated societal levels). Therefore, it may be necessary to conduct a capacity needs analysis against allocated roles and objectives in the implementation process.

It will be also necessary to ensure that capacity development targets individual, organizational and societal levels; identifies and addresses short-term capacity constraints and long-term capacity issues; and ensures that institutions undergo periodic assessment in order to remain robust, relevant and effective in relation to the objectives of the EAA.

3.1.5 Promote appropriate long-term goal-oriented research and dissemination of knowledge

Relevant research and knowledge are essential for the development of a sustainable aquaculture sector. Appropriate research must be guided by participatory processes and focused on ecosystem functioning/services and human components of ecosystems.

While it is important to use science and knowledge developed at the global level, it is often advisable to also consider local knowledge as well as the need to conduct long-term national research and knowledge building. Often "imported knowledge" cannot be readily applied to local conditions.

It is also relevant to promote knowledge sharing and networking for a more efficient dissemination of reliable information.

Where there is a lack of sufficient scientific knowledge or information to permit a sound decision or where the threat of serious or irreversible damage to ecosystems exists, the precautionary approach should be widely applied. However, a lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental or social degradation.

3.2 Management measures to deal with environmental and social issues

Salient aspects of some practical measures facilitating the implementation of the EAA and leading to achieving "sustainable" aquaculture (environmentally, economically and socially) at all spatial scales are detailed below (Soto *et al.,* 2008).

3.2.1 Dealing with environmental issues

There are many specific mechanisms that serve to eliminate or reduce negative effects on ecosystem functions and services. Some of these require voluntary action by associations of farmers through, for example, better management practices (BMPs); others require better planning, management and regulation by the government.

3.2.1.1 Management measures at the farm level

Environmental impact assessment (EIA)

EIA is a useful tool at the farm level and should be undertaken for large aquaculture projects that have the potential to cause significant impacts on the environment or ecosystem, have significant negative socio-economic impact or lead to significant negative socio-economic impact or significant conflicts with other sectors or users of the aquatic resource.

Small-scale farms or farms with low potential impact on the environment or ecosystem should be exempt, although the cumulative impacts of clusters of small farms should be assessed collectively by a programmatic EIA.

EIA may be used as:

- a decision point for determining if a project should go ahead or not;
- an assessment of the impacts on the environment in terms of extent and severity;
- an assessment of the socio-economic impacts of aquaculture on local communities and other stakeholders;
- a means of developing an environmental management plan that should be implemented for mitigation of impacts; and/or
- a means of developing an environmental monitoring plan that should be undertaken regularly.

Most importantly, the EIA should be based on ecosystem quality objectives (including environmental and socio-economic aspects) agreed upon by the relevant stakeholders and supported by sound scientific information, whenever possible. The EIA must be followed up by regular monitoring surveys on water quality, sediment quality, key habitats and aquaculture-sensitive species and sensitive local communities, when appropriate, as identified in the environmental management plan. The environmental survey should be undertaken by independent specialists.

One of the main outputs of the EIA is an environmental management and monitoring plan that the farm or the cluster of farms should follow during and after operation and that would lead to corrective actions and decisions (an extensive global review, analysis and recommendations on EIA for aquaculture can be found in FAO/FIMA, 2009).

Better management practices

BMPs and codes of practice (COP) are the most technically practical and economically feasible methods currently available to reduce the adverse environmental impacts of aquaculture at the farm level and also at a larger scale. The BMP "solutions" are considered soft law instruments and most often are voluntary in nature; however, they usually require action both from governments in the form of better policy, regulation, planning and management procedures and from the farmers and the aquaculture industry through better practices.

BMPs can involve: site selection, pond construction, pond renovation, overflow effluents, pond draining effluents, water conservation, fertilization, feeds and feeding, fish escape, predator control, aquatic plant control, disease and aquatic animal health management, mortality removal and disposal, facility operation and maintenance, processing, transport, consumer information and marketing. Better practices for aquaculture in cages, pens and rafts involve most of these aspects as well.

A good example of better practices for shrimp farming can be found in FAO/NACA/UNEP/WB/WWF (2006) and a full review of environmental BMPs in Tucker and Hargreaves (2008).

A summary of relevant environmental and aquatic animal health good practices at the farm level is included below.

Optimizing feeds and feeding strategy

The feeding process should try to optimize feed conversion rates (FCRs) to increase profits and to decrease nutrient and organic matter losses. The latter also applies to filter feeders (e.g. molluscs).

Diseases and responsible use of veterinary drugs and chemicals
Biosecurity frameworks should be in place to prevent and control diseases and potential health risks to the culture species or to the environment. All veterinary drugs and chemicals used in aquaculture should comply with national regulations and international guidelines such as those recommended by the World Organisation for Animal Health (OIE, 2009).

Prevention and control of escapees from the farm and safe movement of living aquatic organisms
Farm facilities must ensure secure containment and physical safety nets at all times, including during the normal activities of changing nets, water flushing, etc., to avoid escape of farmed individuals. Large farms should have emergency systems to control or mitigate massive escapes. Due notice should be given to proper authorities in the case of massive escapes, also taking into consideration existing biosecurity frameworks.

The movement of live aquatic animals should comply with all relevant health management measures (FAO, 2007) and procedures such as quarantine (Arthur, Bondad-Reantaso and Subasinghe, 2008) to avoid health-related risks to farmed individuals and to wild populations and the environment in general.

Effluent management and excess nutrient reutilization
Effluent discharge to channels, rivers, lakes or coastal waters may cause eutrophication, an undesirable ecosystem change; however, in other cases, depending on dilution rates, effluents may be a beneficial addition of nutrients that boosts natural or agricultural productivity.

Where excessive nutrients are a problem, it may be feasible to use the following:

- local recycling and integration;
- on-farm or higher level infrastructure for wastewater and sediment treatment, coupled with recycling of nutrient-rich residues at whatever scale is cost effective;
- more efficient use of input resources (e.g. higher quality feed and better feed management practices resulting in decreased FCRs);
- limits to entry based on estimated environmental capacity;
- increased environmental capacity through development/enhancement of natural treatment systems or “green infrastructure”; and/or
- site rotation and fallowing (e.g. in cage culture) to reduce local benthic impacts by allowing time for recovery.

Great care is required in promoting any specific mechanisms to implement the ecosystem approach, as optimal solutions depend on context. Guidance must be flexible and adaptable. The principles are far more important than any specific mechanisms, and the latter are a matter for local ingenuity and choice.

Modern recirculation systems that incorporate waste treatment may be employed. However, some of the principles of traditional aquaculture can be used to reduce the adverse environmental impact of intensive aquaculture effluents. Examples include the use of biofloc[7] technology, aquaponics, linking intensive and semi-intensive systems, pellet-fed caged fish fertilizing a surrounding pond, the 80:20 Chinese fish stocking system (Box 9), and

Box 9
Examples of polyculture and partitioned aquaculture systems

A feed-based system that combines intensive production of high-value fish with traditional Chinese polyculture has been developed by the American Soybean Association (ASA). The system is called "80:20 pond fish culture" because about 80 percent of the harvest weight comes from one high-value species such as grass carp, Crucian carp or tilapia fed with pelleted feed, and the other 20 percent comes from a "service species" such as the filter-feeding silver carp, which helps to clean the water, and the carnivorous mandarin fish (*Siniperca chuatsi*), which controls wild fish and other competitors. Feeding the major high-value species with a nutritionally complete and high physical quality extruded feed results in better feed conversion, faster growth, much higher production and higher profits than in traditional polyculture technology, while having much less impact on the environment. Based on 17 years' experience through trials and demonstrations in China of the American Soybean Association International Marketing (ASA-IM) Program in conjunction with the Chinese Extension Service, the ASA-IM has recently expanded its effort to promote the 80:20 system in countries such as India, Indonesia, the Philippines and Viet Nam.

A "partitioned aquaculture system" (PAS) has been researched that adopts high-rate microalgal culture to fish culture. Low-speed paddle wheels move large volumes of water at low velocities uniformly throughout the pond, with filter-feeding tilapia reducing algal biomass in water produced by fertilization from pellet-fed channel catfish raised in adjacent raceways.

Source: Hambrey, Edwards and Belton (2008).

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[7] Biofloc is a bacterial-based system able to recover nutrients and organic waste within an aquaculture facility which can be used to irrigate and fertilize field crops. Microbial flocs can also be taken up by fish or shrimp and serve as a feed source.

Box 10
Integrated multitrophic aquaculture systems

In recent years, the idea of integrated aquaculture has been often considered a mitigation approach against the excess nutrients/organic matter generated by intensive aquaculture activities. A project in Canada has been working on an integrated system involving Atlantic salmon raised in cages nearby kelps and blue mussel culture since 2001 with the integrated multitrophic aquaculture (IMTA) concept. There is about a 50 percent increase in the growth rate of seaweeds and mussels cultured in proximity to cage farms compared with the growth at a distance, due to the increased food and nutrient availability from caged fish wastes, without uptake of the therapeutants used in salmon aquaculture. However, to increase the incentives for farmers to practice IMTA, it may require changes in government policy to internalize the cost of waste disposal of salmon cage farming to account for the environmental services provided by the extractive species in waste treatment, perhaps through "polluter pays" taxes for salmon farmers and/or "biofiltration credits" for seaweed and mussel farming.

Source: Chopin and Robinson (2004).

partitioned aquaculture systems. Many examples and case studies can be found in Hambrey, Edwards and Belton (2008).

Integrated aquaculture can be considered a mitigation approach against the excess nutrients/organic matter generated by intensive aquaculture activities (Box 10) and may be relevant in some circumstances. In this context, integrated multitrophic aquaculture (IMTA) refers to the explicit incorporation of species from different trophic positions or nutritional levels in the same system (Chopin and Robinson, 2004).

The FAO Fisheries Glossary (2009[8]) describes integrated farming systems as: *an output from one subsystem in an integrated farming system, which otherwise may have been wasted, becomes an input to another subsystem resulting in a greater efficiency of output of desired products from the land/water area under a farmer's control.*

In aquaculture, integration could be within a sector or across sectors. Multiple examples and details on freshwater integrated aquaculture can be found in Little and Edwards (2003) and Halwart and Gupta (2004). A global review on integrated mariculture can be found in Soto (2009). Rice-

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[8] FAO Fisheries Glossary: www.fao.org/fi/glossary/default.asp

fish farming is probably one of the oldest forms of integrated agriculture-aquaculture. Rice fields provide the environment and habitat for fish and other aquatic animals, while the fish contribute to nutrient cycling in the process of feeding on invertebrates and organic particles that are produced in these inundated fields. This type of integrated aquaculture also offers a possibility for a balanced and healthy diet, including protein from fish where otherwise there would be mostly rice. Indirect integration involving the transport of local agricultural by-products such as brans, oil cakes and feedlot livestock manure to the farm may lead to significant fish production.

Integrated aquaculture can also be considered as an opportunity in oligotrophic systems, such as the Mediterranean Sea, while integrated aquaculture in coastal tropical regions can include many forms of integration, such as aqua-silviculture using mangroves as biofilters (Soto, 2009).

Remediation of aquaculture impacts through integrated aquaculture is a core benefit, but increased production, diversification of products, a more diverse and secure business and larger profits should not be underestimated as additional advantages.

3.2.1.2 Management measures at the watershed scale

A main difference with the management measures at the farm level where the farmer is a main player is that at this scale there is a need for an institution, a representative body, an organization, etc., that takes responsibility for the waterbody, watershed or coastal zone. Often this "watershed institution" has to take and enforce the actions and measures described below in Box 11.

Box 11
Some examples of "aquaculture area or zone" management

In both Ireland and the United Kingdom of Great Britain and Northern Ireland, aquaculture management frameworks such as Area Management Agreements (in the United Kingdom) and Single Bay Management and Co-ordinated Local Aquaculture Management Systems (in Ireland) have been initiated. These allow the coordinated management of aquaculture (particularly in enclosed bays) for harvesting, fallowing and disease treatments. This can be particularly effective in combating infestations of sea lice in salmon farming.

The clustering of many small-scale aquaculture producers into mariculture parks has been encouraged in the Philippines by the Government to promote further livelihood development in aquaculture and to be able to target support services (jetty, supply of ice, etc.).

Strategic environmental assessment (SEA)

The objective of a strategic environmental assessment (SEA) is to mainstream environmental and social considerations into programmes, plans and policies, mitigate negative impacts and maximize potential positive synergies at the sector watershed/waterbody scale and/or sector scale.

SEA focuses mainly on impact assessment, and its goal is predicting environmental impacts to establish prevention, mitigation and control measures to protect the environment in the waterbody of interest.

Defining limits to change

EAA guiding Principle 1 (Section 1.3) implies that we can define the point at which environmental change threatens sustained delivery of ecosystem services. In practice, this is extremely difficult, especially with respect to changes in biodiversity. The definition of "acceptable" will depend on local social and economic conditions and perspectives.

Defining or agreeing upon acceptable limits is often difficult as, in general, there is no obvious threshold in terms of the characteristics of the system or in terms of service delivery. There may be very different perspectives as to what constitutes a suitable "acceptable limit" or an adequate level of "precaution". The science may be inadequate to inform these discussions. The watershed institution mentioned above requires agreeing on absolute or precautionary limits, and this process should be well informed and participatory to the extent possible.

In some cases, however, defining limits to change is relatively straightforward. For example, a certain concentration of nutrients in water may trigger undesirable or toxic algal blooms. This point may be termed a threshold characterized by significant differences in terms of service provision.

Maintaining an "agreed" biodiversity

Biodiversity is often associated with ecological resilience. A reduction in biodiversity may reduce available pathways for natural processes and by implication, ecosystem resilience. A precautionary approach would seek to conserve as much biodiversity as possible; if local losses are accepted (e.g. under a fish cage), then recovery in the vicinity must be ensured. In setting limits to change, it is essential that some resilience is retained in terms of service provision. This implies two things: (i) acceptable limits include a safety margin; and (ii) factors that strengthen system resilience such as biodiversity and livelihood diversity should be promoted as much as possible.

Providing and enhancing green infrastructure[9]

Most countries have policies to designate nature reserves or protected areas to safeguard ecosystem services in the wider environment. Increasingly, however, the focus on ecosystem services is encouraging a more holistic approach to biodiversity conservation. Ecosystems and their associated biodiversity are part of the "green infrastructure" that sustains ecosystem service delivery.

The nature, amount and pattern or distribution of this green infrastructure should be a matter of national policy, informed by science and local needs and perspectives. The decision on the area to be assigned will be more or less precautionary depending upon the commercial value of land and water, the wealth of the government and/or the people using that resource, and the level of experience and awareness of problems associated with environmental degradation.

Staying within carrying capacity

Understanding and measuring environmental capacity[10] allows for the determination of the scale of activity (using a specified technology) that can be accommodated without threat to an environmental standard. Environmental capacity measures the resilience of the natural environment in the face of impact from human activities and must be measured against some established standard of environmental quality. In setting limits to change, it is essential that some resilience is retained in terms of service provision.

Environmental carrying capacity

Environmental carrying capacity[11] in the context of aquaculture refers to a specific area or waterbody, such as a bay, estuary, lake or river and usually concerns:

- the rate at which nutrients can be added without triggering eutrophication;
- the rate of organic flux to the benthos without major disruption to natural benthic processes; or
- the rate of dissolved oxygen depletion that can be accommodated without causing mortality of the indigenous biota (GESAMP, 1996)

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[9] Providing "green infrastructure" is the strategic allocation of significant patches or swathes of undeveloped land or waterbodies of different types which will increase biodiversity, underpin many other ecosystem services, and increase the resilience of the whole system.

[10] Environmental capacity is a general term for "a property of the environment and its ability to accommodate a particular activity or rate of an activity...without unacceptable impact" (GESAMP, 1986).

[11] However, there is also the concept of production capacity for extractive species such as filter feeders (e.g. bivalves) in relation to the maximum biomass to be produced given the current plankton productivity available for their feeding.

Aquaculture development should always be within the carrying capacity of the ecosystem. An ecosystem approach would examine more carefully the desirability of different nutrient levels in different parts of an agro-ecosystem from the perspectives of the various users and in terms of the stability of the system as a whole. Thus, there needs to be a flexible and participatory approach to setting water quality standards.

Acceptable water quality standards

The water used for aquaculture should be suitable for the production of food that is safe for human consumption. Farms should not be sited where there is a risk of contamination of the water in which animals are reared by chemical and biological hazards. If wastewater is used, World Health Organization (WHO) guidelines for the use of wastewater in aquaculture should be followed (WHO, 2006). Farms should maintain water quality within the relevant national water quality standards.

The standards used by government usually relate, very loosely, to nutrient levels that may cause algal blooms and deoxygenation or compromise drinking water quality. These issues, however, need to be examined in relation to a waterbody or system and the needs and aspirations of the people who depend on it.

Encouraging culture-based fisheries and stock enhancement when appropriate

Stocking of fish in enclosed waterbodies and areas amenable to fencing, especially artificial lakes and reservoirs, may result in yields significantly greater than those from wild fisheries. Such aquaculture-fisheries integration offers a great potential for poverty alleviation and food security with minimal inputs (only the seed) and minimal or no environmental impacts, since there is neither containment nor external feeding.

Institutional arrangements must be secured to ensure equal access to this resource to all relevant stakeholders. There is always the danger of those with greatest capital effectively making the greatest investment and taking the greatest share.

The main caution in this practice is the careful management and selection of the seeds in order to avoid negative genetic impacts on natural populations. Also, the stocking with exotic species should be done with due precaution to avoid ecosystem impacts from the establishment of alien species that would damage wild populations. Some form of risk assessment is recommended as a necessary step before any stocking. For more information on the precautionary approach to species introductions and about genetic resource management in culture-based fisheries, see Bartley *et al*. (2005) and FAO (2008d), respectively.

Discouraging unsustainable use of wild seed, juveniles and broodstock
All forms of capture-based aquaculture (CBA) need to be evaluated in light of economic viability, the wise use of natural resources and the environmental impact as a whole. Appropriate management of wild stock should be in place according to EAF (FAO, 2005). Greater efforts must be made to produce seeds in hatcheries, in terms of research, investment and capacity building. However, the positive livelihood side of wild seed and broodstock fishery must be taken in consideration when attempting to regulate or close such fisheries.

3.2.1.3 Management measures at the global scale
Assessment of progress towards an EAA at the global level entails evaluation of issues such as availability of agriculture and fisheries stocks for aquaculture feeds, economic and social impacts of aquaculture on agricultural and fisheries resources, and impacts on the broader freshwater and marine ecosystems and societies' infrastructure. At the global scale, knowledge enhancement and dissemination of risk assessment tools, risk communication, life cycle analysis[12] and other similar practices to deal with the management of uncertainties may be promoted. Developing global agreements on BMPs and facilitating dissemination of appropriate information to consumers allowing them to differentiate products according to such practices are also relevant.

Wildfish stocks and provision of sustainable fish feed
Aquaculture must reduce its reliance on global fisheries for fishmeal and fish oil if it is to supply a substantial proportion of fish for human consumption in a sustainable way.

Impressive gains have been achieved in reducing FCRs for some carnivorous fish and in substituting non-fish ingredients into formulated feeds. The volume of omnivorous species production has also raised (e.g. tilapia, carps and catfish). Nonetheless, serious challenges remain for lowering the aggregate level of fishmeal and fish oil inputs in feeds and alleviating pressure on reduction fisheries over time.

Global efforts must be made to find alternative, more sustainable feed ingredients for carnivorous fish and for all fed-aquaculture species in general.

The culture of omnivorous and herbivorous species should be enhanced, as well as the culture of filter-feeder and extractive species.

Trade
The aquaculture sector has emerged to increase fish supplies and to meet the demands of the market and must do so through fair trade, considering

[12] Life cycle analysis is a methodological framework used to quantify a wide range of environmental impacts that occur over the entire life cycle of a product or process.

Box 12
Socio-economic issues to be considered at all stages of aquaculture development to optimize benefits and avoid or minimize negative economic consequences

- Rural communities, producer organizations and farmers are supported by whom and by what, and are provided a decent living wage.
- Risks to small-scale producers are minimized through training, extension and appropriate technical and financial support.
- Equitable sharing of benefits and fair wages.
- Employment and alternative livelihood opportunities are created for local community members.
- No negative impacts on the livelihoods of local communities.

Source: FAO, 2008c.

all EAA guiding principles. Adequate certification systems can facilitate and enhance aquaculture production with an ecosystem perspective, taking into consideration all the above.

3.2.2 Dealing with social issues

The EAA requires that all the social costs and benefits are assessed and choices made for the benefit of society as a whole (Box 12). The key question is net benefit and perhaps, more importantly, the distribution of costs and benefits. There is a need to improve the well-being of all relevant stakeholders.

Aquaculture development has the potential to reduce the resilience of human communities. Construction of shrimp ponds in some countries has decreased social resilience by reducing the availability of mangroves that provide a wide array of resources to people living in coastal communities and causing social unrest, although it has led to considerable economic development and employment along the food chain.

New or reformed institutions (see Section 3.1.2) should encompass "in-built" conflict resolution mechanisms (either internally or through a mediator) to deal with conflicts as they arise. Minimization of conflicts should be one of the key outcomes of the implementation of an EAA.

3.3 Incentives

Incentives, where appropriate, should be used throughout the sector to enshrine in the legal framework economic and other incentives for good practices to ensure continuity in the face of political change.

Box 13
Different kinds of incentives that can be developed in isolation or in combination

- improved institutional frameworks (definition of rights and participatory processes);
- developed collective values (education, information and training);
- economic incentives (e.g. tax mechanisms and subsidies) such as special advantageous licences (for example, for integrated aquaculture, for polyculture, for implemented better management, etc.); and
- market incentives (aquaculture certification and tradable property and access rights, e.g. aquaculture concessions).

Modified from FAO (2005).

Incentives can influence the nature and location of development and the management of operations. Incentives do not suffer from the problems of evasion and non-compliance as do regulatory approaches and in some cases can be used to stimulate innovation leading to more environmentally friendly technologies.

According to the EAF practical manual (FAO, 2005), "incentives provide signals reflecting public objectives while leaving some room for individual and collective decision-making to respond to them" (Box 13).

Incentives work indirectly through affecting those factors that lead to particular individual or collective choices. Market or social forces can be efficient means to force the global outcome of individual actions towards collectively set objectives. They may also be necessary to create mechanisms to internalize externalities through advice, development support and training.

Often an important incentive is to allow for gradual implementation and compliance of norms, regulations and agreements, including aspects of economic assistance, for example to bear with initial costs. This needs to go along with a simplification of mechanisms, for example, for certification or compliance.

The use of economic instruments to influence both siting and operation of aquaculture farms holds considerable promise. Loss of biodiversity can be addressed through on-farm incentives to minimize the use of chemicals and through off-farm development of green infrastructure (see Section 3.2.1.2). Although some positive incentives may be costly, it should be possible to pay for them with negative incentives (e.g. taxes on undesirable locations, activities, technologies). However, regulation may nonetheless be necessary and a balanced approach is required.

Financial incentives and deterrents
These may also be considered as legal instruments: non-compliance is "punished" either *ex ante* (by requiring a payment returnable upon compliance) or *ex post* (by charging a fine when non-compliance occurs). A variation of this is liability insurance, where polluters are made legally liable for damage (for example, to fish nursery grounds). This will encourage the establishment of insurance schemes, the premium of which will be related to the risks of environmental damage caused by the operator, offering an incentive for improved design, technology and management.

3.4 Standards for application

An EAA should consider the use of certification and ecolabels, going beyond "meeting the regulations" to include not only production but also environmental and social criteria for product differentiation. These certification schemes should allow for and encourage fair trade and should not create unnecessary obstacles to trade nor be more trade restrictive than necessary to fulfil the legitimate objective of the standards. Efforts must be made to assist small producers operating sustainable production systems, and one way is to encourage certification or ecolabels at the aquaculture zone or waterbody scale where farmers are acting in a coordinated way. They should address social issues, environmental issues, food safety and quality, and animal health and welfare.

3.5 Indicators and monitoring impacts

The use of indicators is included as part of monitoring programmes, where the indicator is directly measured and is used as a measure of severity and extent of social and ecosystem impacts. Indicator thresholds such as in water quality standards or criteria may be set by environmental authorities but can also be determined by stakeholders themselves (e.g. tolerance levels). They may also be set using a participatory process for a watershed or waterbody where aquaculture and other activities take place.

The impact monitoring survey type and frequency should be proportional both to the predicted and actual impact. Monitoring programmes and the use of indicators can be conducted at different levels. Farmers/authorities can perform simple and inexpensive surveys when impacts are expected to be minor, whereas more detailed surveys can be performed by specialist companies or authorities at short intervals when impacts are expected to be greater (this is especially relevant at the watershed or waterbody scale). The outputs of the surveys should be an impact mitigation plan to take corrective actions when some impacts are found to be beyond limits.

3.5.1 Environmental indicators and monitoring

The description of the monitoring programme is often an output of the EIA or EIA statement. The monitoring protocol proposes what type of indicators should be used to monitor the impact of the farm during the operation and the acceptable levels of impact. It uses sampling to quantify the extent and severity to which aquaculture management affects the ecosystem over time, by comparing current data collected at various locations in time during operation with data obtained in the EIA, baseline environmental survey or before development (see recommendations in FAO, 2009).

It is essential to consider monitoring the aquaculture zone, watershed or waterbody. Often this is more important than monitoring individual farms, especially when these are individually small, although their cumulative impact can be large.

Typically, monitoring should include: (i) impacts on water and sediment quality, including physico-chemical and biological indicators; (ii) eutrophication condition and impacts on sensitive habitats such as mangroves, sea grass beds, etc.; and (iii) other impact on fauna and flora. Monitoring should always take place in the potentially impacted site, as well as in a reference site in order to account for impacts of other factors beyond aquaculture.

Monitoring of indicators should provide information relevant to ecosystem "resilience" or "resistance" to the effects of human-induced or other factors. In general, ecosystems recover readily from small disturbances, which are, indeed, part of the natural state of things. The resistance of an ecosystem indicates the amount of disturbance that it can accept without damage to its prospects for rapid and full recovery, for example, the ability of the benthic fauna to recover its original condition after the removal of a fish cage.

3.5.2 Socio-economic indicators and monitoring

There should be identification of social indicators and monitoring to promote integration with local communities and to prevent conflicts with them. It should examine the impacts of production on the creation of new direct and indirect employment and its relation to local employment. Its impacts on other waterbody users should also be identified especially those linked to the utilization of coastal and aquatic resources such as fisheries, tourism, transport and diving. Impacts on the local economy, such as income, taxes and exports, are also a key element.

The socio-economic impacts of well-managed aquaculture are usually positive, although some conflicts may arise. As a mitigation measure, various initiatives can be proposed, such as consultation with the local communities and other sectors during the planning process and, in general, encouraging a positive impact on the local economy (through employment, income, taxes, exports, and transport and harbour infrastructure, Box 14).

Box 14
Most commonly used socio-economic indicators

Indicators	Examples
Educational indicators	• Illiteracy rates (with respect to age and gender) • Years of study (with respect to age and gender)
Employment indicators	• Unemployment rates (with respect to sector, age and gender) • Type of employment and salary distribution (with respect to sector, age and gender)
Family and home facility indicators	• Household income, house ownership and housing facility situation, such as sanitary facilities, water supply facilities, energy supply facilities, etc.
Economic indicators	• Gross income per hectare • Profit • Return to labour (dollars per man per year) • Employment per hectare • Return to labour per hectare • Employment per tonne of product • Capital investment per job created
Shareholder and investor indicators	• Financial returns • Creation of shareholder value • Overall sustainability of the business • Future outlook and challenges
Community indicators	• Sustainability of local fish stocks • Health of the harbour and its suitability for recreational activities (including fishing) and employment rates
Employee indicators	• Competitive rates of pay, working conditions and work/life balance • Employee equity and benefits such as superannuation
Customer indicators	• Quality of the product • Competitive pricing • Steady supply • Environmental standards
Supplier indicators	• Environmental footprint (in particular, waste management and packaging) • Customer satisfaction as well as logistics and fuel efficiency

Adapted from FAO (2008a).

3.6 Tools in support of the approach

3.6.1 Modelling

Modelling plays an important, perhaps essential, role in determining acceptable limits of aquaculture or any other anthropogenic impacts, since without predictive models we cannot assess whether the impacts are acceptable until they have occurred and been observed, which is almost always too late (Silvert and Cromey, 2001).

Sustainable carrying capacity models

Aquaculture production facilities should adjust their production to the carrying capacity of the local environment or the local social context. Each ecosystem has a different capacity to absorb and assimilate excess loading of organic compounds and nutrients. This is particularly important in areas with low water exchange such as shallow, inshore and sheltered areas. The social context in any ecosystem also has some limited capacity to resist impacts.

A breakdown of different sustainable carrying capacities, including social capacity for bivalve aquaculture, was described by McKindsey *et al.* (2006) and is adapted in Box 15.

Ecological models should be used to evaluate quantitative and qualitative relationships between production and habitat attributes (e.g. pollution gradient, organic particles in sediments) and sensitive habitats or species. This is based on the expected production level, the species to be farmed and their faecal particle properties and assimilation, and the current patterns, information on which is obtained from the literature and hydrodynamic models.

3.6.2 Spatial planning tools

Essential elements for the implementation of the EAA are spatial planning tools, including Geographic Information Systems (GIS), remote sensing and mapping for data management, analysis, modelling and decision-making.

There are a number of key issues in the planning and implementation cycle of the ecosystem approach that require explicit consideration of spatial information about ecosystem components and properties. These include: (i) development of aquaculture (i.e. identification of suitable sites, zoning or allocation of space, EAA planning for development); (ii) aquaculture practice and management (i.e. aquaculture impacts at different scales, aquaculture inventory); and (iii) multisectoral development and management that includes aquaculture (i.e. transboundary issues, integration issues).

Some of the uses of spatial planning tools for the development and the implementation of the EAA are:

- Description and mapping of issues, especially with regard to resource use and allocation.

- Specific planning interventions related to site selection criteria and in some cases, to zoning. Recent advances in remote sensing have greatly enhanced our ability to describe and understand natural resources, facilitate planning of aquaculture development, and support EIA and monitoring, and the use of GIS has greatly enhanced our ability to store, analyze and communicate this information.
- For local or enhanced sectoral planning initiatives, the use of existing maps, field visits and "rapid appraisal" could be more cost effective in the short term. Also the imagery from the earth browsers such as Google Earth has provided a free and readily available, valuable tool for use in developing country districts, towns and villages. Here planners who are allocating water and land space for aquaculture can access a spatial

Box 15
Different sustainable carrying capacities for bivalves

Physical carrying capacity: the total area of farms that can be accommodated in the available physical space without undue conflict with other users of water surface area.
Production carrying capacity: the stocking density of production at which harvests are maximized without undue impact on the environment.
Ecological carrying capacity: the stocking or farm density above which there are unacceptable ecological impacts.
Social carrying capacity: the level (intensity, scale, productive system, etc.) of farm development above which there are unacceptable social impacts.

Clarifying the relationships between aquaculture nutrient effluents, the measurement variables and the environmental consequences depends on an understanding of physical, chemical and ecological processes including:

- the dispersal of nutrients or other substances in receiving water;
- the dilution of these substances in the receiving water;
- the degradation or breakdown of these substances in the water column or sediments;
- the adsorption of these substances by sediments;
- the assimilation of these materials by plants or animals; and
- the effects of these materials on different components of the ecosystem.

Adapted from McKindsey *et al.* (2006).

planning tool for aquaculture in a low-cost and effective way. Remote sensing and sophisticated GIS are usually more suitable as higher level planning and management tools, i.e. where their cost can be effectively spread across sectors and where the mechanisms for their maintenance can be more easily implemented.

- GIS can facilitate the task of bringing together the criteria for locating aquaculture and other activities or to define zones suitable for different activities or mixes of activities, including aquaculture. Aguilar-Manjarrez, Kapetsky and Soto (2010) provide an extensive overview on the potential of spatial planning tools to support the ecosystem approach to aquaculture.

4. MONITORING AND EVALUATION

An EAA requires monitoring and evaluation and a system for review and adaptation to be built into the process. The review process must address the achievement of overall objectives and operational objectives (Section 2.5) according to the agreed specific targets and standards, which can be translated in simple indicators. Often there is also the need to review the long term policy (Figure 2). The timing and evaluation system will be specific for each particular situation and local conditions; however this must be done at regular intervals to systematically compare the current situation and what has been achieved to date with reference points defined for each indicator. An EAA would typically include both continuous monitoring and short-term and long-term review and evaluation cycles.

5. FUTURE DEVELOPMENTS

Aquaculture continues to grow rapidly and provides an increasing proportion of fishery products for human consumption. An ecosystem approach to aquaculture (EAA) can identify factors contributing to resilience of both social and biophysical systems and provide a way to plan and manage aquaculture development in integration with other sectors' development and with increased benefit to local communities.

A main challenge for EAA will continue to be the overcoming of sectoral and intergovernmental fragmentation of resource management efforts and the development of institutional mechanisms for effective coordination among the various sectors active in the ecosystems where aquaculture operates and among the various levels of government guiding and regulating aquaculture development. However, there is an increasing awareness about the need for an ecosystem-based management across sectors and, therefore, such coordination is expected to be easier in the near future.

The widespread adoption of an EAA will require a much tighter coupling of science, policy and management. It will require governments to include the EAA in their aquaculture development policies, strategies and development plans.

The present EAA guidelines provide a general framework for implementation and for the promotion of a process of enhanced sectoral management at different scales, taking full account of environmental and social limits and the interests of resource users and stakeholders outside the aquaculture sector. However, there is a need for further practical guidance on different implementation aspects, and FAO's Fisheries and Aquaculture Department is making efforts to develop such practical implementation aids and toolboxes. Hence, these guidelines should be considered as a work in progress, with potential for expansion, alteration and development in the future.

REFERENCES

Aguilar-Manjarrez, J., Kapetsky, J.M. & Soto, D. 2010. *The potential of spatial planning tools to support the ecosystem approach to aquaculture*. Expert Workshop, 19–21 November 2008, Rome, Italy. FAO Fisheries and Aquaculture Proceedings No. 17. Rome, FAO. 176 p.

APFIC. 2009. *APFIC/FAO Regional consultative workshop "Practical implementation of the ecosystem approach to fisheries and aquaculture"*, 18–22 May 2009, Colombo, Sri Lanka. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2009/10. 96 p.

Arthur, J.R., Bondad-Reantaso, M.G., Campbell, M.L., Hewitt, C.L., Phillips, M.J. & Subasinghe, R.P. 2009. *Understanding and applying risk analysis in aquaculture: a manual for decision-makers*. FAO Fisheries and Aquaculture Technical Paper. No. 519/1. Rome, FAO. 113 p. (Available at www.fao.org/docrep/012/i1136e/i1136e00.htm)

Arthur, J.R., Bondad-Reantaso, M.G. & Subasinghe, R.P. 2008. *Procedures for the quarantine of live aquatic animals: a manual.* FAO Fisheries and Aquaculture Technical Paper. No. 502. Rome, FAO. 74 p. (Available at www.fao.org/docrep/010/i0095e/i0095e00.htm)

Bartley, D.M., Bhujel, R.C., Funge-Smith, S., Olin, P.G. & Phillips, M.J. (eds). 2005. *International mechanisms for the control and responsible use of alien species in aquatic ecosystems.* Report of an Ad Hoc Expert Consultation. Xishuangbanna, People's Republic of China, 27–30 August 2003. Rome, FAO. 195 p. (Available at www.fao.org/docrep/009/a0113e/a0113e00.htm)

Bondad-Reantaso, M.G., Arthur, J.R. & Subasinghe, R.P. (eds). 2008. *Understanding and applying risk analysis in aquaculture*. FAO Fisheries and Aquaculture Technical Paper. No. 519. Rome, FAO. 304 pp. (Available at ftp://ftp.fao.org/docrep/fao/011/i0490e/i0490e.pdf)

Brugère, C., Ridler, N., Haylor, G., Macfadyen, G. & Hishamunda, N. 2010. *Aquaculture planning: policy formulation and implementation for sustainable development.* FAO Fisheries and Aquaculture Technical Paper. No. 542. Rome, FAO. 70 p.

Caribbean Natural Resources Institute. 2004. *Guidelines for stakeholder identification and analysis: a manual for Caribbean natural resource managers and planners.* Guidelines Series Caribbean Natural Resources Institute No. 5, 28 p. (Available at www.canari.org/Guidelines5.pdf)

Chopin, T. & Robinson, S. 2004. Defining the appropriate regulatory and policy framework for the development of integrated multi-trophic aquaculture practices: introduction to the workshop and positioning of the issues. *Bulletin of the Aquaculture Association of Canada,* 104 (3): 4–10.

Cochrane, K., De Young, C., Soto, D. & Bahri, T. (eds). 2009. *Climate change implications for fisheries and aquaculture. Overview of current scientific knowledge.* FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome, FAO. 212 p.

FAO. 1995. *Code of Conduct for Responsible Fisheries*. Rome, FAO. 41 p. (Available at ftp://ftp.fao.org/docrep/fao/005/v9878e/v9878e00.pdf)

FAO. 1997. *Aquaculture development.* FAO Technical Guidelines for Responsible Fisheries. No. 5. Rome, FAO. 40 p.
(Available at www.fao.org/docrep/003/w4493e/w4493e00.htm)

FAO. 2003. *The ecosystem approach to fisheries.* FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. Rome, FAO. 112 p.

FAO. 2005. *Putting into practice the ecosystem approach to fisheries*. Rome, FAO. 76 p.
(Available at ftp://ftp.fao.org/docrep/fao/008/a0191e/a0191e00.pdf)

FAO. 2007. *Aquaculture development. 2*. Health management for responsible movement of live aquatic animals. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 2. Rome, FAO. 31 p.

FAO. 2008a. *Human dimensions of the ecosystem approach to fisheries: an overview of context, concepts, tools and methods.* FAO Fisheries Technical Paper. No. 489, Rome, FAO. 152 p.

FAO. 2008b. *Expert Consultation on Improving Planning and Policy Development in Aquaculture*. Rome, 26–29 February 2008, FAO Fisheries Report. No. 858, Rome, FAO. 18 p.
(Available at ftp://ftp.fao.org/docrep/fao/011/i0205e/i0205e00.pdf)

FAO. 2008c. *Report of the expert consultation on the assessment of socio-economic impacts of aquaculture.* Ankara, Turkey, 4–8 February 2008. FAO Fisheries Report. No. 861, Rome, FAO. 53 p.

FAO. 2008d. *Aquaculture development. 3. Genetic resource management.* FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 3. Rome, FAO. 125 p.
(Available at www.fao.org/docrep/011/i0283e/i0283e00.htm)

FAO. 2009. *The State of fisheries and aquaculture 2008*. Rome, FAO. 176 p. (Available at www.fao.org/docrep/011/i0250e/i0250e00.HTM

FAO/FIMA. 2009. *Environmental impact assessment and monitoring in aquaculture.* FAO Fisheries and Aquaculture Technical Paper. No. 527, Rome, FAO. 649 p.
(Available at www.fao.org/docrep/012/i0970e/i0970e00.htm)

FAO/NACA/UNEP/WB/WWF. 2006. *International principles for responsible shrimp farming.* Bangkok, Network of Aquaculture Centres in Asia-Pacific, 20 p.

GESAMP. 1986. *Environmental capacity. An approach to marine pollution prevention.* Reports and Studies GESAMP No. 30, 49 p.

GESAMP. 1996. *Monitoring the ecological effects of coastal aquaculture wastes*. Reports and Studies GESAMP No. 57. Rome, FAO. 38 p. (Available at: www.fao.org/docrep/006/w3242e/w3242e00.htm)

GESAMP. 2001. *Planning and management for sustainable coastal aquaculture development.* Reports and Studies GESAMP No. 68. Rome, FAO, 90 p.

GESAMP. 2008. *Assessment and communication of environmental risks in coastal aquaculture.* Reports and Studies GESAMP No. 76. Rome, FAO. 198 p. (Available at www.fao.org/docrep/010/i0035e/i0035e00.htm)

Halwart, M. & Gupta, M.W. (eds). 2004. *Culture of fish in rice fields*. FAO and the World Fish Centre, 85 p. (Available at www.worldfishcenter.org/pubs/cultureoffish/Culture-of-Fish.pdf).

Hambrey, J., Edwards, P. & Belton, B. 2008. An ecosystem approach to freshwater aquaculture: a global review, *In* D. Soto, J. Aguilar-Manjarrez & N. Hishamunda, eds. B*uilding an ecosystem approach to aquaculture*. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain. FAO Fisheries and Aquaculture Proceedings No. 14. Rome, FAO. 221 p.
(Available at www.fao.org/docrep/011/i0339e/i0339e00.htm)

Little, D.C. & Edwards P. 2003. *Integrated livestock-fish farming systems*. Rome, FAO. 177 p.

McKindsey, C.W., Thetmeyer, H., Landry, T. & Silvert, W. 2006. Review of recent carrying capacity models for bivalve culture and recommendations for research and management. *Aquaculture*. 261(2): 451-462.

NACA/FAO. 2000. *Aquaculture development beyond 2000: the Bangkok Declaration and Strategy*. Conference on Aquaculture in the Third Millennium, 20–25 February 2000, Bangkok, Thailand. Bangkok, NACA and Rome, FAO. 27 p.

OIE. 2009. *Aquatic animal health code*. 12th Edn. Paris, World Organisation for Animal Health.
(Available at www.oie.int/eng/normes/fcode/A_summry.htm)

Shmueli, D. 2009. *Key issue–stakeholder mapping tool for coastal zone regions.* Science and Policy Integration for Coastal Systems Assessment (SPICOSA), part of Work Package One deliverable, 29 p.
(More information at www.spicosa.eu/index.htm)

Silvert, W. & Cromey, C. 2001. Modeling impacts. *In* K.D. Black, ed. *Environmental impacts of aquaculture*, pp. 154–181. Sheffield, Sheffield Academic Press.

Soto, D. 2009. *Integrated mariculture: a global review.* FAO Fisheries and Aquaculture Technical Paper. No. 529. Rome. FAO. 185 p.

Soto, D., Aguilar-Manjarrez, J. & Hishamunda, N. (eds). 2008. *Building an ecosystem approach to aquaculture.* FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain. FAO Fisheries and Aquaculture Proceedings. No. 14. Rome, FAO. 221 p. (Available at www.fao.org/docrep/011/i0339e/i0339e00.htm)

Soto, D., Aguilar-Manjarrez, J., Brugère, C., Angel, D., Bailey, C., Black, K., Edwards, P., Costa-Pierce, B., Chopin, T., Deudero, S., Freeman, S., Hambrey, J., Hishamunda, N., Knowler, D., Silvert, W., Marba, N., Mathe, S., Norambuena, R., Simard, F., Tett, P., Troell, M. & Wainberg, A. 2008. Applying an ecosystem-based approach to aquaculture: principles, scales and some management measures. *In* D. Soto, J. Aguilar-Manjarrez & N. Hishamunda, eds. *Building an ecosystem approach to aquaculture,* pp. 15–35. FAO/Universitat de les Illes Balears Expert Workshop. 7–11 May 2007, Palma de Mallorca, Spain. FAO Fisheries and Aquaculture Proceedings. No. 14. Rome, FAO. (Available at www.fao.org/docrep/011/i0339e/i0339e00.htm)

Tucker, C. & Hargreaves, J.A. (eds). 2008. *Environmental best management practices for aquaculture.* Wiley-Blackwell, New York. 592 p.

UNCBD. 1993. *The Convention on Biological Diversity.* (Available at www.cbd.int/doc/legal/cbd-un-en.pdf)

WHO. 2006. Volume 3: *Wastewater and excreta use in aquaculture*. Non-serial publication. 140 p. (Available at www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html)

APPENDIX

Main potential effects and/or issues related to aquaculture inputs, resource use and outputs at different spatial scales.

Issues at different scales	Farm	Watershed	Global
		INPUTS	
Collection of seed from the wild		+ effects on local communities that rely on this fishery - effects on wild stocks	
Production of seed		+ culture-based fisheries + restocking threatened species	
Collection of feed (e.g. trashfish)		+ effects on local communities that live on this fishery - effects on wild stocks used as feed (e.g. trashfish)	
Production of feed (e.g. pellets)			+ livelihoods in countries that provide fishmeal and fish oil - effects on pelagic stocks used to produce fishmeal/ oil
Production of local feeds	+ diminishing production costs	+ increased integration to other sectors + increased livelihood opportunities and diversification	
Labour	+ livelihoods and job opportunities - unfair wages	+ livelihoods and job opportunities - lack of social security - lack of natural calamity insurance	

Issues at different scales	Farm	Watershed	Global
Infrastructure	- impacts of large construction in large farms	+ roads and communications development by private sector - competition with fisheries for jetty, port infrastructure	
	RESOURCE USE		
Water	- use of water surface area - reduces wild fishery area - hampers navigation	- competing with other sectors for use of freshwater	
Land/coastal habitats	- conversion of sensitive habitats for aquaculture use in large farms (mangroves, wetlands)	- conversion of sensitive habitats for aquaculture use (mangroves, wetlands) - competition for coastal resources - conversion of rice fields and other agricultural land to fish ponds	
Energy	- use of energy for pumping water and aerators	- use of fuels for transport of product to local market	- use of fuels for cold chain and transport of product to local market
	OUTPUTS		
Biomass	+ biomass production for hunger alleviation and food security	+ biomass production for hunger alleviation and food security	+ biomass production for food security - negative impact on fisheries through competition for common markets

Issues at different scales	**Farm**	**Watershed**	**Global**
Income	+ provision of alternative livelihoods and jobs + opportunities for family labour - unfair distribution of incomes	+ provision of alternative livelihoods and job opportunities (direct and indirect) + opportunities for women and other minorities - unfair distribution of incomes and benefits	
Seed	+ supply to other on-growing farms	+ restocking of waterbodies (culture-based fisheries)	
Nutrients	+ extractive species such as molluscs and seaweed reduce nutrient loading - anoxic sediments below cages and in ponds - add to nutrient loading close to farm (fed species)	+ provides additional nutrients for increased primary productivity - impact on sensitive habitats (corals, seagrasses, etc.) - add to eutrophication pressures	
Escapees	- economic loss to the farm	+ potential for additional wild fisheries - potential carriers of disease - potential to change genetics of local strains	- spread of exotic species
Diseases	- economic loss to the farm	- escapees potential carriers of disease for wild fish	- spread of exotic diseases
Chemicals	- potential to impact local fauna and flora		

The main objective of the guidelines is to assist countries, institutions and policy-makers in the development and implementation of a strategy to ensure the sustainability of the aquaculture sector, integration of aquaculture with other sectors and its contribution to social and economic development.

"An ecosystem approach to aquaculture is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity and resilience of interlinked social-ecological systems." Being a strategy, the ecosystem approach to aquaculture (EAA) is not what is done, but rather how it is done. The participation of stakeholders is at the base of the strategy.

The EAA requires an appropriate policy framework under which the strategy develops through several steps: (i) the scoping and definition of ecosystem boundaries and stakeholder identification; (ii) identification of the main issues; (iii) prioritization of the issues; (iv) definition of operational objectives; (v) elaboration of an implementation plan; (vi) the corresponding implementation process, which includes reinforcing, monitoring and evaluation; and (vii) a long-term policy review. All these are steps informed by the best available knowledge.

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