Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture
Full document

**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS/
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Cover photograph:

Oyster culture in Chanthaburi, Thailand

Molluscs feed low on the food chain, which make them a relatively cheap source of protein. Culture plots can be established and managed by individual farmers, a cluster of farmers, or the community. This neat and well-managed stretch of oyster culture units in Chantaburi Province, Thailand, reflects some of the advantages of community-based aquaculture management in terms of an equitable and conflict-free access to the water resource, clean culture environment and improved incomes. Off-bottom culture techniques include polyethylene rafts, longlines, racks and cages.

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PREPARATION OF THIS DOCUMENT

The Seventh Session of the Sub-Committee on Aquaculture of the FAO Committee on Fisheries (COFI) acknowledged the growing importance of spatial planning to promote aquaculture growth, and requested the Food and Agriculture Organization of the United Nations (FAO) to develop a step-by-step guide for the implementation of spatial planning tools and continue capacity building in developing countries. Furthermore, environmental, aquatic animal health and socioeconomic issues require an ecosystem approach to management of the sector moving beyond individual farms to the management of spatial units such as aquaculture zones or aquaculture management areas. To this end, FAO in partnership with the World Bank have prepared this publication on aquaculture zoning, site selection and aquaculture management areas under the ecosystem approach to aquaculture. It is aimed primarily at managers and policy-makers, but has relevance to a wide range of stakeholders.

An expert workshop on Site Selection and Carrying Capacities for Inland and Coastal Aquaculture convened on 6–8 December 2010 at the Institute of Aquaculture, University of Stirling, the United Kingdom of Great Britain and Northern Ireland, and proposed the development of a guide for aquaculture site selection and carrying capacity estimation within an ecosystem approach to aquaculture.

This publication builds on the experiences gained in that expert workshop. This document was validated by contributors to this publication and other international experts at a workshop in Izmir, Turkey, on 5–8 July 2015. It was also tested in a few countries such as Angola, Kenya and the United Republic of Tanzania before it was finalized.

The purpose of the publication is to provide practical guidance on spatial planning to managers, policy-makers, technical staff and farmers. The publication reviews spatial planning and management of aquaculture development within the framework of the ecosystem approach to aquaculture development, and also presents suggestions for a strategy for their implementation using an area management approach to ensure greater sustainability for future aquaculture development initiatives by governments. It is based on the FAO Code of Conduct for Responsible Fisheries, which contains principles and provisions in support of sustainable aquaculture development. The publication is global in its reach and is aimed to be of relevance and use in developing countries.

The handbook and Annexes 1, 2, 3 and 4 were edited by FAO/World Bank. However, Annexes 5 (case studies) and 6 (workshop report) have been reproduced as submitted.

ABSTRACT

The ecosystem approach to aquaculture provides the conceptual guideline for spatial planning and management. This publication describes the major steps related to these activities. The rationale for and objectives of each step, the ways (methodologies) to implement it, and the means (tools) that are available to enable a methodology are described in a stepwise fashion. Recommendations to practitioners and policy-makers are provided. A separate policy brief accompanies this paper. The benefits from spatial planning and management are numerous and include higher productivity and returns for investors, and more effective mitigation of environmental, economic and social risks, the details of which are provided in this paper. While the costs are not explicit, the publication describes the resources required–some in broad terms, others in more detail –to apply the methodologies and to acquire and use essential tools.

This publication is organized in two parts. Part one is the "Guidance"; it is the main body of the document and describes the processes and steps for spatial planning, including aquaculture zoning, site selection and area management.

Part two of the publication includes six annexes that present key topics, including: (i) binding and non-legally binding international instruments, which set the context for sustainable national aquaculture; (ii) biosecurity, zoning and compartments, infected zones and disease-free zones; (iii) aquaculture certification and zonal management; (iv) an overview of key tools and models that can be used to facilitate and inform the spatial planning process; (v) case studies from ten countries–Brazil, Chile, China, Indonesia, Mexico, Oman, the Philippines, Turkey, Uganda and the United Kingdom of Great Britain and Northern Ireland; and (vi) a workshop report.

The country case studies illustrate key aspects of the implementation of spatial planning and management at the national level, but mostly within local contexts. Take-home messages include the ways in which institutional, legal and policy issues are addressed to implement the process, or parts of the process. Some of the case studies such as Chile, Turkey and the United Kingdom of Great Britain and Northern Ireland provide examples of the benefits to the aquaculture industry from the application of spatial planning and management.

Aguilar-Manjarrez, J., Soto, D. & Brummett, R. 2017. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document.* Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

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A separate policy brief that accompanies this paper was prepared with inputs of Pete Bueno. The authors would also like to thank the Institute of Marine Sciences and Technology, Dokuz Eylul University, for hosting the workshop in Turkey in 2015 where this publication was presented and improved, and in particular Guzel Yucel Gier for her kind assistance in the organization and assistance at the workshop. The authors thank Maria Giannini for proofreading the document, and the participants at the workshop in Turkey for their valuable inputs. The document layout specialist was Koen Ivens.

This publication has been realized with the financial support of the World Bank.

ABBREVIATIONS AND ACRONYMS

AMA	aquaculture management area
COFI	AO Committee on Fisheries
DEPOMOD	computer particle tracking model
DFO	Department of Fisheries and Oceans Canada
EAA	ecosystem approach to aquaculture
EIA	environmental impact assessment
FAO	Food and Agriculture Organization of the United Nations
GIS	geographic information system
IUCN	International Union for Conservation of Nature and Natural Resources
MOM	Modelling–Ongrowing fish farms–Monitoring
BMP	better management practice
EQS	environmental quality standards
FARM	Farm Aquaculture Resource Management
FCR	feed conversion ratio
HAB	harmful algal bloom
HACCP	hazard analysis and critical control point
IMTA	integrated multi-trophic aquaculture
ISA	infectious salmon anemia
SSPO	Scottish Salmon Producers Organisation

FOREWORD

With increasing wealth, health consciousness and global population, coupled with continued reliance of poor coastal communities on fish for protein, demand for seafood is increasing. Current levels of wild capture fisheries are unsustainable and declining. Aquaculture is a key component of closing the distance between demand and supply.

New investment in the order of US$100 billion is needed to grow aquaculture, but the generally small scale and organic growth of the aquaculture industry has made it difficult to plan and regulate, contributing importantly to the high levels of risk perceived by potential new investors. In particular, poor spatial planning can undermine the viability of businesses and the social and economic benefits derived from aquaculture development. Vulnerability to external shocks, the outbreak and spread of disease, environmental impacts, and social conflicts with other resource users are all symptomatic of bad planning. And, of course, the flip side is true: good spatial planning can attract investment while ensuring equitable access to ecosystem services by communities, helping countries achieve the desired social and economic outcomes resulting from aquaculture development and at the same time protecting the environment, all essential elements of the "Blue Economy". It is also a key element in building resilience to climate change and resolving transboundary issues around trade and biosecurity.

The Food and Agriculture Organization of the United Nations (FAO) Fisheries and Aquaculture Proceedings No. 21 on Site selection and carrying capacities for inland and coastal aquaculture, published in 2013, lays out the theoretical underpinnings of an ecosystem approach to aquaculture. This handbook seeks to describe its implementation and ensure that countries and communities can integrate their investments in aquaculture within the wider ecosystem, such that it promotes sustainable development, equity, and resilience of interlinked socio-economic systems.

Good spatial planning and management are absolutely essential if aquaculture is to maximize its potential to reduce poverty and hunger and meet the demand from the growing middle class. The World Bank and FAO together are delighted to have, at last, a comprehensive handbook to help us do just that.

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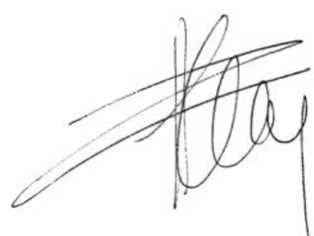

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1. INTRODUCTION

1.1 Objectives and target audience

Generally, the starting point for national aquaculture planning comes from a need for fish, jobs and/or taxable revenues from organized aquaculture development. Unplanned aquaculture development has led to negative environmental and social impacts that can outweigh the benefits of growing more fish or other aquatic products. Some countries with experience in aquaculture have adopted spatial planning[1] based on a balance between environmental carrying capacity, social risks and economic opportunities to minimize negative impacts while permitting the industry to contribute to the national economy. The main objective of this publication is to provide practical guidance on spatial planning to a broad range of stakeholders. These stakeholders are the target audience for this publication and include policy-makers, regulators, developers, farm managers, scientists and providers of extension services, whose relevance is defined in Table 1.

This publication is presented in two parts. Part 1 "Guidance" is the main body of the document and describes the processes and steps for spatial planning, including aquaculture zoning, site selection and area management.[2]

Specific processes and steps are placed in their relevant context to highlight their rationale and how they can be applied within a spatial planning framework. The guidance (Part 1) can be used as a "standalone" section by policy-makers, planners and stakeholders with reference to Part 2 as appropriate. The guidance is necessarily generic because the approaches will vary significantly depending on location and application, but broadly agreed-upon steps and a common framework for more sustainable approaches are described. Possible activities and spatial planning tools are briefly introduced in Part 1 with a few examples of their application.

Part 2 includes "six annexes" that present key topics: (i) binding and non-legally binding international instruments, which set the context for sustainable

TABLE 1. Users of this publication

Users	Relevant processes and activities
Policy-makers	Guide on policies, requirements and processes for responsible aquaculture planning and management
Regulators	All the sections and steps are relevant to improve norms, regulations and enforcement, including zoning, site selection, licencing and permitting, fish health management, area management systems, monitoring and feedback
Farm developers	Relevant guide on farm site selection, carrying capacity and maximum production limits, environmental impact assessments and biosecurity
Farm managers	Management of the farm and coordination with neighbouring farms within the aquaculture management area for biosecurity, health management and environmental management
Scientists	Zone and site selection tools, carrying capacity estimation, and environmental and health monitoring surveys
Extension services	Support zoning processes, aquaculture management area development and servicing, including biosecurity

[1] Spatial planning refers to the methods used by the public sector to influence the distribution of people and activities in spaces of various scales. Spatial planning takes place at the local, regional, national and international levels and often results in the creation of a spatial plan. Spatial planning also entails a system that is not only spatial, but one that also engages processes and secures outcomes that are sustainable, integrated and inclusive (FAO, 2013).

[2] A separate policy brief accompanies this paper. See FAO & World Bank. 2015. Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Policy brief. Rome, FAO. (also available at www.fao.org/documents/card/en/c/4c777b3a-6afc-4475-bfc2-a51646471b0d/)

national aquaculture; (ii) biosecurity, zoning and compartments, infected zones and disease-free zones; (iii) aquaculture certification and zonal management; (iv) an overview of key activities and relevant tools that can be used to facilitate and inform the spatial planning process; (v) case studies from ten countries –Brazil, Chile, China, Indonesia, Mexico, Oman, the Philippines, Turkey, Uganda and the United Kingdom of Great Britain and Northern Ireland; and (vi) a workshop report. A summary analysis of the ten case studies is provided to highlight the main gaps and issues in the processes of zoning, site selection and design of aquaculture management areas. The ten case studies are presented in detail to describe the processes and steps carried out by each country.

Part 2 should be read in conjunction with Part 1, as the latter provides the context and rationale for the former. The most important activities and tools that can be used to facilitate more integrated planning are reviewed. Where appropriate, the reader is directed to other more comprehensive reviews and other documents.

This publication provides practical advice based on field experience in planning of aquaculture using selected case studies from around the world. Practitioners are encouraged to select, modify and continuously adapt their approaches and tools to their own specific circumstances. It calls for pragmatic and systematic, but flexible planning and management, combined with a good dose of participation, patience, persistence, adequate funding and good governance to create an enabling environment conducive to sustainable aquaculture development.

1.2 Why spatial planning of aquaculture?

Inappropriate spatial arrangement and site selection of aquaculture is a major constraint to sustainable development and expansion of the industry. To create a successful aquaculture business, it is necessary to have farm sites based in locations that are suitable for sustainable production. All aquaculture species have specific biological needs such as oxygen, temperature and good water quality that have to be fulfilled to secure high production and to minimize stress and disease. Location of aquaculture farms require access to land and water where use must also co-exist with other human activities. Access to roads and electricity (infrastructure) is also necessary. A poor location of an aquaculture farm or zone will not only create environmental problems such as localized eutrophication, it may also have a broader impact on environmental, social and economic aspects, such as conflicts with other human activities over the use of inland and coastal zone resources, that can detract from the benefits of a sustainable aquaculture industry.

Common problems arising from the lack of spatial planning and management of aquaculture can be categorized as: (i) fish disease; (ii) environmental issues; (iii) production issues; (iv) social conflict; (v) post-harvest and marketing issues; (vi) risk financing; and (vii) lack of resilience to climatic variability, climate change and other external threats and disasters. Spatial planning and management of aquaculture can be done at several geographical scales to address problems in aquaculture and provide opportunities to enhance development (Table 2).

When spatial planning is within a Blue Growth or Blue Economy Programme, there are additional opportunities to link to other initiatives such as innovative financing and energy efficiencies which can improve social, economic and ecosystem outcomes.[3]

Spatial planning could also be a means to improve negative public perception about potential environmental impacts, especially those associated with marine fish farming, and on access to and use of coastal resources.[4,5]

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3 FAO. 2015. Achieving Blue Growth through implementation of the Code of Conduct for Responsible Fisheries. Policy Brief. Rome, FAO. (also available at www.fao.org/fileadmin/user_upload/newsroom/docs/BlueGrowth_LR.pdf).

4 Bacher (2015) provides a global overview and synthesis of studies on perceptions of aquaculture in both developed and developing countries. The document also includes recommendations for policy-makers, the industry and other stakeholders on improving public understanding of aquaculture and on the roles various actors can play in this process.

5 The FAO workshop *"Increasing Public Understanding and Acceptance of Aquaculture – the Role of Truth, Transparency and Transformation"* was held in Vigo, Spain, in October 2015. The workshop covered a number of core topics related to the perceptions of aquaculture, including transparency and ethics, communication, collaboration, responsibilities and new approaches to better management of sector performance and perceptions (FAO, 2016a).

TABLE 2. Problems associated from the lack of spatial planning and opportunities through aquaculture zoning and area management

Problems	Opportunities
Fish disease and lack of effective biosecurity, e.g. when farms are too close to each other and/or do not respect basic rules of farm-level disease prevention.	• Minimize fish disease risks and coordinated response to outbreaks. • Improve access to finance when overcoming biosecurity concerns.
Environmental issues such as eutrophication, biodiversity and ecosystem service losses, e.g. when there are too many farms in a given area or waterbody.	• Better coordinated and integrated approaches to the use and management of natural resources. • Improved animal welfare and growth rates.
Production issues such as lower growth and biomass of filter feeders (e.g. oysters, mussels) due to excessive farming density and overharvesting of common-pool oxygen and microalgae.	• Improved filter-feeders' productivity and yield
Social conflicts, equity issues and lack of public confidence in the sustainability of aquaculture, e.g. when aquaculture is competing with other users for access to water and space use.	• Improved accountability and transparency through relevant stakeholder involvement at all levels and documented environmental management. • improved public perception of aquaculture
Post-harvest and marketing issues, e.g. when individual neighbour farmers do not have access to post-harvest services.	• Clusters of farmers having better access to common post-harvest processes and other services. • Area-based management and certification as a governance and risk-sharing model for sustainable aquaculture.
Risk financing. National governments and financing institutions do not have a good knowledge of where the prospects for aquaculture development are the most promising before committing resources to development.	• National-level information on areas available to invest on aquaculture. • Implementing area-based management strategies (e.g. clusters of farmers) to facilitate access to finance.
Lack of resilience to climatic variability, climate change, and other external threats and disasters, e.g. hurricanes, tsunamis, drought, and industrial pollution of water sources.	• A more resilient sector, better adapted to shocks. • More effective mechanisms for governments and other institutions, including civil society organizations, to deliver services and fulfil their commitments to sustainable aquaculture development.

1.3 The ecosystem approach to aquaculture

One of the major challenges for the sustainable development of aquaculture is the sharing of water, land and other resources with alternative uses, such as fisheries, agriculture and tourism. Spatial planning for aquaculture, including zoning, site selection and the design of aquaculture management areas, should consider the balance between the social, economic, environmental and governance objectives of local communities and sustainable development. It is now widely recognized that further aquaculture development should be a planned activity that is designed in a more responsible manner so as to minimize negative social and environmental impacts as much as possible. One essential step is appropriate spatial planning at the local, regional and national levels, and accounting for transboundary issues where these are relevant. Although many of the social and environmental concerns surrounding impacts derived from aquaculture may be addressed at the individual farm level, most impacts are cumulative. Impacts may be insignificant when an individual farm is considered, but potentially highly significant when multiple farms are located in the same area, or when the entire sector is taken as a whole. The process and steps through which aquaculture is spatially planned and managed, and integrated into the local economy and ecological context is termed the ecosystem approach to aquaculture (EAA). Three principles govern the implementation of the EAA:

(i) Aquaculture should be developed in the context of ecosystem functions and services (including biodiversity) with no degradation of these beyond their resilience.
(ii) Aquaculture should improve human well-being with equity for all relevant stakeholders (e.g. access rights and fair share of incomes).
(iii) Aquaculture should be developed in the context of other sectors, policies and goals, as appropriate.

The EAA provides a planning and management framework to effectively integrate aquaculture into local planning, and give clear mechanisms for engaging with producers and the government for the effective sustainable management of aquaculture operations by taking into account local and national social, economic, environmental and governance objectives.

The EAA benefits from having a national aquaculture and/or other relevant policy (e.g. food security, coastal zone management) to guide implementation, and depends on legally binding and fair regulation and allocation of user rights. Mandated under the EAA are permanent stakeholder consultations and use of best available knowledge to underpin policy and enforcement (FAO, 2010).

2. IMPLEMENTATION OF AQUACULTURE SPATIAL PLANNING AND MANAGEMENT

2.1 Process

A process for aquaculture site selection and carrying capacity estimation within the framework of an ecosystem approach to aquaculture was initially elaborated by Ross *et al.* (2013). A comprehensive planning process should begin with the formation of an appropriate task team to evaluate the pros and cons of aquaculture and to create a roadmap for its sustainable development. The task team is usually comprised of government policy-makers and technical experts in aquaculture, business development and aquatic ecosystem management.

The first activity of the aquaculture task team is to undertake a national scoping exercise aimed at establishing objectives for aquaculture, reviewing relevant laws, identifying general areas that might be suitable for various types of aquaculture, establishing national priorities for ecosystem conservation and conversion, and determining who might be the relevant stakeholders to engage in decision-making. Scoping is often done within the context of a national aquaculture strategy or policy exercise and influences each subsequent step in the spatial management process.

Once scoping has identified aquaculture as a priority at the national level, detailed plans are elaborated for progressively smaller geographical units at the regional and local levels, as appropriate. The process of spatial planning usually consists of the following three steps:

(i) Aquaculture zoning: bringing together the criteria for locating aquaculture and other activities in order to define broad zones suitable for different activities or mixes of activities.
(ii) Site selection: identifying the most appropriate locations for individual farm development within zones.
(iii) Aquaculture management areas (AMAs): within zones, AMAs contain a number of individual farms that share a common water supply and/or are in such proximity that disease and water quality are best managed collectively rather than by individual farms.

An aquaculture zone can be all or part of any hydrological system that is at least partly suitable for aquaculture, whether it be the open ocean (normally within the exclusive economic zone), a bay, part of a river or estuary, or any inland waterbody (lake or dam). The creation of zones facilitates the integration of aquaculture activities into areas already being exploited by other users. The effectiveness of zoning depends upon its simplicity, clarity and degree of local support.

Site selection is the process by which the biophysical attributes of a prospective site are compared with the needs of cultured organisms and the proper functioning of aquaculture farms. Poor site selection is a major cause of failure in aquaculture development. This process is normally led by the private sector, local landowners and others seeking to embark on an aquaculture business venture. Governments maintain control through clear regulations that define the process and requirements for site licencing.

As all farms within a constrained space contribute to nutrient loading, the spread of diseases and other impacts of aquaculture, some kind of collective management is often needed. AMAs are defined as shared waterbodies, or parts thereof, where all the aquaculture operators agree (coordinate and cooperate) to certain management practices or codes of conduct that act to minimize the overall impacts from their collective activities. Estimation and evaluation of the biological carrying capacity of zones, farm sites and AMAs, and biosecurity considerations are the baseline upon which allowable fish and farm density are based.

Once AMAs have been established with a clear management plan, a system for monitoring the plan is needed to allow for review and iterative adjustment as the need arises. Individual components of the plan such as biosecurity, social and environment measures will need to be periodically adjusted as technology and the local production and socio-economic context evolve. A schematic diagram of the potential steps in the spatial planning and management process is presented in Figure 1.

2.2 Recommended steps

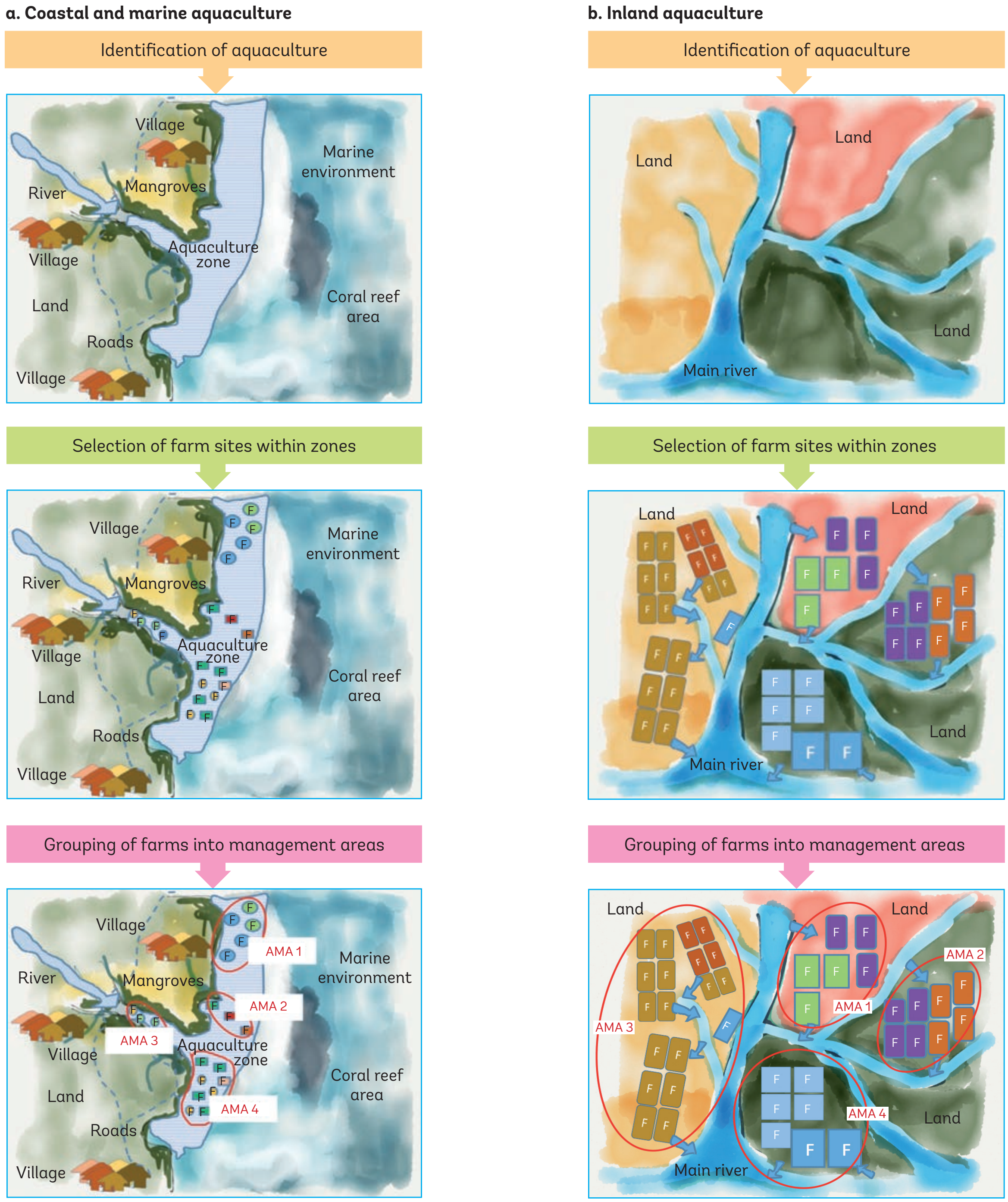
The order in which the main steps shown in Figure 1 and Table 3 are taken depends upon the local situation. For example, when aquaculture is completely new to a country or to a large geographical area, practicioners might want to start with a broad scoping exercise, followed by zoning, site selection, design of aquaculture management areas, and elaboration of the corresponding management plans. In countries or geographical areas where aquaculture farms/ structures are well established, however, it may not be possible to relocate farm/structures (e.g. ponds, tanks, raceways) to meet carrying capacity, biosecurity and socially acceptable thresholds. Under these circumstances, there may be an obligation to begin with the definition of AMAs and management plans;

TABLE 3. Main characteristics of the process for scoping, zoning, site selection and area management for aquaculture

Characteristics	Scoping	Zoning	Site selection	Area management
Main purpose	Plan strategically for development and management	Regulate development; minimize conflict; reduce risks; maximize complementary uses of land and water	Reduce risk; optimize production	Protect environment; reduce disease risk; reduce conflict
Spatial scale	Global to national	Subnational	Farm or farm clusters	Farm clusters
Executing entity	Organizations operating globally; national aquaculture departments	National and local governments with aquaculture responsibilities	Commercial entities	Farmer associations; regulating agencies
Data needs	Basic, relating to technical and economic feasibility, growth and other uses	Basic environmental, social and economic sets	All available data	Data for carrying capacity and disease risk models
Required resolution	Low	Moderate	High	High
Results obtained	Broad, indicative	Directed, moderately detailed	Specific, fully detailed	Moderately to fully detailed

Source: Kapetsky and Aguilar-Manjarrez (2013).

FIGURE 1. Potential steps in the spatial planning and management process for coastal, marine and inland aquaculture



Note:

- Schematic figure of a designated aquaculture zone (hatched area in blue colour) representing an estuary and the adjacent coastal marine area. Individual farms/sites (F), owned by different farmers, are presented in different colours and can incorporate different species and farming systems.

Note:

- Schematic figure of an existing aquaculture zone (the whole depicted area) representing individual land-based farms (F), e.g. catfish ponds and/or other species, that may be owned by different farmers (presented in different colours).
- The designation of AMAs depends upon mutual and exclusive use of incoming and outgoing water supplies by a given set of farmers.

The order in which the main steps are taken above depends upon the local situation.

this has been the case in countries where disease outbreaks have forced governments and producers to develop collective response protocols. In some cases, an entire zone might share a common water supply or be configured in such a way that it functions as an AMA. There is no fixed pathway; the steps are flexible and should be adapted to local/national circumstances and capacities as necessary. There are a range of different zoning, site selection and AMA schemes that have been developed worldwide to address different constraints to aquaculture sustainability and local conditions. Selected examples are described in the case studies in Annex 5.

The main steps for spatial planning and area management can be broken down into a more detailed set of processes, each drawing on a range of activities and tools (Table 4). The components, and the associated activities and tools, are briefly described in the sections below. Some of the main tools and their application to aquaculture development and management are reviewed in Annex 4.

The inclusion of all these components in any planning initiative may be a formidable task. However, if the larger goal of long-term sustainable development is to be realized, most of these components will need to be considered. The outcomes of the process will also be more durable if the principles of stakeholder participation and use of best available knowledge are applied at all stages of the process.

Many of the processes and components in Table 3 are repeated in each main step defined in Table 4 (e.g. identification of issues) because each component should serve to inform the scope and focus of others steps, and because some countries may want to focus more on specific aspects without having to follow all the steps in sequence. It is recommended that countries in which aquaculture is a new activity would need to follow all the steps, broadly in sequence.

TABLE 4. Potential framework to guide the implementation of aquaculture spatial planning and area management

Steps	Process	Activities and tools
National/ subnational scoping	• Review national/subnational priorities for aquaculture • Identification of relevant stakeholders for consultation • Review and possible adaptation of laws, policies, regulations and institutional frameworks affecting aquaculture • Identification of general issues and opportunities • Identification of potential for cultured species and farming systems	• Review relevant policy and legal frameworks • Institutional mapping and analysis • Stakeholder mapping and analysis • Aquaculture species/systems review • Issue trees • Geographic information system (GIS), remote sensing and mapping • Google Earth marking of aquaculture areas
Zoning	• Identification of areas suitable for aquaculture • Identification of issues and risks in zoning • Broad carrying capacity estimation for aquaculture zones • Biosecurity and zoning strategies • Legal designation of zones for aquaculture	• Identification of high-level objectives • Description and mapping (GIS-related tools) • Zone selection and modelling • Issue trees • Strategic environmental assessment and other related approaches • Tools/proxies to estimate carrying capacity for large areas • Land use planning maps • Marine spatial planning • Mass balance equation models • Dynamic models • Risk mapping and analysis • Stakeholder consultation to identify issues and potential conflicts • Environmental indicators such as the TRIX index
Site selection	• Assessment of suitability for aquaculture • Detailed estimation of carrying capacity for sites • Biosecurity planning and disease control • Authorization arrangements	• Description and mapping (GIS-related tools) • Site selection modelling • Issue trees • Environmental impact assessment, licences, permits • Environmental management plan • Description and mapping • Nutrient mass balance equation models • Dynamic models for environmental impact • Landscape and seascape analysis • Choice of environmental indicators (e.g. benthic diversity, water quality)
Aquaculture management areas (AMAs)	• Delineation of management area boundaries with appropriate stakeholder consultation • Establishing an area management entity involving local communities as appropriate • Carrying capacity and environmental monitoring of AMAs • Disease control in AMAs • Better management practices • Group certification • Essential steps in the implementation, monitoring and evaluation of a management plan for an AMA	• Agreement on the administration and leadership of the AMA • Description and mapping (GIS-related tools) • Stakeholder identification • Participatory, facilitation tools • Issue trees • Mass balance equation models • Dynamic models for environmental impact • Biosecurity tools • Value chain tools • Farmer organization inclusion and responsibilities • Agreed management plan and management measures • Environmental management tools • Conflict resolution and communication tools • Enforcement measures • Better management practices • Standard operating procedures • Traceability • HACCP and food safety guidelines • Environmental monitoring surveys

Notes:
- Some of the main tools and models are described in Annex 4.
- Scoping is also needed for zoning and the design of management areas.
- Ehler and Douvere (2009) describe marine spatial planning (MSP) as "a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process". Meaden *et al.* (2016) provide a comprehensive listing of additional information about MSP, including worldwide examples where MSP has been applied under varied local conditions at highly variable geographic scales.

Fish ponds for culture of Nile tilapia, African catfish and African bonytongue, Cameroon

There is considerable potential to expand inland aquaculture in Africa to improve food security. The first step in aquaculture planning is identifying areas that have potential for aquaculture. In this scoping process, it is important to review any existing coastal zone management plan to establish whether it facilitates aquaculture development. Legal and regulatory frameworks should establish clear mechanisms for aquaculture zoning and site selection in waterbodies considered "common property" and the granting of tenure rights, including aquaculture licences.

Courtesy of José Aguilar-Manjarrez

3. SCOPING

The first step in spatial planning is scoping, which includes as the main tasks: collection of baseline information, definition of priorities for aquaculture, identifying stakeholders, and setting broad objectives. It is important in this step to define the boundaries of both the management unit and the ecosystem, which are often different. Availability of baseline data (through a baseline report) is essential. Not only does a proper baseline report enable a project to measure impact, it also ensures that everyone is clear regarding the challenges, opportunities and issues for sustainable aquaculture development.

Led by the aquaculture task team, scoping is the largely subjective weighing of national and regional development and conservation objectives. It influences decision-making at all subsequent levels of aquaculture spatial planning and management. The main processes undertaken in scoping include:

- review of national and subnational priorities for aquaculture;
- identification of relevant stakeholders for consultation;
- review and possible adaptation of laws, policies, regulations and institutional frameworks affecting aquaculture;
- identification of general issues and opportunities; and
- identification of potential for cultured species and farming systems.

3.1 Review of national and subnational priorities for aquaculture

The first step is to understand the priorities that the government attaches to the aquaculture sector relative to other national or subnational priorities for economic development and natural resource conservation. There is a need to understand whether aquaculture is to be undertaken for food and/or food security, income generation, expanding the tax base, local jobs, some other expected benefit, or a combination with differing priorities. The answers to these issues will determine the amount of land, water, institutional resources, types of systems, and aquaculture species that will be targeted for government support and development. For example, government revenues may be higher with a focus on high-value species for export grown in seawater cages by large corporations with relatively few employees, meaning that aquaculture sector planning should focus on coastal areas and on developing strong relationships with the private sector. Pond aquaculture of cheaper species by small- and medium-scale farms employing relatively large numbers of local people could supply more fish to local markets at reasonable prices for consumers, but will require land and freshwater that may or may not be locally available. Acceptable levels of risk to important biodiversity or natural areas are other key considerations to be weighed. Reviewing priorities, therefore, influences the decisions made in relation to the type of aquaculture development that could be undertaken. Consultation with stakeholders is critical in clarifying national priorities.

3.2 Identification of relevant stakeholders for consultation

The identification of relevant stakeholders for consultation is central to the success and durability of aquaculture spatial planning. Box 1 provides guidance for identifying and selecting stakeholders, some of which may be more or less relevant depending upon the step in the process: scoping, zoning, site selection or area management. It may not be necessary or possible to involve all stakeholder groups throughout the whole process, so careful consideration must be given as to who needs to be encouraged and supported to participate, and at what stage of the planning process. To make best use of identified stakeholders, refer to the participatory tools for facilitation of group decision-making described by FAO (2010).

BOX 1
A guide to stakeholder identification in aquaculture planning and management

Criteria for selection of stakeholders:
- those who have sufficient political clout to draw in officials with the public authority to make decisions;
- 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 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.

According to the criteria above, stakeholders could include:
- fish farmers;
- capture fishers;
- local communities and/or businesses reliant on aquaculture and fisheries value chains;
- authorities (local, regional, national, other): aquaculture, fisheries, environment, animal health etc.
- tourism;
- environmentalists;
- scientists and other technical experts;
- homeowners;
- recreational users;
- enterprises directly using the waterbody concerned (marinas, ports, shipping, wind farms); and
- enterprises indirectly using the coast or waterbody (urban or industrial consumers of water, polluters, etc.).

Source: FAO (2010).

3.3 Review and possible adaptation of laws, policies, regulations and institutional frameworks affecting aquaculture

The collection of relevant information and the review of policy and legal frameworks will need to be undertaken. The need for different levels of planning in order to identify aquaculture zones or sites, to designate aquaculture management areas, and to manage or overcome social conflicts such as competition for space and conflicts of interest and environmental considerations necessitate the following:

- a clear and efficient institutional framework with clearly defined competencies;
- clear policy and legal frameworks and rules and regulations that govern development and management of aquaculture, including, for example, access use rights and duties; and
- encouragement and empowerment of the aquaculture sector to self-regulate where appropriate.

The policy and legal frameworks for sustainable aquaculture must be based on the law of the sea, as reflected in the United Nations Convention on the Law of the Sea of 10 December 1982 (UNCLOS) and international environmental law as well as various soft law instruments (Table 5 and Annex 1). There is also a need for a review of different areas of national law and administration frameworks that may relate to or have an impact on aquaculture activity. For example, spatial and area management requirements may exist in legislation relating to the authorization and conduct of commercial or development activities, public works, zoning and planning, public health and environmental legislation. A review of these legal frameworks in the scoping phase will help determine whether they need to be strengthened to include aquaculture development. In countries where there is no legal framework for aquaculture, which sets out the main requirements for aquaculture management including spatial planning and management in one legislation, appropriate legislation may need to be developed.

There has been an increase in effort in the development of enhanced national policy, legal and institutional frameworks for aquaculture administration in the last decades with the expansion of the sector. A corresponding growth in environmental consciousness is also being noted in the increased number and breadth of environmental considerations in policy, regulations and management. The FAO fisheries National Aquaculture Legislation Overview (NALO) Web page (www.fao.org/fishery/nalo/search/en) includes legal fact sheets for 61 countries. A list of legal issues for sustainable aquaculture planning and management, adapted from the NALO fact sheets are presented in Table 5.

Institutional analysis should cover both formal and informal institutions (FAO, 2010). Formal institutions are those such as government departments or agencies that typically have a legally defined role and structure. Informal institutions are those such as business, social or family networks or associations. The latter in this group also have structure and sets of procedures, although they may have no legal or written basis. In essence, institutional analysis requires that a specific set of questions be addressed, including: What are the rules? Who decides, and how is this done (process and decision criteria)? Who implements what rules, and how? How and when is progress assessed? and What are the relationships between different institutions (both formal and informal)?

3.4 Identification of general issues and opportunities

It is advisable to identify social, economic, environmental, and governance issues and opportunities. In most cases, environmental, social and economic issues have a root cause that needs to be overcome, such as governance and institutional factors, lack of adequate knowledge, lack of training, inappropriate legislation, lack of enforcement, problems with user rights, and so on. It is important that these root causes are investigated, and mitigation or remedial actions proposed. These are not factors that can always be overcome instantaneously and may require investment of time and financial resources. External forcing factors should also be considered to include, for example, catastrophic events, climate change impacts, sudden changes in international markets, and the effects of other users of aquatic ecosystems on aquaculture such as agriculture and urban pollution of aquatic environments that may negatively affect aquaculture.

A large number of issues can be identified, but their importance varies greatly. Consequently, it is necessary to have some way of prioritizing them so that those that require immediate management decisions receive more attention within a plan of action. Examples and more details of issue identification and priorization can be found in FAO (2010), FAO (2003) and APFIC (2009).

The identification of issues also represents an opportunity for the implementation of a spatial planning process under an ecosystem approach to aquaculture, which ensures coordinated, orderly development and promotes sustainability. As an example, if one of the issues is fish disease and the lack of effective biosecurity (e.g. when farms are too close to each other leading to quick infection and reinfection), there is an opportunity to minimize fish disease risks and better respond to outbreaks through good spatial planning.

TABLE 5. Policy, institutional and legal aspects involved in sustainable aquaculture planning and management

Policy, institutional and legal aspects	Instruments, institutions, requirements
International binding and non-binding instruments*	• Binding instruments include, for example, the Ramsar Convention on Wetlands of International Importance (Ramsar, 1971)[1] and the United Nations Convention on the Law of the Sea (Montego Bay, 1982)[2] • Non-binding instruments include the Kyoto Declaration on Aquaculture, Agenda 21, Rio Declaration, and the Code of Conduct for Responsible Fisheries (FAO, 1995)[3], among others
Basic national legislation	• Fisheries and/or aquaculture law • Planning law • Water law • Sanitary law • Tax law • User rights law
Institutions	• Fisheries and aquaculture authorities • Health and sanitary authority • Environmental authority • Forestry and water resources authority • Culture and tourism authority • Indigenous peoples authority • Commerce authority • Local authorities • Trade/farmer associations
Site allocation	• Site allocation criteria and user rights • Required distance between farm sites • Required distance between farm sites and other activities • Interaction with other activities • Indigenous/artisanal fishing community rights
Authorization system	• Leasing or permitting system • Operation licence (duration, renovation, revocation) • New site, change of use, or change of capacity
Environmental impact	• Emission standards • Water quality • Sedimentation models • Waste management
Control mechanisms	• Environmental assessments • Self-monitoring • Citizens' participation • Enforcement and penalties • Conflict resolution procedures
Production system	• Production volume • Species mix • Animal Welfare

Policy, institutional and legal aspects	Instruments, institutions, requirements
Fish movement	• Notification and information • Transport of species • Accidental release of farmed species
Disease control	• Quarantine • Outbreak management • Therapeutants
Feed	• Feed quality • Effect of feed residues on environment
Product safety and traceability	• Certification systems
Education, research and development	• Extension and training • Research and development • Public information and awareness
Aqualculture management areas (AMAs)	• Organization and management of AMAs

*For more details on binding and non-binding agreements, see Annex 1.

[1] United Nations. 1976. *Convention on Wetlands of International Importance especially as Waterfowl Habitat.* United Nations Treaty Series, Vol. 996, I-I-1583. Entered into force 21 December 1975. (also available at https://treaties.un.org/doc/Publication/UNTS/Volume%20996/volume-996-I-14583-English.pdf).

[2] United Nations. 1994. *United Nations Convention on the Law of the Sea. 10 December 1982, Montego Bay, Jamaica.* United Nations Treaty Series, Vol. 1833, 1-31363. Entered into force 16 November 1994. (also available at https://treaties.un.org/doc/Publication/UNTS/Volume%201833/volume-1833-A-31363-English.pdf).

[3] FAO. 1995. *Code of Conduct for Responsible Fisheries.* Rome, FAO. 41 pp. (also available at www.fao.org/docrep/005/v9878e/v9878e00.htm).

Note:

Brugère *et al.*(2010) provide practical guidance on policy formulation and processes. It starts by reviewing governance concepts and international policy agendas relevant to aquaculture development and proceeds by defining "policy", "strategy" and "plan" while explaining common planning terminology. See 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 pp. (also available at www.fao.org/docrep/012/i1601e/i1601e00.pdf).

3.5 Identification of potential for cultured species and farming systems

Species should be mainly those with proven culture technologies and with established national or international markets. Some environmental concerns can be overcome by selecting native species depending on the region of interest, the species already cultured, or those undergoing trials. The identification of potential areas for aquaculture should be based on criteria that would be favourable for grow-out of these species. For instance, it is well known that temperature affects the feeding, growth and metabolism of fish and shellfish; thus, water temperature is a common area selection criterion for all species.

Also essential is a broad assessment of areas where it is technologically feasible to place appropriate culture installations. For example, sea cages for fish grow-out and longlines for mussel grow-out are the prevalent culture structures in current offshore mariculture practice. Both sea cages and longlines are tethered to the sea floor, and thus the key assumption is that both sea cages and longlines will, for the time being and until technology develops, be located close to coastlines because of the technical and cost limits related to the depth of tethering. For land-based systems, especially ponds for the growth of relatively cheaper species, costs become an issue, so ready access to a suitable freshwater source is needed on relatively flat land whose soil structure means ponds do not need to be lined.

Shrimp aquaculture ponds in Sinaloa, Mexico

The Mexican National programme for Aquaculture Management was created to: (i) enable an orderly and competitive aquaculture sector that is sustainable; and (ii) regulate and administrate the sector using processes and tools such as the delimitation of aquaculture zones. In this programme, shrimp farming in Sinaloa State is used as one example to illustrate how aquaculture is managed through aquaculture production units or aquaculture zones.

Courtesy of Giovanni Fiore Amaral

4. ZONING

Zoning implies bringing together the criteria for locating aquaculture and other activities in order to define broad zones suitable for different activities or mixes of activities. Zoning is a process that countries can use to sustainably and responsibly identify and allocate areas that are biophysically and socio-economically suitable for aquaculture. In broad terms, zoning can be used to identify potential areas for growth where aquaculture is new, and help regulate the development of aquaculture where it is already established (Table 6). Definition of the legal boundaries of zones demands a consultative process that aligns policy, law, local interests and ecological carrying capacity (more details on carrying capacity are found in Annex 4). More specifically, zoning according to GESAMP (2001) can be used to:

- prevent and control environmental deterioration at the farm and watershed scale;
- implement biosecurity measures and disaster risk management;
- reduce adverse social and environmental interactions; and
- serve as a focus for estimates of environmental capacity.

Additionally, zoning can also be used to:

- increase production and social development;
- serve as a platform for dialogue to reduce conflict among potential resource users;
- help potential developers identify prospective farm sites where long-term investments are possible (user rights);
- establish clear norms/regulations for commercial behaviour within zones; and
- define the area over which planners and regulators set and monitor objectives.

TABLE 6. Examples of zoning initiatives in different countries

Country	Zoning initiatives	Source
Australia	The responsible minister may identify within state waters: • Aquaculture zones, in which specified classes of aquaculture will be permitted. • Prospective aquaculture zones, which are in effect for a specified period not exceeding three years during which investigations are to be completed to determine whether the zone should become an aquaculture zone. • Aquaculture exclusion zones, in which no aquaculture will be permitted. • Aquaculture emergency zones for short-term relocation of aquaculture operations.	South Australia Aquaculture Act (2001, as amended in 2003, 2005 and 2015)[1]
Chile	Twelve regions have been identified so far as authorized areas for the establishment of aquaculture activities (A.A.A.: Areas autorizadas para el ejercicio de la acuicultura); defined as: "geographical areas classified as such by the Sub-Secretariat of Fisheries to be adequate for the establishment of an aquaculture facility". Only areas so classified are eligible for aquaculture investments.	Fisheries and Aquaculture Law[2]
New Zealand	The Resource Management Act establishes that aquaculture activities are restricted to designated coastal marine areas. The regional council develops regional plans and policy statements in order to manage coastal resources, including aquaculture, and the plans are approved by the Department of Conservation.	Resource Management Act 1991 as amended in 2016[3]

[1] South Australia Aquaculture Act. 2001. Consolidated version of Act No. 66 of 2001, as amended 1 July 2015, Australia (South Australia). FAOLEX No. LEX-FAOC044087. (also available at http://faolex.fao.org/docs/pdf/sa44087.pdf).

[2] General Law on Fisheries and Aquaculture (No. 18.892). Ley General de Pesca y Acuicultura (Ley No. 18.892 de 1989). Texto refundido, coordinado y sistematizado ha sido fijado por el Decreto No. 430. Chile. FAOLEX No. LEX-FAOC001227. (also available at http://faolex.fao.org/docs/pdf/chi1227.pdf).

[3] Resource Management Act. 1991. Act No. 69 of 1991. Reprint as at 18 October 2016, New Zealand. (also available at www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html).

The zoning process is normally led by the government at the relevant geographical scale through a consultative interaction with national and local stakeholders, especially those who may invest or set up fish farms, and those who may be affected by aquaculture development (Hambrey *et al*., 2000). Defining and agreeing on broad development objectives for an aquaculture zone is the focus for public involvement and participation. A range of rapid rural appraisal communication techniques are available and can be adapted to local circumstances to facilitate quality dialogue (see tools in Annex 4).

At the zoning stage, it is important to include policy-makers and government planners; scientists (fishery, environment, rural sociology, economics) and farmer leaders; private industry representatives (supply inputs, traders, processors, exporters); and local authorities (agriculture, forestry, industry, tourism) where local development objectives and priorities are reviewed. In some cases, the inclusion of non-governmental organizations (NGOs) and/or consumer groups might also be useful.

When the process of actual boundary definition, zone allocation and identification of possible impacts and mitigation strategies are discussed, it will be important to have representatives of local government; the fishery management agency; other local regulatory bodies (agriculture, forestry, industry, tourism); farmer groups; and relevant local communities, including indigenous groups. Depending upon the nature of the zone, valuable inputs from representatives of private industry, consumer groups and agribusiness associations might also be useful.

The key steps in the zoning process are:

(i) identification of areas suitable for aquaculture;
(ii) identification of issues and risks in zoning;
(iii) broad carrying capacity estimation for aquaculture zones;
(iv) biosecurity and zoning strategies; and
(v) legal designation of zones for aquaculture.

4.1 Identification of areas suitable for aquaculture

Zone boundaries are initially based on hydrographical or hydrological parameters at a scale from a few to hundreds of kilometres, and are usually all or part of a contiguous waterbody or basin such as a fjord, tributary of a river or whole river system, a whole lake, a coastal bay, or an estuary or a semi-enclosed sea.

Geographies with the potential to become an aquaculture zone generally are those that have relatively few existing users, abundant water of a quality adequate for farmed species, have basic production infrastructure (e.g. electricity, roads) and access to input and output markets (including labour), and are not located near ecologically sensitive sites.

At the subnational, national or regional scales, it may only be possible to define in very general terms where aquaculture would most likely prosper. Remote sensing and geographic information systems (GIS) are excellent for this kind of work, and are useful tools to support stakeholder perceptions and insight. Satellite images can show where human settlement and other important land uses could be expected to conflict with aquaculture development; for example, GIS-based flood-zone mapping is commonly used by insurance companies to identify areas prone to inundation and can also provide useful information on such risks.

At the zoning stage, some detail is needed to define good places for aquaculture. In this context, local knowledge, organized data collection, property maps and site visits should be used to focus stakeholder discussion on defining where boundaries for aquaculture zones should be located within the broader regions identified during the scoping exercise.

The fundamental factors that determine the viability of a zone for aquaculture are basic topography/bathymetry (i.e. available flat land or open water), temperature, current velocity, and water quantity and water quality (e.g. salinity, hardness). These determine the species that can be cultured efficiently in a particular area, and give a broad indication of the production system that is best suited. The larger the population, the greater the potential market for aquatic products and the availability of labour and services. Urban market centres are potential locations for on-processing and marketing of the fish. However, there are risks associated with urban centres, including theft and pollution.

Pre-existing aquaculture also has an influence on where new aquaculture should be placed. The presence of successful aquaculture sites is indicative of more general suitability, but should not be automatically assumed. The presence of critical infrastructure, such as roads, power facilities, feed mills, processing facilities and so on, also argue for clustering of aquaculture within zones. This must be balanced with the need to provide sufficient space so that effluents and disease from one farm cannot flow onto another and the carrying capacity of the local environment.

Table 7 outlines the main suitability criteria that apply to most aquaculture farming systems. The various criteria listed in Table 7 will each have their own degree of importance, and it is essential that these can be ranked or measured for specific locations, even if this can only be done crudely. It is also important to determine "thresholds" that pertain to a desired level of suitability for each criterion. The selection of the thresholds involves interpretation of the data selected, and such interpretation should be guided with literature research and opinions from experts and farmers. Thresholds will vary according to location, scale, environment, species and culture systems, and some of the thresholds may change over time. For example, species generally have an optimal range within which they will grow well, suboptimal ranges when stress is induced, and lethal levels above and below this, but will change only slowly or not at all. Social thresholds are likely to me more flexible, as these can change over time. In such cases, it is advisable to operate within optimal ranges where possible to ensure efficiency and cost effectiveness.

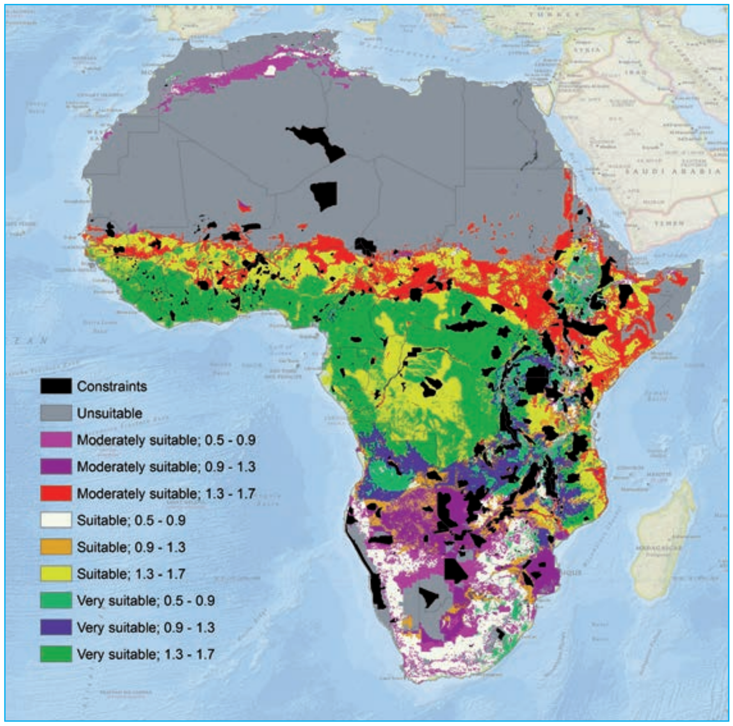
Knowledgeable technicians using the tools listed in Table 4 can identify zones with potential for aquaculture and provide advice on the most suitable species. There is also a myriad of published literature available on criteria for spatial planning and management of aquaculture, many examples of which can be found at:

- The GISFish Global Gateway to Geographic Information Systems, Remote Sensing and Mapping for Fisheries and Aquaculture (www.fao.org/fishery/gisfish).
- GIS and spatial analysis. GIS and remote sensing journal articles from the Institute of Aquaculture, University of Stirling, the United Kingdom of Great Britain and Northern Ireland (www.aqua.stir.ac.uk/GISAP/gis-group/journal-papers).

A good example of the use of GIS to identify potential aquaculture zones is an FAO study by Aguilar-Manjarrez and Nath (1998), who estimated inland fish farming potential at a continental scale. By overlaying the temperature regime, water availability, suitability of topography and soil texture, availability of agricultural by-products, local markets and road density on a map of Africa (Figure 2), they were able to identify in broad terms which areas on the African continent would be suitable for aquaculture.

While at this scale, it is not possible to identify exact locations for aquaculture zones, at the scoping stage this kind of information is useful to identify parks, deserts, flooded areas, cities and other major geographical features that would rule out aquaculture a priori.

FIGURE 2. Suitability for small-scale farming and potential yield (crops/year) of Nile tilapia in Africa



Source: Aguilar-Manjarrez and Nath (1998).

4.2 Identification of issues and risks in zoning

There are a broad range of issues and risks for zoning, and it is advisable to identify, inter alia, those related to environment, biosecurity, climate-related risks, social conflicts and governance. A good approach to identify issues is to focus on the different steps in the aquaculture production process, including upstream (e.g. feed supply) and downstream (e.g. post-harvest) aspects, and understand the impacts on such processes and the likelihood of occurrence. By doing this, it should be possible to determine whether the risk and likelihood of occurrence means a specific zone is unsuitable to become an aquaculture zone. 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 need to be identified within a specific scale and ecosystem boundary, so risks can be defined as local only, or regional, or national. Tranboundary issues should also be addressed where, for example (rivers), water starts within one country, but flows through another and then used for aquaculture development. The converse is also true when water, potentially impacted by nutrients from aquaculture, flows across borders into another country or region.

In most cases, issues such as climate change impacts and urban pollution of aquatic environments have damaging effects on aquaculture. Aquaculture is vulnerable to a number of potentially catastrophic climatic and other disturbances. In addition to wildlife (especially bird) predation, disease and theft, which affect all aquaculture systems, there are likely to be risks that apply only to specific production systems and zone location, such as:

Risks specific for pond/raceway aquaculture:
- floods
- droughts
- severe winters
- earthquakes
- volcanic eruptions
- tidal surges/storm surges/tsunamis

TABLE 7. Essential criteria for scoping, zoning, site selection and aquaculture management areas. Depending upon the species and systems being considered for aquaculture, other criteria deserve consideration

Criteria	Scoping	Zoning	Site selection	Aquaculture management areas
Biophysical (requirements for farmed species and systems)	Water quantity (overall water resources available); Water quality (distance from potential pollution sources); Suitable water temperature ranges; Areas with suitable soil types and slopes for ponds; Suitable depth ranges for culture structures; Exposure to climate disturbances; Land use	Water quantity (amount of surface and groundwater available); Water quality (especially salinity and pollution); Optimal water temperatures; Areas with suitable soil texture and slope for pond construction; Suitable depth ranges for floating structures (e.g. cages, racks); Hydrodynamics (e.g. current velocity); Infrastructure (roads, access, landing sites, etc.)	Water quantity and quality; Soil chemistry and structure (if ponds); Suitable topography for construction pond dykes and farm infrastructure; Land use; Suitable depth for culture structures; Hydrodynamics (e.g. current velocity); Shelter suitable for culture structures; Access/roads landing	Farms are reasonably close; Common waterbody; Common water source; Common species; Common access/roads; Landing sites
Environmental	Avoid protected areas, critical habitats and very exposed areas	Buffer distances to mitigate impacts from sensitive habitats, protected areas, natural biodiversity condition; Distance from other aquaculture zones; Suitable wave heights; Distance from pollution sources	Water depth; Turbidity and suspended solids; Chlorophyll and dissolved nutrients; Hydrodynamics (e.g. current velocity); Sensitive habitats and species; Water quality and condition of the benthos; Presence of predators; Distance from other farms	Water turnover; Nearness of farms; Level of eutrophication; Benthic diversity; Bottom anoxia; Feed conversion rate; Presence of predators; Environmental impact data in general
Social (minimize conflict)	Avoid socially sensitive areas (indigenous peoples' traditional sites, etc.)	Mitigate/reduce visual impact of farm clusters; Potential to integrate with adjacent land and water uses; Population density (availability of inputs, labour, markets, etc.); Access to capital, social services; Potential integration with traditional fisheries	No visual impact of farm; Local labour available; Potential participation of local/indigenous communities, women; Minimal theft, vandalism risks	Farmers are organized locally; There is good potential for cooperation; Potential interest and involvement of local communities
Economic	Distance to urban areas (access, availability of main markets, inputs, etc.)	Distance from other aquaculture zones/ fish farms (for sharing resources); Access to local markets; Access to roads	Access to electricity; Access to markets in close proximity to site; Availability of inputs; Reliable access to roads and ports; Access to services	Access to common market; Common access to inputs and services; Common infrastructure/roads, landing sites
Governance	Legal and regulatory frameworks available; National strategy and development plans	Multisector regulatory frameworks; Sea and coastal access rights	Aquaculture permitting rules and regulations	Extension for the adoption of best management practices available; Available aquaculture certification systems; Compliance with management measures; Available regulations/norms, to address cumulative impacts of resource use
Aquatic animal health	Legal aspects; Existing biosecurity frameworks	Distance from other aquaculture zones; Environmental conditions and other forcing factors that minimize disease risks	Pathogen dissemination pathways; Water flows and hydrodynamics; Water quality	Level of disease outbreak; Water quality; Need for implementation of biosecurity

Risks specific to cage aquaculture include:

- oil spills/chemical spills/chemical runoff
- pollution
- superchill/ice
- storms
- harmful algal blooms and jellyfish
- hypoxia

In addition to these biophysical risks, conflicts with other natural resource users are common. Chief among these are the direct competition for water and space with agriculture and real estate developers; access to traditional sites of indigenous people; and disagreements over visual impact with the tourism sector. Conflict with fishers is also common, given that sea space or lake space can become off limits when structures such as cages are added, which reduces the ability of fishers to exploit such areas.

Risk analysis involves answering the following questions (Bondad-Reantaso, Arthur and Subasinghe, 2008): (i) What can go wrong? How likely is it to go wrong and what are the consequence of its going wrong? and (ii) What can be done to reduce either the likelihood or the consequences of its going wrong?

Risk mapping can help to identify the most important threats. Examples of risk maps for aquaculture zoning include:

- **Fish cage farming and tourism.** Use of GIS-based models for integrating and developing marine fish cages within the tourism industry in Tenerife, Canary Islands (Pérez, Telfer and Ross, 2003a).
- **Islands and wave strength.** Climate-related wave risk maps for offshore cage culture site selection in Tenerife, Canary Islands (Pérez, Telfer and Ross, 2003b)
- **Floods and aquaculture.** Modelling the flood cycle, aquaculture development potential and risk using MODIS data: a case study for the floodplain of the Rio Paraná, Argentina (Handisyde *et al.*, 2014).
- **Monitoring algal bloom development.** Environmental information system using remote sensing data and modelling to provide advanced warning of potentially harmful algal blooms in Chile so that their impacts can be minimized by the aquaculture industry (Stockwell *et al.*, 2006).

It is also important to assess the environmental and socio-economic risks that aquaculture can pose to other sectors and on itself. These may include biodiversity losses due to organic and chemical pollution, diseases generated by fish farms, and impacts from escaped fish. These risks are evaluated and mitigated through a solid understanding and management of a zone, or AMA location, and carrying capacity. For large industrial farms (e.g. salmon cages), there are models to estimate the spatial distribution of organic matter and related risks and the consequences in terms of water quality and overall carrying capacity (see section 4.3 and Annex 4).

4.3 Broad carrying capacity estimation for aquaculture zones

For purposes of aquaculture zoning, carrying capacity sets an upper limit for the number of farms and their intensity of production that retains environmental and social impacts at manageable and/or acceptable levels, which then implies overall sustainability. At the zone level, carrying capacity will typically be expressed as a level of production (in tonnes) produced through a number of farms located in geographic space, or production in tonnes per hectare or km^2. Within aquaculture zones, carrying capacity has two primary dimensions:

- ecological carrying capacity: the maximum production that does not cause unacceptable impacts on the environment; and
- social carrying capacity: the social licence for the level of farm development that does not disenfranchise people or result in net economic losses to local communities.

At a large zone level, preliminary limits to the number of farms and intensity of production are set based on a large-scale understanding of the area or waterbody proposed to be or already allocated to aquaculture. This contrasts with setting more detailed carrying capacity estimates for AMAs and for individual sites in which more specific assessment is made of local conditions. There are circumstances where an aquaculture zone could become an aquaculture management area if a suitable management plan is developed and implemented. Typically, however, aquaculture zones are broader scale areas that may contain one or more AMAs and numerous sites.

4.3.1 Ecological carrying capacity

To estimate carrying capacity in the context of fish aquaculture, models are usually used to estimate a maximum allowable production, limited primarily by modelling changes to environmental conditions. Nutrient input or extraction and oxygen changes (depending on the species to be cultivated) can be assessed, for example, on a specific catchment area or waterbody for a given number of aquaculture units. For extractive production, such as shellfish, food depletion is the major consideration along with effects on wild species and food availability for them.

The assessment of ecological carrying capacity is based on the capacity of the ecosystem to continue to function through the application of environmental quality standards that cannot be exceeded when aquaculture is included into the system. It is sometimes referred to as assimilative capacity, implying the system is able to assimilate a certain level of nutrients or oxygen uptake without causing detrimental effects such as eutrophication. Aquaculture produces or uses dissolved and particulate matter that enter the environment, uses oxygen and other resources, and adds residues from diseases or parasites and other treatment chemicals. It is the consequences of these on the ecosystem that are used in estimating ecological carrying capacity. The capacity of a particular area also depends on water depth, flushing rates/current velocity, temperature and biological activity in the water column and bottom sediments, and attempting to define the level of ecological resilience. The multifactor nature of ecological capacity is one of the reasons why models are often applied, as models can attempt to integrate the multiplicative and cumulative nature of these factors.

It may also be important to take into account background wastes entering a shared waterbody, coming from other sources such as sewage discharges and diffuse inputs from agriculture, domestic waste and forestry. The basic reasoning is that the collective consequences of all aquaculture farms and background inputs can be compared with the ecological capacity of the ecosystem, which can then determine how much aquaculture can sustainably be conducted within a certain physical space. In reality, diffuse inputs (as opposed to point sources) are difficult to assess and measure, which makes estimating the existing consequences of these background wastes difficult. It may also be that activities such as forestry or agriculture have occurred for millennia already, and therefore current water quality and conditions may already reflect the impacts of such activity.

The negative impacts of exceeding ecological carrying capacity include eutrophication, increases in primary productivity and potential phytoplankton blooms fueled by nutrients discharged from farms, accumulation of noxious sediments in the form of fish faeces and feed wastes, and loss of biodiversity due to declining habitat quality. The consequences for aquaculture farmers can be dramatic, including loss of fish stocks on the farms because of blooms, oxygen stress and disease; and exceeding ecological carrying capacity often aggravates fish health problems and social conflicts. Environmental impacts of aquaculture vary with location, the production system and species being grown. Fish cage culture is an open system that extracts oxygen from water, and discharges faecal and feed and other wastes into the surrounding water and sediments. Pond culture is a closed system, and releases nutrient-rich water and effluents during water exchange and/or pond draining during harvest. Bivalves depend upon natural productivity for their food, but compete with other organisms for food (organic matter, microalgae, etc.) and dissolved oxygen in the water column, and seaweed production can reduce light penetration affecting environmental conditions and species below. The fact that there is no "consequence free" aquaculture means that there is a basic need to determine ecological carrying capacity.

One of the earliest applications of mass-balance modelling in aquaculture was the use of Dillon and Rigler's (1974) modification of a model originally proposed by Vollenweider (1968), which used phosphorus (P) concentration to estimate the ecological carrying capacity of freshwater lakes, assuming that P limits phytoplankton growth and therefore eutrophication (Beveridge, 1984). Inputs to the environment from fish culture are evaluated to determine likely changes in overall water quality. This model has been used widely to estimate carrying capacity of lakes to support fish farming, as in Chile. Further modifications of this model have also been used assuming nitrogen as the limiting factor (Soto, Salazar and Alfaro, 2007).

Ecological carrying capacity models integrate hydrodynamic, biogeochemical and ecological processes in the environment with oxygen consumption, sources, and sinks of organic matter and nutrients derived from farm activity linked to the ecosystem state. There are currently few models that assess carrying capacity fully at the zonal scale; EcoWin (Ferreira, 1995) is one example that combines hydrodynamic models with changes to water biogeochemistry to look at large-scale, multi-year changes under non-aquaculture and aquaculture conditions (Ferreira, 2008a; Sequeira *et al.*, 2008).

On a slightly smaller zonal scale, models such as the Loch Ecosystem State Vector model (Tett *et al.*, 2011) resolve seasonal variations in oxygen and chlorophyll in defined sea areas; and the Modelling—Ongrowing fish farms—Monitoring (MOM) model used for farm level assessment also contains a module for wider scale evaluation of water quality and oxygen concentration (Stigebrandt, 2011).

In Chesapeake Bay and the Puget Sound, United States of America, the EcoWin model has been combined with a farm-level model (FARM) and with other tools into a production, ecological, and social capacity assessment that builds together ecological carrying capacity modelling with a stakeholder engagement process that seeks to reduce social conflicts (see Bricker *et al*., 2013; Saurel *et al.*, 2014). Other similar projects have occurred in Portugal (Ferreira *et al.*, 2014) and Ireland (Nunes *et al.*, 2011). Availability of models to assess freshwater systems is more limited.

Until more precise modelling can be undertaken at the zonal level, it is possible to apply simplistic approaches to limit production to acceptable levels. Examples include the Philippines where a maximum of 5 percent of an aquatic body can be used for aquaculture, although this does not estimate carrying capacity per se. In Norway from 1996 to 2005, feed purchases were used to monitor aquaculture development.
This worked initially as a quota that limited the amount of feed that could be delivered to farms.
As well as serving as an indicator of production (rather than capacity), this system had the benefit of rapidly reducing feed conversion ratio (FCR), as farmers tried to optimize the use of the feed allocated to them while maximizing production, which in turn reduced environmental consequences. This was combined with a limit on the cage volume of 12 000 m^3 per licence together with a maximum fish density in cages. This number of licences with volume limit, along with rules for biomass and feed quota, was the framework used to control production development. Norway's approach has since been updated to now assess carrying capacity directly at site and/or small area scales.

Indices have also been used to assign the status of waterbodies into discrete categories that define typically a specific water status with regards to aquaculture development, or whether or not aquaculture is liable to have an effect (e.g. in the latter case, of eutrophication potential using the TRIX index in Turkey, see Annex 5); or to define areas considered to be the most environmentally sensitive to further fish farming development due to the high predicted levels of nutrient enhancement and/or benthic impact (Gillibrand *et al.*, 2002). Gillibrand *et al*. (2002) scaled model outputs from 0 to 5, and the two scaled values (nutrients and benthic impact) were added together to provide a single combined index. On the basis of this combined index, areas were designated as Category 1 (sensitive to more production, and therefore no more production allowed); Category 2 (production potential, with caution); or Category 3 (least sensitive, and opportunities to increase production).

Overall, the larger the area or zone being evaluated, the more complex and more difficult it is to make reliable estimations of carrying capacity owing to the multiple interacting dynamic factors that affect it and acceptable limits in environmental change.

4.3.2 Social carrying capacity

Social carrying capacity is less tangible than other carrying capacities, but is the amount of aquaculture that can be developed without adverse social impacts (Angel and Freeman, 2009; Byron and Costa-Pierce, 2013). Social licence for aquaculture is affected by cultural norms, and can be affected by social mobility and wealth of people and by the species grown and aquaculture practices undertaken, seen as either polluting (e.g. fed fish) or non-polluting (e.g. non-fed fish or extractive species) whether or not this is explicitly correct. Social capacity for aquaculture is also affected by perceived or actual ecological degradation, the extent to which aquaculture impacts other livelihoods, exclusion of legitimate stakeholders from decision-making, and incompatibility of aquaculture with alternative uses, which are all key sources of social conflict.

Social conflicts can be minimized through good engagement in the development and management of aquaculture zones, adverse impacts on the ecosystem and use of space. Fair business practices and the creation of opportunities for local communities along the aquaculture value chain from manufacture and supply of inputs through to processing, transport and marketing will build alliances among the local population. Proper stakeholder engagement, sharing of information and timely communication in the planning process can help investors avoid social conflicts.

4.4 Biosecurity and zoning strategies

Disease is probably the main threat and cause of disaster to aquaculture everywhere and requires planning at all scales, from individual farms to aquaculture zones and aquaculture management areas. The development and implementation of biosecurity and zoning strategies is increasingly recognized by countries and industries as essential to sustainable growth in aquaculture (Håstein *et al.*, 2008; Hine *et al.*, 2012). The World Organisation for Animal Health defines a zone as a portion of a contiguous water system with a distinct health status with respect to certain diseases; the recognition of zones is thus based on geographical boundaries. A zone may comprise one or more water catchments from the source of a river to an estuary or lake, or only part of a water catchment from the source of a river to a barrier that effectively prevents introduction of specific infectious agents. Coastal areas and estuaries with precise geographic delineation may also comprise a zone. For more detail on zoning and spatial planning from the biosecurity perspective, see Annex 2.

4.5 Legal designation of zones for aquaculture

The allocation of aquaculture zones is the final step in zoning and is the legal and normative process that creates an area(s) dedicated to aquaculture activities, whereby any future development thereof must respect this zone.

Aquaculture zones should be established within the remit of local or national aquaculture plans and legislative frameworks with the aim of ensuring the sustainability of aquaculture development and of promoting equity and resilience of interlinked social and ecological systems. Regulations and/or restrictions should be assigned to each zone in accordance with their degree of suitability for aquaculture activities and carrying capacity limit. Zones to be allocated to aquaculture activities can be classified, inter alia, as "areas suitable for aquaculture activities", "areas unsuitable for aquaculture activities", and "areas for aquaculture activities with particular regulation and/or restriction". To this end, guidelines should be developed by governments according to the specific location.

Zoning plans guide the granting or denial of individual permits for the use of space. This process includes additional elements of implementation, enforcement, monitoring, evaluation, research, public participation and financing, all of which must be present to carry out effective management over time.

Salmon farming in a remote fjord in southern Chile

The location of a salmon farm must consider the environmental carrying capacity of the recipient waterbody and the local social context in order to be environmentally, socially and economically sustainable.

Courtesy of Doris Soto

5. SITE SELECTION

Site selection ensures that farms are located in a specific location, which has attributes that enable the necessary production with the least possible adverse impact on the environment and society. Site selection is a process that defines what is proposed (species, infrastructure, and so on), estimates the likely outputs and impacts from that proposal, and assesses the biological and social carrying capacities of the site so that the intensity and density of aquaculture do not exceed these capacities and cause environmental degradation or social conflicts. It also provides an assessment for locating farms so that they are not exposed to adverse impacts from other economic sectors and vice versa.

Site selection for individual farms within designated zones is normally led by private-sector stakeholders with direct interest in a specific aquaculture investment. The government assists by defining clear site licencing, environmental impact assessment procedures, and what is acceptable within the zones where the sites will be located. The key steps in the site selection process are:

(i) assessment of suitability for aquaculture;
(ii) detailed estimation of carrying capacity for sites;
(iii) biosecurity planning and disease control; and
(iv) authorization arrangements.

5.1 Assessment of suitability for aquaculture

Table 8 lists the most important criteria to be considered in the selection of individual farm sites within aquaculture zones. Because of the multidisciplinary nature of the criteria and the assessment that needs to be undertaken, it is normal practice to employ professional aquaculture technicians and/or consultants. It is always wise to use conservative estimates (i.e. precautionary principle) in production system planning.

The assessment should thus include a review of local conditions (e.g. temperature, water quantity), historic conditions (such as historical climate data from the local meteorological agency or other sources), and some prediction of impacts from aquaculture activity and measures to be undertaken to minimize impacts (i.e. mitigation). Before finalizing a site suitability assessment, a historical review of external risks should be done, which can include storm, flood and drought frequency, and intensity data from the zoning exercise (section 4.2), that should be made available to individuals or groups seeking permits for aquaculture.

Spacing between the proposed site and other farms and between the proposed fish farm and other economic, cultural or ecological assets is of critical concern in determining where a farm is likely to succeed and how much product a farm can generate (Table 9). This is particularly true in the case of disease transfer, which has proved costly to the aquaculture community. If farms are too close together, diseases can easily spread from one farm to another, and diseases can recirculate leading to persistent problems. This is what happened in the Chilean salmon farming industry prior to zoning and carrying capacity based management, with too many farms crowded into too small a space. When one farm had a disease outbreak, it rapidly spread from one farm to another, resulting in near collapse of the entire industry (see Chile case study in Annex 5). In the Mekong Delta of Viet Nam, farm overcrowding has been identified as a key factor in the inability to manage disease outbreaks (World Bank, 2014).

The choice of an aquaculture site should also take into consideration the location and distance of sensitive habitats, tourist facilities, sites of cultural importance and other service infrastructure, with a consideration of the potential to impact these activities or be impacted by these activities. Table 10 provides an example of distances from aquaculture facilities to other areas or activity in British Columbia, Canada.

Being potential sources of pollution or introduction of disease, human habitation has the potential to be a threat to the viability of a farm and should, where possible, be kept at a safe distance. Potentially, tourism can also be negatively affected, both from a visual perspective (e.g. visual impacts from tourists visiting

TABLE 8. Criteria and data requirements to address production, ecological, and social opportunities and risks

Farming system	Production	Ecological	Social
Coastal marine cages	Temperature Wind, waves, currents Storm and tsunami exposure Depth Salinity Oxygen Diet type Feed regime Infrastructure Investment costs Nearness to other farms Nearness to human settlements Markets Etc.	Feed regime Critical habitats Biodiversity Eutrophication indicators Bottom anoxia indicators Environmental impact assessment (EIA) data in general Visual impact Etc.	Sea and coastal access rights Access to capital Beneficiaries Workforce Etc.
Ponds (inland/ coastal)	Water source Water quantity and quality Soils, slopes Rainfall, evaporation Drought and flood potential Nearness to other farms Temperature Diet type Feed regime Infrastructure Investment costs Markets Etc.	Feed regime Critical habitats Biodiversity Eutrophication indicators Visual impact EIA data in general Etc.	Landownership Water and riparian rights Access to capital Workforce Beneficiaries Etc.
Freshwater cages and pens	Temperature Wind, waves, currents Depth Storm exposure Oxygen Diet type Feed regime Infrastructure Investment, costs Nearness to other farms Nearness to human settlements Markets Etc.	Feed regime Critical habitats Biodiversity Eutrophication indicators Bottom anoxia indicators Visual impact EIA data in general Etc.	Landownership Water and riparian rights Access to capital Beneficiaries Etc.
Hatcheries	Water source Water quantity and quality Temperature Diets Infrastructure Investment, costs Markets Etc.	Critical habitats Biodiversity Eutrophication indicators Visual impact EIA data in general Etc.	Local needs Landownership Water rights Workforce Skills availability Visual impact Etc.
Bivalve culture on the bottom, in plastic trays, in mesh bags, on rafts or on longlines, either in shallow water or in the intertidal zone	Temperature Wind, waves, currents Depth Storm exposure Salinity pH Chlorophyll and productivity Investment, costs Nearness to other farms Nearness to human settlements Markets Etc.	Critical habitats Biodiversity Bottom anoxia indicators Visual impact EIA data in general Etc.	Sea and coastal access rights Access to capital Workforce Beneficiaries Etc.
Seaweed culture on the bottom, or off bottom on rafts or longlines	Temperature Wind, waves, currents Storm exposure Depth Salinity Nutrients availability Investment, costs Markets Etc.	Critical habitats Biodiversity Visual impact EIA data in general Etc.	Sea and coastal access rights Access to capital Workforce Beneficiaries Etc.

Modified from Ross *et al.* (2013).
Notes: Includes social, economic, environmental and governance considerations. Takes into account considerations of carrying capacity for site selection for different farming systems. The list of criteria is indicative rather than exhaustive.

TABLE 9. Some examples of regulated site-to-site minimum distances

Country	Site-to-site distances in national regulations	Source
Chile	Extensive production systems must maintain a minimum distance of 200 metres between them and 400 metres to intensive production systems. Excluded from this requirement are cultures of macroalgae crops fixed to a substrate. Suspended cultures of macroalgae must maintain a minimum distance of 50 metres between them and to other centres.	Art. 11°- 15 Aquaculture environmental regulation, 2001[1]
Norway	The act establishes a licencing system for aquaculture and provides that the Norwegian Ministry of Trade, Industry and Fisheries may, through regulations, prescribe limitations on the number of licences for aquaculture that are allocated. Accordingly, the Norwegian Ministry of Trade, Industry and Fisheries may prescribe: • the number of licences to be allocated; • geographic distribution of licences; • prioritization criteria; • selection of qualified applications in accordance with prioritization criteria; and • licence fees.	The Aquaculture Act (2005)[2]
Turkey	Distance between cage farms is determined by the Central Aquaculture Department, according to criteria such as projected annual production capacity, water depth and current speed. Distance between tuna cage farms and tuna and other fish farms may not be less than 2 kilometres, and less than 1 kilometre between other fish farms.	Aquaculture Regulation No. 25507[3]

[1] Environmental Regulations for Aquaculture. 2001. Reglamento ambiental para la acuicultura (Decreto No. 320), 14 de Diciembre de 2001, Chile. FAOLEX No. LEX-FAOC050323. (also available at http://faolex.fao.org/docs/pdf/chi50323.pdf).
[2] Act of 17 June 2005, No. 79, relating to aquaculture (Aquaculture Act). Lov om Akvakultur (Akvakulturloven), I 2005 hefte 8, Norway. FAOLEX No. LEX-FAOC064840. (English translation by Norwegian Directorate of Fisheries of 24 April 2006 (also available at https://www.regjeringen.no/globalassets/upload/kilde/fkd/reg/2005/0001/ddd/pdfv/255327-l-0525_akvakulturloveneng.pdf).
[3] Aquaculture Regulation No. 25507. Su Ürünleri Yetiştiriciliği Yönetmeliği, T.C Resmî Gazete No. 25507. 29 June 2004, Turkey. FAOLEX No. LEX-FAOC044968. (also available at http://faolex.fao.org/docs/texts/tur44968.doc).

picturesque places that also contain aquaculture) and from an environmental perspective, whereby negative impacts on water quality may impact a tourist's enjoyment of a local area. It is generally desired that fish farming operations be located away from tourist areas. Conversely, biological assets, such as coral reefs, mangroves, seagrass beds, shellfish beds, fish spawning grounds and other biodiversity assets, should be protected by locating aquaculture sites at a safe distance, preferably downstream where effluents cannot cause problems. Sites sacred to indigenous peoples and sites of historical significance should be respected and only developed through consultation with stakeholders and with explicit permission.

5.2 Detailed estimation of carrying capacity for sites

Assessment of carrying capacity at the site level is much more developed than the assessment at the zonal or area scales, especially for the marine environment, but nonetheless still contends with many of the complexities outlined above when considering production impacts on water quality and sediments, and resolving what an acceptable level of production is. In the majority of cases, site-level carrying capacity models estimate nutrient inputs to the environment and assess impacts on sediments, on the water column, or both. More often than not, models assess these impacts against minimum environmental quality standards, often defined

TABLE 10. Distances between salmon aquaculture sites and other areas in British Columbia, Canada

Distance	To
At least 1 km	in all directions from a First Nations reserve (unless consent is received from the First Nations).
At least 1 km	from the mouth of a salmonid bearing stream determined as significant in consultation with the Department of Fisheries and Oceans Canada (DFO) and the province.
At least 1 km	from herring spawning areas designated as having "vital", "major" or "high" importance.
At least 300 m	from intertidal shellfish beds that are exposed to water flow from a salmon farm and which have regular or traditional use by First Nations, recreational or commercial fisheries.
At least 125 m	from all other wild shellfish beds and commercial shellfish-growing operations.
An appropriate distance	from areas of "sensitive fish habitat", as determined by DFO and the province.
An appropriate distance	from the areas used extensively by marine mammals, as determined by DFO and the province.
At least 30 m	from the edge of the approach channel to a small craft harbour, federal wharf or dock.
At least 1 km	from ecological reserves smaller than 1.000 ha, or approved proposals for ecological reserves smaller than 1 000 ha.
Not within a 1 km line	of sight from existing federal, provincial or regional parks, or marine protected areas (or ap-proved proposals for these).
In order to not	infringe on the riparian rights of an upland owner, without consent, for the term of the tenu-re licence.
Not in areas	that would pre-empt important aboriginal, commercial or recreational fisheries, as determined by the province in consultation with First Nations and DFO.
Not in areas	of cultural or heritage significance, as determined in the Heritage Conservation Act. Consistent with approved local government by laws for land use planning and zoning.
At least 3 km	from any existing finfish aquaculture site, or in accordance with a local area plan or Coastal Zone Management Plan.
Not in areas	that would pre-empt important aboriginal, commercial or recreational fisheries, as determined by the province in consultation with First Nations and DFO.
Not in areas	of cultural or heritage significance, as determined in the Heritage Conservation Act. Consistent with approved local government by laws for land use planning and zoning.
At least 3 km	from any existing finfish aquaculture site, or in accordance with a local area plan or Coastal Zone Management Plan.

Source: Dow (2004).

nationally through scientific endeavour and (in some cases) set specifically by regulators, which then set a maximum production level, often derived through an iterative process. Some models take this further by assessing profitability to ensure the ecological limits defined are profitable for the farmer as well.

Site carrying capacity models can range from simple mathematical calculations to more complex integrated processes that require specialized software. In perhaps the simplest form, model equations produce a mass balance for many different parameters, the most widely used being nitrogen and phosphorus concentrations into and from aquaculture systems. There is a determination of how much of a specific nutrient enters or is removed from a local (site) system and analysis of the consequences of that input/removal for the waterbody.

A relatively simple example of a nutrient-based carrying capacity model was developed by Halide, Brinkman and McKinnon (2008) and is available online at http://epubs.aims.gov.au/handle/11068/7831; it is in part based on the MOM model (see below).

Other models are significantly more complex, and a few only are summarized here to indicate what is possible. The MOM model (Ervik *et al.*, 1997; Stigebrandt, 2011) defines, among other things, changes to sediment oxygen concentration from the deposition of particulate matter for a certain level of production, which is compared with a minimum environmental quality standard. Additionally, the Farm Aquaculture Resource Management (FARM) model assesses species growth and the likely impacts of that growth on environmental conditions (Ferreira, Hawkins and Bricker, 2007; Cubillo *et al.*, 2016).

Another approach to carrying capacity estimation at the farm scale uses depositional models (Cromey, Nickell and Black, 2002; Corner *et al.*, 2006; Ferreira, Hawkins and Bricker, 2007; Ferreira *et al.*, 2008a, 2008b; Cubillo *et al.*, 2016), which predict the accumulation of particulate outputs from fish cage aquaculture in the sediments below fish cages (Figure 3) or other aquaculture systems, and can be used in local-scale assessment of the effects of fish cages on sensitive demersal flora and fauna. The DEPOMOD model (Cromey, Nickell and Black, 2002) is a particle tracking model for predicting flux and resuspension of particulate waste material and assesses the associated benthic community, the outcome of which can be a definition of an allowable zone of effect; see Cromey (2008). The ORGANIX model (Cubillo *et al.*, 2016) can be used to evaluate settlement of wastes, and combined with the FARM model can assess the local impacts of multiple species, individually, and in combination in an integrated multi-trophic aquaculture (IMTA) system.

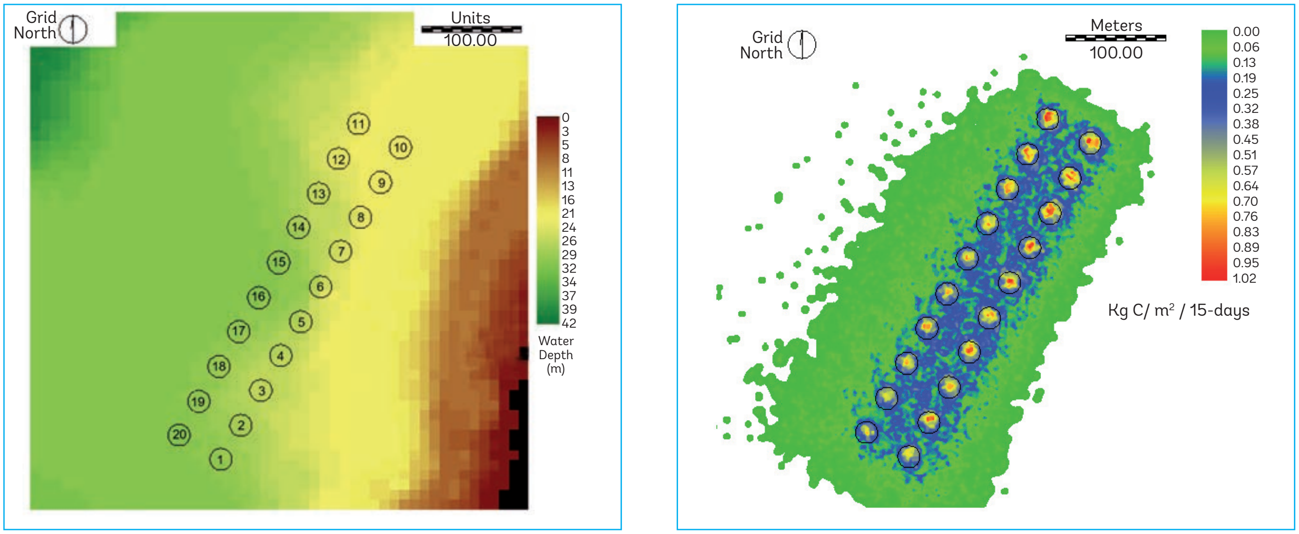
To estimate carrying capacity of shellfish and seaweeds, which do not pollute through nutrient outfall, but do compete with wild organisms for food, nutrients and oxygen, models should calculate the amount of shellfish that can be grown in a particular site without starving either the cultured or wild animals in the area. Ferreira (1995), Nobre *et al.* (2005, 2011), and Ferreira *et al.* (2008a) describe a carrying capacity model applicable for such systems. EcoWin is based on hydrodynamics, suspended matter transport, nitrogen cycle, phytoplankton and detrital dynamics, shellfish growth and human interaction and has been field tested in a number of locations, notably in Ireland (Ferreira, Hawkins and Bricker, 2007) and China (Ferreira *et al.*, 2008b).

An efficient production plan for aquaculture needs to consider carrying capacity and site characteristics to determine how much production can be accommodated in a particular location and, consequently, the amount of money that could be generated in order to achieve sustainability. Crowded production units mean that the stock can suffer from crowding stress, which lowers productivity (Figure 4), in addition to the disease transfer risks outlined previously. Figure 4 shows the evolution of productivity for three fish species in Chile over time, with dips in productivity associated with overcrowding, particularly of Atlantic salmon (*Salmo salar*). The decrease was critical in 2008 and 2009, and at this time saw the introduction of new regulations that established area management and coordinated fallowing periods, which resulted in improved productivity for all three species. Achieving production within the carrying capacity of the local system means managing for maximum productivity rather than maximum standing stock (e.g. the number of fish in the water at any one time), which will reduce pollution and costs while ensuring the welfare and maximizing the growth rate of the stock.

Carrying capacity estimation for individual farm sites is usually undertaken as part of the environmental impact assessment (EIA) and the licencing procedure (FAO, 2009). A fair and equitable licencing procedure, an EIA and an assessment of carrying capacity enable the setting of limits on farm size, including permits to discharge nutrients or other wastes to a waterbody, to ensure that there is no deterioration of water quality. This is particularly important for fed culture systems that generate wastes, but also for extractive species where wild stocks also need to be maintained.

For project planners at all levels, estimating carrying capacity is crucial to ensure overall sustainability of farms, and a number of modelling tools are available

FIGURE 3. Output from a particulate waste distribution model developed for fish culture in Huangdun Bay, China, using GIS, which provides a footprint of organic enrichment beneath fish farms



Source: Corner *et al.* (2006).

to be able to better understand what the limits are (see Annex 4). Models are generally the domain of knowledgeable specialists, and it is recommended that a suitable consultant conversant with appropriate models be engaged to develop systems relevant to specific circumstances.

5.3 Biosecurity planning and disease control

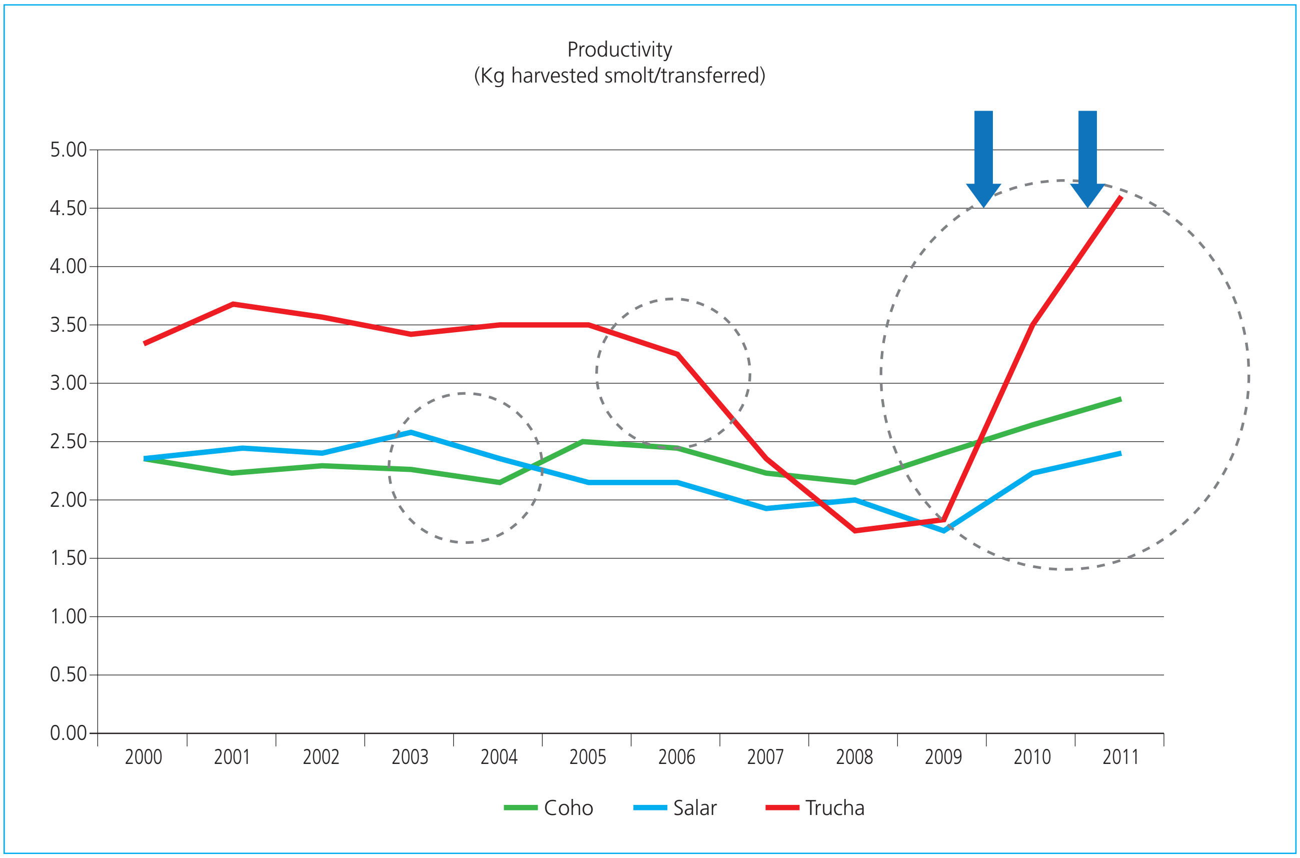
Diseases cause up to 40 percent of all losses in aquaculture systems, so biosecurity is an essential component of proper farm management at the site level. Diseases can spread to and from wild animals in the water surrounding a farm and through the water to other farms, and thus they are of concern to all stakeholders locally and within an aquaculture zone. Individual farms must maintain strict measures to prevent diseases coming into the farm (e.g. using certified disease-free stock), and maintain healthy and unstressed stocks and implement good hygiene practices so that diseases cannot gain a foothold and spread.

Most diseases affecting aquaculture organisms are more or less ubiquitous, present in low numbers in wild populations or in the environment. In most populations, some individuals will be resistant to a disease, but could still be a carrier. The onset of a disease outbreak not only requires the pathogen to be present, but stocks will also need to be in a vulnerable state, typically induced by some kind of stress. Common stressors in aquaculture include rough handling, low dissolved oxygen, inadequate feeding, and temperatures being either too high or too low or fluctuating. The combination of stressed fish and pathogen presence can lead to a disease outbreak.

The World Organisation for Animal Health is the leading international authority on disease management, including fish and shellfish. It proposes guidelines, published as the Aquatic Animal Health Code (available at www.oie.int/international-standard-setting/aquatic-code/access-online). Additionally, the fundamentals of aquaculture animal disease management have been reviewed by Scarfe *et al.* (2009). The basic components of a farm- or site-level biosecurity plan are:

- Screening and quarantine—all animals coming onto the farm should be certified disease free and tested for disease on arrival, and be maintained in separate holding facilities for a period of time to ensure that they are not infected.
- Isolation—nets, tanks and other equipment should be routinely disinfected, and farm workers should

FIGURE 4. Changes in productivity for three species of fish (kg harvest per smolt) under overcrowded (pre-2009) and properly spaced (post-2008) farm density



Source: Data from Alvial (2011).

maintain good hygiene, including handwashing and foot or boot washing. The amount of vehicular traffic (cars, boats) between the farm and the surrounding area should be kept to a minimum and disinfected upon return when possible.

- Proper handling—to avoid stress, fish should be kept in well-oxygenated water at an optimum temperature during holding and transport, and handled as little as possible during transport and when on site.
- Proper stocking density—in addition to causing stress, high-density conditions increase the frequency of contact among individual fish, leading to increased rates of disease transmission and infection.
- Regular monitoring—one of the first signs of disease is loss of appetite. Fish should be monitored closely during routine feeding to ensure that the fish are eating well and are healthy. Suspect animals should be removed immediately.
- Veterinary services—a licenced veterinarian should sample the farmed stock at regular intervals to ensure that any latent problem is detected as early as possible. If a government veterinarian is not available, farmers should call on a local specialist.

A more detailed analysis of the biosecurity implications for spatial planning and management can be found in Annex 2. Overall, a well-managed site, with maintained and healthy, well-fed stock along with appropriate and implemented hygiene procedures, reduces the likelihood of a disease outbreak and transmission between sites.

5.4 Authorization arrangements

The aquaculture leasing, licencing or permitting system is normally established through legislation or aquaculture-specific regulations. Implementation of these legislative or regulatory instruments and any protocols that define the procedures to be followed leads to the issuance of authorization to conduct aquaculture, usually containing specific terms and conditions that bind the lease, licence or permit holder.

The leasing, licencing or permitting system provides the authorities with the means to verify the legality of an aquaculture operation at a proposed site, and can be used as a basis for controlling and monitoring the potential environmental and social impacts of the operation. These authorizations/licences/permits typically outline what the holder is permitted to do by establishing the permitted physical dimensions of the site, the species that can be grown, acceptable operating conditions in relation to production and nutrient load limits, and the period over which permission to operate is valid.

A proper leasing, licencing or permitting system provides a legally secure right to conduct aquaculture operations in a specific location for a specified period of time. It provides exclusivity and ownership over the farmed organisms to the holder of the authorization, and protects investors from interference and from political vagaries in order to provide investor confidence. The authorization also allows the holder of such authorization to enforce the right accorded under the authorization against third parties, if the right is frustrated or denied or cancelled without good or legal reason for such cancellation.

Regulations governing the issuance of leases, licences and permits should consider the different stages of aquaculture development in a particular locale:

- New site—a proposal for a new previously undeveloped site for aquaculture. Most countries have specific rules for the location of a new farm to avoid locating it near habitats of special interest (recreation, wildlife, fishing zones) or near industries and sewage outfall. In many cases, site selection decisions are made in response to singular applications.
- Change of use—proposals that involve a change in the species that will be farmed on site, new or modified production practices, or requests to increase production. A new EIA and carrying capacity estimation could be needed to make an appropriate decision.

All leasing, licencing and permitting systems should include consideration of distances among aquaculture sites existing and planned, and between aquaculture and other, potentially conflicting, uses. Safe minimum site distance depends on many factors, including, but not necessarily limited to, wind direction and speed, water currents and direction, visibility of installations, wildlife corridors and nature reserves, and transportation routes.

5.4.1 Aquaculture licences or permits

Each separate company or legal entity operating within an aquaculture zone should be required to have an aquaculture licence or permit that defines:

- species to be cultured;
- maximum permitted annual production or peak biomass;
- culture method;
- site marking for navigation safety; and
- any special conditions such as regular environmental surveys and other monitoring.

There should be penalties or measures taken for contravening a condition of an aquaculture licence. In addition, a licence should also contain a provision giving the licensor the right to cancel, suspend or not renew a licence where the holder fails to adhere to the required standards, or where new information means the site is no longer acceptable or sustainable.

5.4.2 Aquaculture leases

Each separate company or legal entity operating within the zone should be granted legal tenure by way of an aquaculture lease issued by the competent authority. The aquaculture lease would include terms and conditions that specify:

- the terms or duration of the lease and its renewal options;
- perimeter location (latitude and longitude);
- lease fees; and
- other specific criteria such as what happens if there is no operation of the site within a specified time, or penalties for non-payment of fees or abandonment.

For both licences and permits, there should be regular surveys to monitor social and environmental impacts to ensure that they remain within acceptable levels. In cases where problems are occurring, flexibility in the licencing, permitting and/or lease terms should provide the farmer/owner with sufficient time to enable mitigation measures to be put in place and changes to be made before more drastic action is taken (such as removal of the licence).

Tilapia cage culture in Beihai, China

When there are several farms in an enclosed or well contained waterbody, it is essential to develop and implement an area management plan to minimize risks of disease and environmental risks.

Tilapia is cultured in many types of production systems. This flexibility makes the fish attractive to farmers in many parts of the world for subsistence and commercial production. Tilapia is also a favourite for many consumers. Fish from this farm in China is destined for the American market, although consumption is increasing locally. This strong demand is supporting increased production around the world in ponds and cages, in fresh and brackish water. However, as the industry grows, the risks also grow. Farmers must do their part to reduce environmental and disease risks on each farm as part of a larger resource management system that will protect the quality of water resources and the livelihoods for producers. Standardizing production practices and coordinating disease risks through area management strategies are key aspects for ensuring sustainable growth of the industry.

Courtesy of Jack Morales

6. AQUACULTURE MANAGEMENT AREAS

The designation and operation of an aquaculture management area (AMA) lies at the heart of the ecosystem approach to aquaculture. It is at this level of organization that collective farm and environmental management decisions are made that can more broadly protect the environment, reduce risk for aquaculture investors, and minimize conflict with other natural resource users.

There are activities that are amenable to area management that often fail to be effective when implemented at the individual farm level. Examples include the coordination of cropping cycles for sales and marketing purposes; synchronicity of treatments in disease management; environmental monitoring that ensures the cumulative effects of multiple farms are not unduly harming the environment; waste treatment and management; collective negotiation of input (e.g. feed supply) and service (e.g. monitoring) contracts; collective certification and marketing of products; the ability to implement a comprehensive biosecurity and veterinary plan; and provision of collective representation to the government and with other stakeholders. The key steps in the definition and management of AMAs are:

(i) delineation of management area boundaries with appropriate stakeholder consultation;
(ii) establishing an area management entity involving local communities as appropriate;
(iii) carrying capacity and environmental monitoring of AMAs;
(iv) disease control in AMAs;
(v) better management practices;
(vi) group certification; and
(vii) essential steps in the implementation, monitoring and evaluation of a management plan for an AMA.

6.1 Delineation of management area boundaries with appropriate stakeholder consultation

Within a defined aquaculture zone, AMA boundaries can be based on biophysical, environmental, socioeconomic and/or governance based criteria that, by overlapping, result in one geographical area with an identifiable physical/ecosystem base. For ease of regulation, AMAs should ideally be within one governance administrative unit (e.g. municipal, state, district, region). The AMA should be large enough to make a real difference in the ability of the components to increase their operating efficiency, but small enough to be functional and easily managed. Without specific governmental interference, farms and farmers will often self-organize around areas that are good for aquaculture. Their designation as aquaculture management areas simply allows for more formal and better overall management.

The most common means to delineate an AMA is related to disease, in particular disease transfer, which is spread through a common water source. Since diseases move through water and environmental loading is a function of the outflow of nutrients and wastes from all farms within a given area, it would be typical for the AMA to be delineated by the water surface/supply that is shared by all farms within it. Ensuring that all users of a common water source are in the same AMA creates incentives for cooperation in maintaining good water quality and in coordinated disease management. In cases where it is not obvious how water flow and diseases move from farm to farm, it may be necessary to develop a hydrological (freshwater) or hydrodynamic (marine water) map of the area. Such a map would identify major water sources, or tides and currents, that effect water movement or flows, and will assist in determining where the AMA boundaries should be located.

It is important that all farms within a designated AMA cooperate. Failure by one or a few farms to participate fully and to find solutions to problems when they occur may result in farmers who do participate becoming discouraged with a resultant loss of interest in cooperating. This is potentially wasteful in terms of time and energy on the part of the government seeking to sustainably develop aquaculture.

It is not always the case that farms in close physical proximity necessarily share a common water supply. In these circumstances, due to their close proximity, it may increase the likelihood of a disease transfer through other means (e.g. sharing workers, predation of diseased stock by birds that are then dropped into the neighbouring farm), and these farms should be extra vigilant in managing how they interact to minimize the overall risks.

Broadly, designating physical boundaries for cage aquaculture in a lake or embayment is relatively straightforward (Figure 5a). Pond aquaculture systems are more complex, as it is often difficult to spatially arrange ponds in any meaningful way; for example, in a river delta where the catchment (and therefore the water source) may be significantly larger and more dispersed than the aquaculture activity using that water. Nonetheless, attempts should be made to delineate AMAs for freshwater pond systems (e.g. Figure 5b), and then to undertake periodic assessments to ensure they function correctly. It is much easier to organize AMAs before aquaculture becomes well established, and therefore difficult to move, rather than later when farms are already operating and unable to relocate. Nonetheless, the rewards from better management, perhaps increased production, better coordination of shared resources and reduction of risk, mean that even where farms are long established the development of an AMA system is worth the time and effort.

It is not necessary that an AMA is specific to a single kind of aquaculture system or to a single species. For example, IMTA provides the by-products, including waste, from one aquatic species as inputs (fertilizers, food) to another. Farmers combine fed aquaculture monitoring (e.g. fish, shrimp) with inorganic extractive (e.g. seaweed) and organic extractive (e.g. shellfish) aquaculture to create balanced systems for environment remediation (biomitigation), economic stability (improved output, lower cost, product diversification and risk reduction), and social acceptability (better management practices). IMTA is most appropriate at the landscape level, and it is thus very relevant for an AMA. The delineation of management area boundaries should be done in consultation with all relevant stakeholders.
A consultation process is an opportunity for stakeholders to obtain information as well as give feedback. Stakeholders can use the opportunity to educate about the local context, raise issues and concerns, ask questions, and potentially make suggestions for the delineation of the management area. Therefore, a planned participatory process with consultation with all relevant stakeholders needs to be in place, commencing with clear objectives about what is to be achieved.

6.2 Establishing an area management entity involving local communities as appropriate

In any specific farm, it is imperative that the farmer operates to the highest standards in managing the site. It may not, however, be possible to influence everything that happens in the wider area, especially when other farms are in operation. Added to this, the impacts of disease and environmental loading to a waterbody or watershed are the result of all farms operating in that waterbody or watershed; and control cannot be managed by any single farm working alone, and collective activity becomes important in these circumstances. Where possible, all operating farms within an AMA should be members of a farmers' or producers' association as a means to allow representation in an area management entity, and which can set and enforce among members the norms of responsible behaviour, including, for example, the development of codes of conduct.
There is more than one way to develop an entity for an AMA, given that the legal, regulatory and institutional framework will vary at the national, regional and local levels. While the main impetus for the establishment of a farmers' or producers' association must come from the farmers themselves, there is nonetheless a significant role for the government as a convening body and, ultimately, the government has specific responsibility as the regulator and can place a high degree of impetus on the farmers to coordinate.
The government could help by providing basic services (e.g. veterinary, environmental impact monitoring, conflict resolution) through the farmers' association, which will encourage cooperation by all farmers.

Importantly, the government may also need to create a formal structure through which it engages with the farmers' associations that develop.

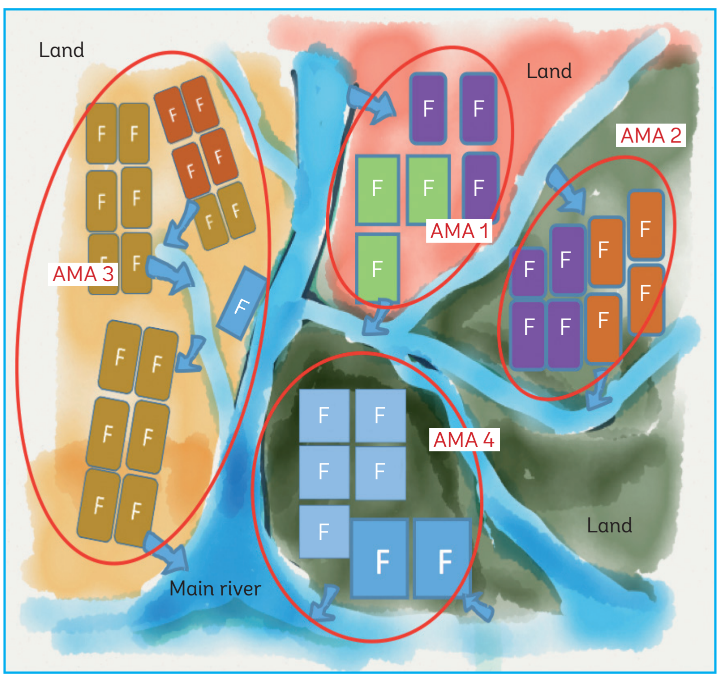
FIGURE 5a and 5b. Conceptual arrangement of aquaculture farming sites clustered within management areas designated within aquaculture zones

a. Coastal and marine aquaculture

Note:

Schematic figure of a designated aquaculture zone (hatched area in blue colour) representing an estuary and the adjacent coastal marine area. Individual farms/sites (F), owned by different farmers, are presented in different colours and can incorporate different species and farming systems. Four clusters of farms illustrate examples of AMAs, grouped according to a set of criteria that include risks and opportunities and that account for tides and water movement.

b. Inland aquaculture



Note:

Schematic figure of an existing aquaculture zone (the whole depicted area) representing individual land-based farms (F), e.g. catfish ponds and/or other species, that may be owned by different farmers (presented in different colours). In this example, there are four AMAs. The commonality in the AMA is the water sources and water flow (arrows) as the priority criteria (e.g. addressing fish health and environmental risks) used to set boundaries of the AMAs.

The number of individual farmers to be included in an AMA should be carefully planned and discussed to make the AMA operational. Some good examples of farmer associations include those in Chile, Hainan Island (China), India and the United Kingdom of Great Britain and Northern Ireland.

In Chile, there are approximately 17 corporate entities in the main producer's association, Salmon Chile, and when a significant disease outbreak occurred, aquaculture area management was used to overcome and manage the outbreak, with Salmon Chile developing and implementing some of the response measures.

The Scottish Salmon Producers Organisation (SSPO) incorporates 10 commercial decision-making entities, all of whom adhere to common principles of behaviour, adopt best practices, and share important disease and market information for the benefit of all members. In Scotland, the United Kingdom of Great Britain and Northern Ireland, AMAs were also developed out of a need to contain a disease outbreak, infectious salmon anemia (ISA), and which included control measures to eliminate transfer of stock between AMAs.

The Sustainable Fisheries Partnership (SFP) organizes farmers' associations into groups of approximately 20 on Hainan Island (China) and continues to support the Hainan Tilapia Sustainability Alliance. It is driven by a group of leading local companies who support the associations with seed, feed, technical support, farming and processing, and increasingly involving more of the local industry.

Cluster management, used to implement appropriate better management practices in Andhra Pradesh, India, can be an effective tool for improving aquaculture governance and management in the small-scale farming sector, enabling farmers to work together, improve production, develop sufficient economies of scale and knowledge to participate in modern market chains, increase their ability to join certification schemes, improve their reliability of production, and reduce risks such as disease (Kassam, Subasinghe and Phillips, 2011).

To be effective, it is important that all or nearly all of the farmers are part of the management plan, so as to avoid cheating on best practices that can lead to disaster for all. The SSPO in Scotland, the United Kingdom of Great Britain and Northern Ireland, and Salmon Chile in Chile represent ~90 percent of production in their respective management areas, and have been successful in coordinating and expanding production.

Where there is already a well-established aquaculture industry, it may be practically difficult to reorganize farms into defined aquaculture areas, in which case it may be necessary to adopt a strategic approach that establishes a working area management entity around a core of interested farmers, and gradually expanding to incorporate as many other farmers in the watershed as possible. If a serious problem occurs, such as a disease outbreak or pollution problems that affect an aquaculture area, and a sizeable number of farmers refuse to cooperate with the area management entity, it may be necessary for the government to impose regulations that require participation in an AMA as part of the permitting/leasing process to force the process.

The different scales of farmer groups will have a different internal governance and management system. Any system developed must formally identify how decisions will be made, have clear leadership and hierarchy within the group, and determine how the costs and any profits will be managed. In small farmer groups, it is easy for all members to be involved in day-to-day decision-making, but as farmer groups become larger, representatives are usually chosen to manage the group on behalf of members. In some cases, group members may not have sufficient business and management skills and experience to manage the AMA effectively and could employ professional managers from outside the group to manage their organization until sufficient experience is gained. Management of larger, more complex AMAs can be a time-consuming task, leaving little time for people to focus on their own individual farm management and production, and is another reason why a professional manager may be useful.

The structure of the AMA entity will vary depending on whether parties are the same size. AMA entities should be inclusive, as appropriate, for identification of issues, and stakeholder participation is essential. Under these circumstances, undue dominance by one or more larger commercial entities within an AMA can lead to disagreement on a course of action (e.g. affordable by some but not all), which might place a burden on the larger companies in providing the needed financial and other support to smaller farmers within the AMA. Conversely, there are instances where larger companies that support small farmers facilitate overall development and support to small farmers who have less capacity to take action. Some AMAs will make more sense for large-scale commercial aquaculture, while other AMAs could include a mix of producer sizes and types or could be designed just for small-scale farmers.

6.2.1 What does the area management entity do?

The purpose of the area management entity is the setting and implementation of general management goals and objectives for the AMA, developing common practices that ensure commonality in operations to the best and highest standards possible, and focusing on the activity that cannot be achieved by each farmer alone. In doing so, the entity is able to develop a management plan for the AMA.

A range of issues that could be best addressed at the level of the farmer's association are listed in Table 11. What is important is that the activity is of direct relevance and benefit to farmers, and that it leads to effective management of the AMA. The entity is not there specifically to resolve individual disputes between farmers, although the management entity can of course play a conciliation role where this does occur.

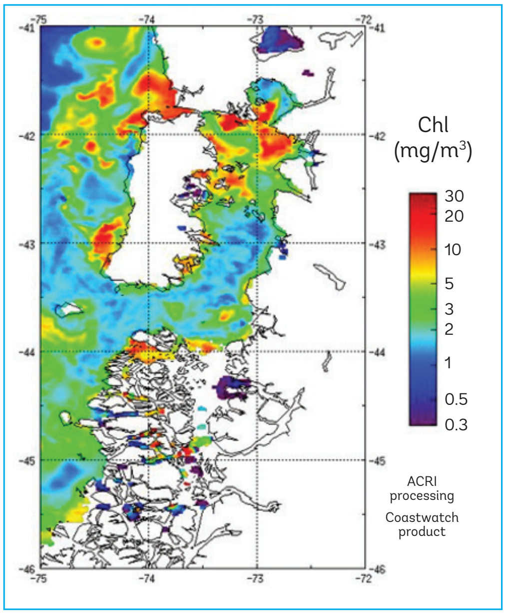
A major justification for collective action on the part of fish farmers is the reduction of risk to the farming system and to natural and social systems. To guide the creation of an area management plan, a thorough risk assessment should be considered to prioritize the most important risks that should be addressed, and identify actions to be implemented to overcome or otherwise mitigate the risks.

The majority of relevant threats "from and to" aquaculture have a spatial dimension and can be mapped. Risk mapping of AMAs should include those risks associated with the clustering of a number of farms within the same water resource, as well as external impacts that can affect the farm cluster, for example:

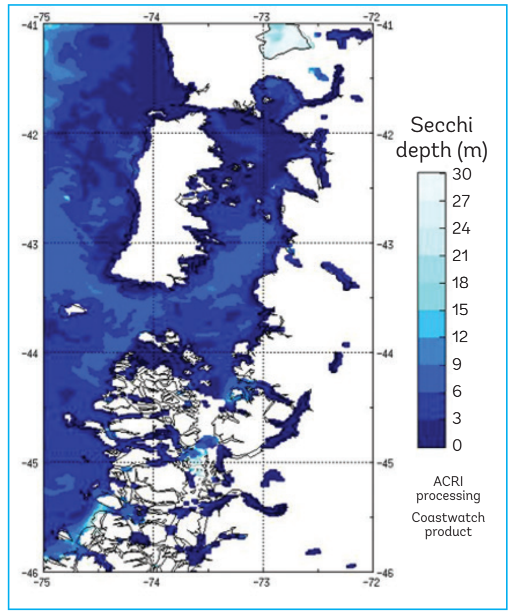
- eutrophication or low dissolved oxygen levels;
- impact on sensitive habitats;
- impact on sensitive flora (e.g. posidonia beds) or fauna;
- predators (e.g. diving birds, otters, seals);
- epizootics/fish disease outbreaks (e.g. ISA);
- social impact and conflict with local communities and other users of the resource, including, for example, theft;
- storms and storm surge;
- flooding; and
- algal blooms.

A variety of data and tools exist to support risk mapping analysis. Some GIS-capable systems are specifically targeted at risk mapping, and many general-use GIS systems have sufficient capability to be incorporated into risk management strategies. Remote sensing is a useful tool for the capture of data subsequently to be incorporated into a GIS, and for real-time monitoring of environmental conditions for operational management of aquaculture facilities. Satellite imagery has an important role to play in the early detection of harmful algal blooms (HABs). For example, in Chile, an early warning service based on Earth observation data delivers forecasts of potential HABs to aquaculture companies via a customized Internet portal (Figure 6). This Chilean case was led by Hatfield Consultants Ltd (Hatfield, UK), using funding from the European Space Agency-funded Chilean Aquaculture Project.

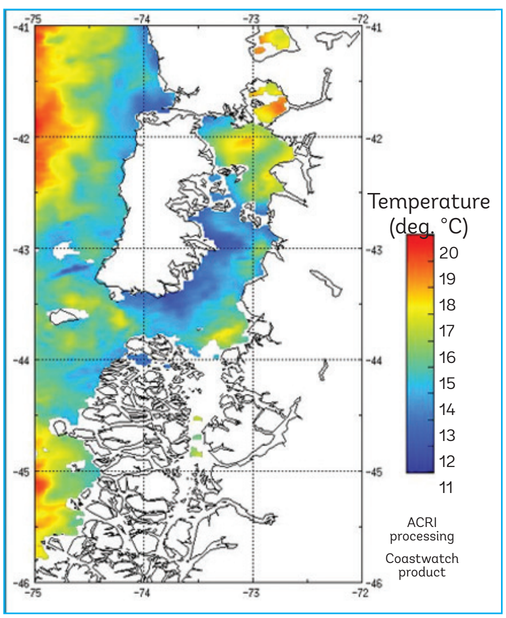
FIGURE 6. Monitoring and modelling of bloom events in the Gulf of Ancud and Corcovado, south of Puerto Montt in Chile



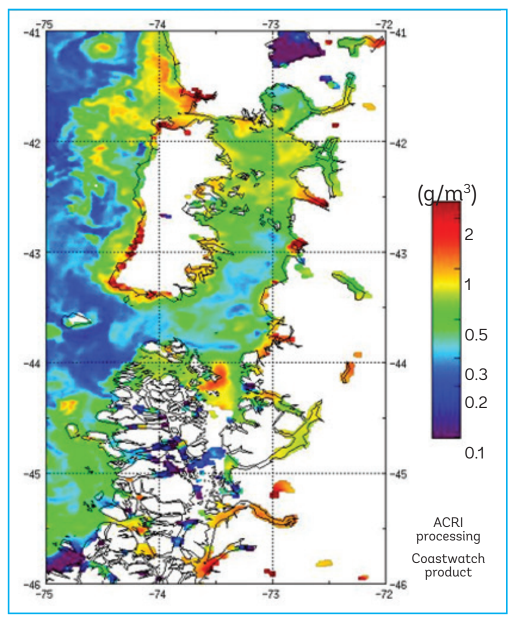
Chlorophyll-a pigment concentration
Time period: 2005-02-23 to 2005-03-02



Secchi disk transparency
Precision of ± 2m.
Time period: 2005-02-16 to 2005-03-02



Sea surface temperature
Precision of ± 0.5°C.
Time period: 2005-02-23 to 2005-03-02



Suspended particulate matter
Time period: 2005-03-02

Notes:

- Data extracted from Moderate Resolution Imaging Spectroradiometer (or MODIS), presented in a composite image showing data over a period of 15 days. Data distributed daily to the end users.
- MODIS is a key instrument aboard the Terra and Aqua satellites. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days. These data improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.

Source: Stockwell *et al.* (2006).

Another example of early warning for aquaculture is in Europe: the project Applied Simulations and Integrated Modelling for the Understanding of Toxic and Harmful Algal Blooms (ASIMUTH) funded by the European Union (www.asimuth.eu) used a collection of satellite and modelling data to construct a HAB forecasting tool. They incorporated ocean, geophysical, biological and toxicity data to build a near-real-time warning system, which took the form of a Web portal, an SMS alert system for farmers, and a smartphone app. The Web portal is curated and maintained by scientists in each country participating in ASIMUTH (France, Ireland, Portugal, Spain and the United Kingdom of Great Britain and Northern Ireland).

Over and above the issues listed in Table 11 are the key management measures that have been taken to address the key issues listed above where collective action is better than singular action, namely:

Improving aquatic animal health management and biosecurity

- Develop a common aquatic animal health and biosecurity plan for the area. Defines the approach to mitigate against disease risks for the area.
- Implementation of single year classes of stock (e.g. fish) where juvenile inputs are coordinated and managed in order to ensure there is no disease transfer through mixing stocks and to allow for a fallow period to break disease cycles.
- Disease control through regular disease surveillance and synchronized disease and parasite treatments. Treatment with the same medication is useful, and use of only authorized medication is expected.
- Vaccination of stock for specific diseases, where vaccines are available, with vaccination of all juveniles prior to stocking.

TABLE 11. Common issues to be addressed in aquaculture management areas

Social	Economic	Environmental	Governance
User rights conflicts	Production losses due to fish diseases and fish kills	Eutrophication of the common area	Weak management body
Resource use conflicts (e.g. water use, space, etc.)	Production losses due to thievery and general security	Poor discard of solid wastes (feed sacs, dead fish, etc.)	Non-compliance by farmers
Lack of training	Poor access to markets/low selling prices, etc.	Disease and parasite transfer to wild stocks	Inadequate monitoring and control
Lack of adequate services	Limited access to inputs (seed, feed, capital, etc.)	Escapes impacting biodiversity	Poor or slow conflict resolution
Lack of employment and poor labour conditions	Lack of post-harvest facilities	Use of chemicals impacting biodiversity	Lack of institutional capacity
Lack of opportunities for women		Use of fish as feed with negative impacts on local fisheries	Lack of political will towards aquaculture
Food safety problems		Poor management of water use	Absence of biosecurity frameworks
		Habitat disturbance (on mangroves, coral reefs, seagrasses, etc.)	Damage to the farms caused by climatic variability, climate change or other external forcing factors

- Coordination for fallowing and restocking dates. Synchronized fallowing, leaving the whole area empty of cultured fish for a specified time, and subsequent coordinated restocking supports biosecurity. Dates should be agreed upon between all parties and should be obligatory.
- Monitor the health status of newly stocked juveniles. There should be agreement on the quality of the juveniles to be stocked into a management area, which may include: physiological status of juveniles; use of vaccines; sourcing juveniles from specific pathogen free sources; and tests for specific pathogens on arrival.
- Control of movement of gametes/eggs/stock between the farms within the AMA and into the AMA from external sources.
- Disinfection of equipment, well boats, and so on at farms, and following any movements between different farms by defining the expected disinfection protocols.
- Regular monitoring and reporting of aquatic animal health status, regular monitoring of disease criteria, and other management measures within the AMA. This should include measures to be taken against non-conforming or non-complying farmers.
- Reconsidering the AMA boundaries to control a disease; for example, following the definition of epidemiological units in order to limit spread and impact of disease outbreaks within the common area.

For more information on biosecurity, see Annex 2.

Control of environmental impact, particularly cumulative impact

- Establishing the carrying capacity for the area to receive nutrients. In most cases, this is one of the first measures needed to adjust production and plan for the future of the AMA.
- Protecting natural genetic resources. Preparation of containment and contingency plans to minimize escapes and to control the input of alien (non-native) species introduction.
- Improving water quality by reducing contribution to eutrophication. This will involve an improvement in FCR so that excess nutrient wastes are also reduced. May involve re-siting farming structures (e.g. in the case of cages) where a new layout for the AMA could improve nutrient flows. This is also related to the first bullet point above.
- Environmental monitoring and implementation of regular environmental monitoring surveys and reporting and sharing of results.
- Fallowing of aquaculture areas. Synchronized fallowing of aquaculture areas, which leaves the whole area empty of cultured fish for a specified time. This is a biosecurity as well as an environmental management measure. It helps to break the disease and parasite cycle and allows the sediments and water quality to partially recover.

Improved economic performance of member farms

- Negotiation of supply and service contracts, whereby effective economies of scale and better terms can be achieved by negotiating contracts for common services (such as environmental monitoring), as well as for technology, fertilizer and feed supplies, among others.
- Marketing. Sharing post-harvest facilities (ice machines, packing facilities, refrigeration facilities, etc.). Establishing a common marketing platform.
- Sharing of infrastructure, such as jetties, boat ramps, feed storage facilities, sorting, grading and marketing areas, and ice production plants.
- Sharing of services, such as net-making, net-washing and net-repair facilities.
- Data collection, reporting, analysis and information exchange. Information exchange may include: veterinary reports; mortality rates; timing and types of medicines used; and mutual inspections for assurance purposes, both within the AMA entity and with external stakeholders, such as government departments.
- Coordinated harvesting and marketing that allows farms within the AMA to have a larger and continuous sales and marketing platform from which to sell products.

Social management measures and minimizing conflict with other resource users

- Facilitating and strengthening clusters and farmer associations.
- Identifying relevant social issues generated by aquaculture in the coastal communities.
- Social impact monitoring by agreeing on and setting indicators of impacts and regular monitoring of the impacts on local communities and other users of the water and other resources.
- Management of labour by monitoring workers' health and that of their families, implementing safety standards, providing appropriate wages and benefits, and identifying additional employment opportunities along the value chain. This will also include developing and implementing training activities to upgrade the skills of workers.
- Implement conflict resolution and measures to avoid conflict. If conflict does occur between farmers and between the management area and local interests (with fishers, for example), then resolution procedures should be fair, uncomplicated and inexpensive.

Once key issues are identified and agreed upon by the group, the management entity should develop management measures to address the key issues. These will then be incorporated into an area management agreement or plan that can guide future action for implementation.[6] The measures should be the most cost-effective set of management arrangements designed to generate acceptable performance in pursuit of the objectives.

Without a clear set of objectives and time frame for their achievement, the area management entity can turn into a "talk shop" and lose credibility among farmers, reducing its effectiveness and influence. Some elements of an area management agreement or plan that should be considered are as follows:

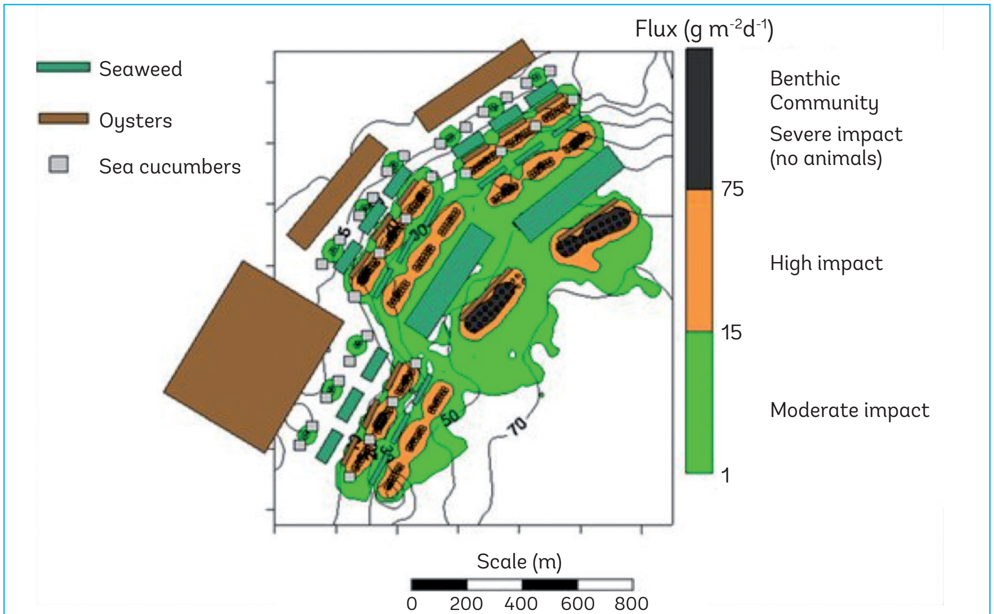
- agreement on the participants;
- clear statements on the objectives and expected outcomes;
- definition of the area and the farms included;
- agreement on the management measures;
- a management structure must have a mechanism to engage with public agencies and organizations, representatives from stakeholders, NGOs and other sectors that use the aquatic resource;
- responsibilities for implementation of the management plan must be clearly allocated to particular institutions and individuals;
- all farmers within the AMA must agree to conform to the management plan;
- the management structure must be able, willing, and allowed to implement or administer the incentives and disincentives to farmers who do not conform to the management plan;
- an agreed upon timetable;
- the roles and responsibilities and desired competencies for the key persons participating in key management positions within the zone; and
- financial arrangements supporting the management plan and area management entity.

6.3 Carrying capacity and environmental monitoring of AMAs

Estimates of environmental carrying capacity of the area should be made and regular surveys conducted to reassess the area. Carrying capacity at the AMA scale could be undertaken, for example, using depositional models (particle tracking) that predict the particulate outputs from fish cage aquaculture and that can be used in local-scale assessment of the effects of fish cages on the organic footprint impact on the sediment and sensitive demersal flora and fauna. Particulate tracking models use the output from a spatially explicit hydrodynamic-dependent particle tracking model to predict (organic) flux from culture sites to the bottom. At the local scale, screening models may be used to look at aquaculture yields,local impacts of fish farming and water quality. Figure 7 shows the modelled sediment impact below a cluster of fish farms in Panabo Mariculture Park, the Philippines, based on the existing situation (2012) and proposed rearrangement of the layout to increase production while trying to minimize impact.

[6] For more information on EAA management plans, see FAO (2010); FAO (2012); Gumy, Soto and Morales (2014); and FAO (2016b).

FIGURE 7. Output from a particulate waste distribution model (TROPOMOD) developed for fish cage culture, which provides a footprint of organic enrichment beneath clusters of fish farms (Panabo Mariculture Park, the Philippines)



Source: Lopez and White. Case study of the Philippines; Annex 5 of this publication.

Regular environmental monitoring surveys of individual farms for local impact and aquaculture area monitoring for clusters of farms are needed. In Turkey, aquaculture zones are monitored using the TRIX index, which is a measure of eutrophication, and is a tool for the regulation of Turkish marine finfish aquaculture to protect coastal waters, especially those of enclosed bays and gulfs from pollution by fish farming. Environmental monitoring systems are essential to address climatic variability and climate change (Box 2).

BOX 2

Area-based environmental monitoring systems to address climatic variability and climate change

Even though each farmer may collect some information and may have access to meteorological forecasts, these may not be enough for early warning on local extreme events. Simple information collected and shared on a permanent basis (e.g. water temperature, oxygen, transparency, water level, fish behaviour, salinity) can be highly relevant for decision-making, especially when changes can produce dramatic consequences. For example, temperatures above or below average can trigger diseases, or can bring anoxic water to the surface or trigger algal blooms that kill fish. The monitoring of environmental variables such as oxygen and water transparency can also indicate excessive nutrient output from farms, etc. The sharing of monitoring information in common areas combined with early warning systems can assist rapid response to diseases and other threats such as algal blooms and anoxic bouts. In general, environmental monitoring systems should follow a risk-based approach that recognizes that increased risk requires increased monitoring efforts. The involvement and value of locally collected information should be seen as very relevant to farmers to better understand the biophysical processes and become part of the solution, e.g. rapid adaptation measures and early warning, long-term behavioural and investment changes. Key activities include training of local stakeholders on the value of the information, monitoring, and use of the feedback for decision-making. It is also advisable to provide/implement some simple network/platform to receive and analyse the information, to coordinate and connect with broader forecasts and monitoring systems, and to provide timely feedback that is useful to local stakeholders. In such cases, well organized AMAs can generate information and facilitate feedback for faster responses.

A recent consultation on developing an environmental monitoring system to strengthen fisheries and aquaculture resilience and improve early warning in the Lower Mekong Basin took place in Bangkok, Thailand, in 2015 (FAO, 2017).

Capacity building

The FAO-INPESCA workshop on estimating carrying capacity for shrimp farming in Estero Real, Gulf of Fonseca, Nicaragua, targeted 25 stakeholder representatives, including national and local government aquaculture technical personnel, shrimp farmer companies, shrimp farming cooperatives, local communities, and representatives of fishers from Estero Real. The workshop focused on the process and steps to assess carrying capacity for shrimp farming in a Ramsar area and review current aquaculture zoning and management measures to ensure a sustainable shrimp farming sector.

Courtesy of Doris Soto

6.3.1 Some key actions to establish ecological carrying capacity and maximum allowable aquaculture production in aquaculture zones and aquaculture management areas

1. **Define the boundaries of the aquaculture zone or aquaculture management area, considering it as an ecosystem unit.** In freshwater systems boundaries are generally physical boundaries such as a river basin, a water catchment, a lake or oxbow lake. Boundaries in marine systems for enclosed bays or Fjordic systems can be defined as the point at which they connect with the open sea, and are easier to define than an open coastal zone or offshore area. The latter marine cases may require operational boundaries such as a current border or a sharp change in hydrography, oceanographic conditions or benthic morphometry.

2. **Establish baseline conditions for the aquaculture zone or AMA**. This requires data collection (either remotely or directly) to establish the pre-existing conditions. Here, satellite remote sensing is useful to define physio-chemical properties such as temperature in marine systems, and land use in freshwater systems. Direct data collection can include samples for water quality and benthic conditions.

3. **Agree a set of standards or thresholds that determine environmental, ecological and social limits of change to the zone/area through stakeholder consultations, scientific research and local knowledge.** All aquaculture has "impact", whether this is change to conditions in the immediate vicinity of fishpond outlets or further down river systems, under or surrounding fish cages and mussel rafts, or changes to water flows, where there may be temporary deterioration of some environmental conditions. Standards account for the baseline conditions and determine acceptable changes in those conditions, leading to definitions of maximum acceptable criteria. What is important is to ensure resilience in the overall area or ecosystem unit to ensure sufficient sustainability in the long term, so that there remain areas without aquaculture, with buffers and where no other human interventions are permitted. Environmental standards tend to be related to biological and chemical parameters such as maximum chlorophyll (eutrophication). Ecological standards could include the presence and abundance of indicator species such as a fish, crab, marine grass, or maximum water abstraction. Social limits might involve ensuring fishing rights/areas are maintained, or minimising visibility from urban or tourism areas.

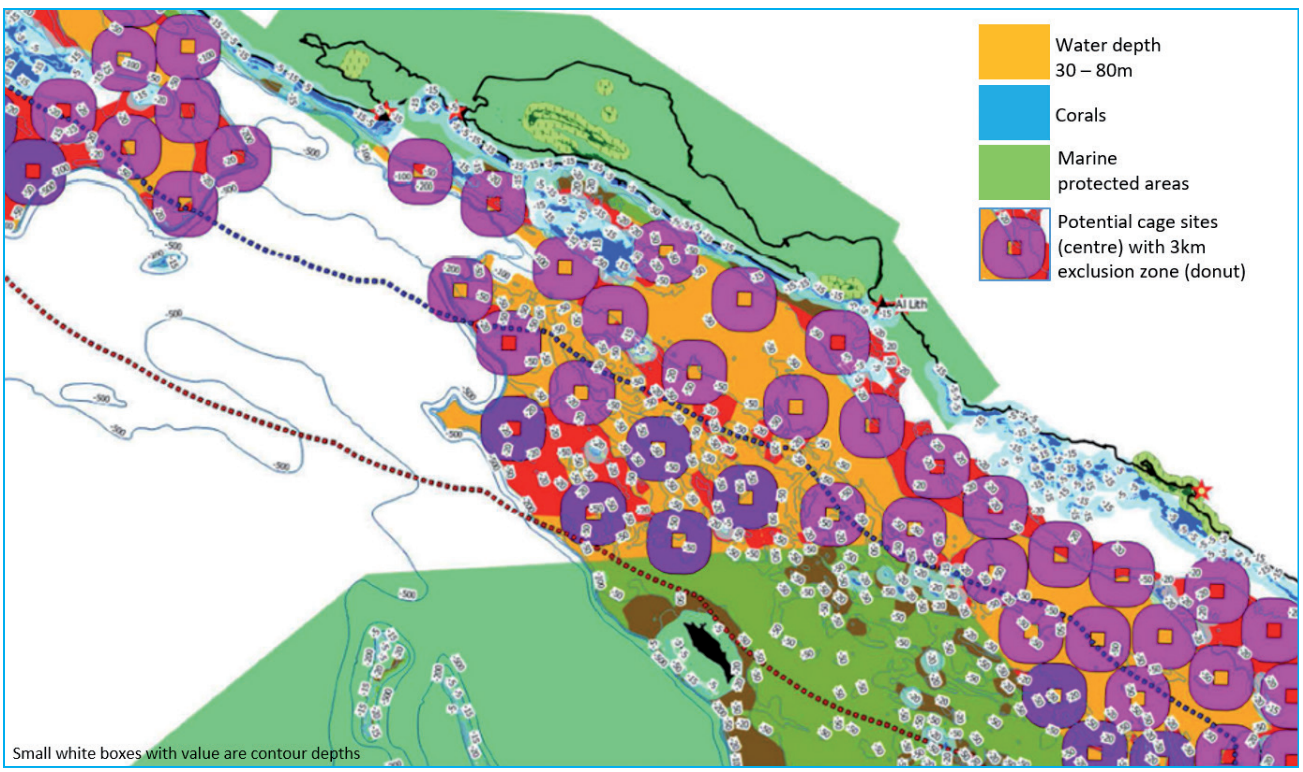
4. **Estimate the maximum ecological carrying capacity of the ecosystem unit to include the maximum aquaculture production permitted; estimated using the best available models (see Annex 4) and application of the standards and thresholds agreed.** There are some classical models for assessing lakes and contained water bodies (e.g. modifications of Vollenweider, 1968; Beveridge, 1984) to estimate likely changes in phosphorus and nitrogen according to the known inputs from aquaculture and certain thresholds for chlorophyll concentration, as an indicator of ecosystem response (i.e. eutrophication effects). Establishing carrying capacity in coastal ecosystems or open water systems is much more challenging due to complex oceanographic and biological conditions and the lack of clear boundaries. Some models can estimate likely changes over large areas, others assess impact of individual fish farms or mussel farms that could be extrapolated to larger areas. The application of GIS is also useful in determining physical limits on location through the application of basic criteria such as water depth and buffers from existing activities. This could also include minimum distances between aquaculture sites and other areas (see distance ranges in Tables 9 and 10 in Chapter 5 on site selection) along with sufficient distance from each other, adequate water depth, and circulation. Figure 8 provides an example of the application of GIS to estimate possible locations of farms and broad evaluation of overall capacity in Saudi Arabia based on physical limits.

5. **Invest in appropriate research** to address carrying capacity estimation of complex systems or open systems for aquaculture development.

6. **Permit production to commence through a set application and licencing system.** Increase production slowly at first, applying a conservative approach, and increase production when it is clear the current production is not having undue environmental and social impacts. It is better to be able to increase production slowly as ecosystem indicators show that there is no or minimal harm to the ecosystem and/or the farming system, instead of starting big and being forced to reduce production due to serious environmental and/or fish health damage.

7. **Establish an integrated environmental monitoring system at the farm scale and/or at the system scale.** Integrated monitoring is required since monitoring individual farms is not sufficient on its own to establish multiplicative effects of many farms in a zone/area. The monitoring of reference areas, away from farms but in key positions in the AMA or aquaculture zone, can provide the reference conditions to evaluate and compare ecosystem change. Also, permanent monitoring of other similar habitats, such as aquatic reserves, marine reserves and protected areas, can be useful to compare with areas being used by aquaculture.

FIGURE 8. Example output from GIS to identify potential sites for cage aquaculture within a zone along the Red Sea coast of Saudi Arabia



Note:

Basic criteria has bee applied to delimit suitable locations (i.e. maximum distance from coast, water depth, protected species and areas, and basic criteria for distance between sites. This does not define ecological capacity, which requires investigation of ecosystem quality and use of models to assess actual capacity.

Source: Saunders *et al.* (2016).

6.4 Disease control in AMAs

Disease outbreaks pose one of the most significant risks to the sustainability of aquaculture. There are many examples of how the introduction of a disease or diseases has brought large aquaculture industries to the verge of collapse with serious economic and socio-economic consequences. Biosecurity can be broadly described as a strategic and integrated approach that encompasses both policy and regulatory frameworks aimed at analysing and managing risks relevant to human, animal and plant life, and health, as well as associated environmental risks (FAO, 2007a; 2007b). As such, it has direct relevance to the sustainability of aquaculture, protection of public health, the environment, and biodiversity.

In the context of aquatic animal health, the term biosecurity is used to describe the measures used to prevent the introduction of unwanted biological agents, particularly infectious pathogens, and to manage the adverse effects associated with contagious agents. It encompasses both farmed and wild aquatic animals; exotic, endemic and emerging diseases; and is applied from the farm to the ecosystem, and at the national and international levels (Scarfe *et al.*, 2009). Farmers should be encouraged or possibly mandated to follow sound biosecurity practices that provide the framework for disease management on the farm and that are implemented through documented standard operating procedures. At the farm level, the owner or operator is responsible for ensuring implementation of biosecurity. Auditing and certification of the efficacy of a biosecurity programme is provided by the attending veterinarian and competent government officer.

Biosecurity planning, applied from the farm to the national level, provides an effective means of implementing disease control at multiple levels and for preventing catastrophic disease events. At the zone, compartment or AMA level, the biosecurity plan provides an auditable process of management procedures that can be evaluated by hazard analysis and critical control point (HACCP) methodologies (Zepeda, Jones and Zagmutt, 2008). Control measures designed to mitigate the impact of aquatic animal diseases may include containment, eradication, disinfection and fallowing. Control measures should be based on the ability to define epidemiological units. Depending on the infection pathway of an aquatic animal disease, the epidemiological unit may need to encompass the entire AMA, or a subpopulation within the AMA, for instance, one of a group of farm sites within an AMA. Well-defined subpopulations of aquatic animals can then be managed according to realistic outcomes. The identification and prioritization of hazards represents the first step justifying implementation of a biosecurity scheme. This is followed by assessment of the risk posed by these hazards and the evaluation of critical control points whereby the risk can be remediated. Establishment of appropriate measures against a defined hazard or disease, including appropriate contingency planning, allows the risk to be mitigated. A programme of disease surveillance is instituted for the AMA to monitor occurrence or absence of a disease. Where a hazard or disease is detected or has been introduced, eradication and disinfection provides a method of managing the impact of disease with the possibility of reinstating a disease-free status. One of the outcomes of a biosecurity scheme is audited third-party certification. In order for a third party to provide disease status assurances, transparent and credible written records must demonstrate the effectiveness of the biosecurity scheme in preventing, controlling and eradicating disease within an AMA.

The devastation of the Chilean salmon farming industry by the ISA disease in 2007 provides an example of how AMAs have been implemented in this country to help rehabilitate the farming of salmon and to create an environment conducive to the sustainable growth of the industry (Ibieta *et al.*, 2011). Establishment of AMAs appropriate for aquaculture has been legislated in Chile through the so-called "neighbourhood system". These areas represent suitable zones for aquaculture activities according to appropriate epidemiological, oceanographic, operational or geographic characteristics, and incorporate complementary environmental, sanitary and licencing regulations. Epidemiological, operational and logistical characteristics of the AMAs are aimed to address the ISA virus infection and control. These site regulations include movement of all aquaculture concessions to AMAs, limiting the life span of a concession to 25 years (renewable), and banning the movement of fish from and between sea sites. This limits the movement of broodstock from sea sites to freshwater facilities, as well as the temporary use of estuarine sites. Fish inputs, disease prophylaxis, therapeutic interventions, sanitary issues, harvesting and fallowing are coordinated among the farms within the AMAs (neighbourhoods). The distance between neighbourhoods has been established at a minimum of 3 nautical miles (about 5.6 km), and aquaculture sites must be spaced out by at least 1.5 nautical miles (about 2.8 km) from each other and from marine protected areas (natural parks and reserves) (Ibieta *et al.*, 2011).

6.5 Better management practices

Better management practices (BMPs) are a set of guidelines that promote improved farming practices to increase production through responsible and sustainable aquaculture. There is a significant level of variation in BMPs for different commodities, culture systems and locations. In India, BMPs implemented by farmer clusters have resulted in improved yields, fewer disease occurrences and higher profitability, as well as other private and public benefits.

In the Philippines, each mariculture park has an operations manual containing production guidelines and management measures following the principles of good aquaculture practices, and serves as the guideline for all activities within the parks. The guideline covers zone and farm location, layout and design, biosecurity sanitation and hygiene, waste storage and removal, good farm management measures, including feeds and feeding, farm effluent treatment, worker health and safety, disease diagnosis, treatment and chemical use, harvesting, post-harvest, traceability and food safety.

In Scotland, the United Kingdom of Great Britain and Northern Ireland, area management agreements follow the Code of Good Practice for Scottish Finfish Aquaculture. The code, developed in 2006, is an evolving document that is regularly reviewed to incorporate essential changes in legislation and emerging priorities in environmental management and the sustainable development of the industry. It brings the standard of practice of every participating farmer up to a specified acceptable level, and is based on science and experience, reflecting the industry's desire to remain at the forefront of good practice.

6.6 Group certification

The ability to provide third-party auditing and certification through an effective and justifiable biosecurity plan, when applied at the farm or compartment level, can allow farmers to access markets that require disease-status assurances that may not be available on a national level. This allows trade from a suitably certified AMA, even where a region or country is not certified free from a disease and cannot provide relevant disease-status guarantees.

If the environmental or social indicator threshold was breached, there would be need for measures to reduce the impact. For instance, these could include improved feeding strategies to reduce FCR, longer fallowing periods, synchronization of grow-out calendars to minimize excessive biomass at any one time, and other measures. If these fail to reduce the impact to the acceptable level, a drastic step may be needed, including reductions in the total production or maximum standing biomass levels within the AMA.

6.7 Essential steps in the implementation, monitoring and evaluation of a management plan for an AMA

The implementation of the management plan should be time bound. Two aspects are important relative to a time frame. The first is to decide on a base year for the management system. This will represent a year (or period) against which progress can be measured. The second time aspect relates to target years or periods by which various aspects of the work plan can be achieved, or by which any quantitative programme output should be attained. Overall, it is likely that the management system should be envisaged as spanning

TABLE 12. Examples of indicators for aquaculture management areas

Social	Economic	Environmental	Governance
• Quality of labour conditions • Socio-economic benefit to the local community • Positive perception by local community • % of local people employed • % of local women employed	• Average farm profitability • Level of disease outbreak • % of losses during production period • Market demand • Product quality and safety • % certified	• Average food conversion rate • Level of eutrophication (e.g. TRIX index) • Benthic diversity at edge of area (cages) • Water quality at outfall (ponds)	• Adoption of Code of Conduct or good aquaculture practices • AMA certification • Compliance of farmers to management measures • Level of transparency

a 5- to 10-year time frame, but during this period the system will need periodic reviews over shorter time scales.

The management plan must address all the relevant issues, have very clear and achievable operational objectives for each issue, and a clear timeline for completion with targets and indicators (Table 12).

The management plan must have responsible people/institutions/entities and requires adequate funding for each management approach and also must have resources to implement the measures as appropriate. Since it will generally be the central government that will be implementing the work, financing will mainly come from general tax revenues, though other sources of funding include stakeholder contributions, funding from external donors, international and multinational organizations, grant funding, foundations and the private sector. Since many of the activities that stand to gain from a management system will be in the private sector, it would not be unreasonable to expect that a range of business associations might be willing to help with financing. For example, an alternative source of funding tried in China is that all users of the sea must pay a "marine user fee" if they intend to carry out production and other economic activities.
It is almost certain that the eventual financial support will be delivered from more than one source. Clearly, funding will need careful planning ahead of the systems implementation.

Performance indicators must be set to inform whether set targets are being achieved, while efficiency indicators would show if there has been any improvement. The indicators that are selected should cover sustainability dimensions–social, economic, environmental, and overarching governance–at the aquaculture area scale. For each objective, an indicator and its associated performance measures should be selected so that the performance of each objective can be measured and verified (Table 12 and Table 13). The choice of indicators to be measured should reflect the cumulative impacts within the management area.

A monitoring programme to keep track of implementation must be put in place. In the context of an AMA, monitoring keeps track of the progress of the management plan based on indicators. Just as important, it provides an indication of compliance by AMA members with the agreed plan. Monitoring involves: (i) continuous or ongoing collection and analysis of information about implementation to review progress; and (ii) compares actual progress with what had been planned so that adjustments can be made in implementation.

Corrective measures can be implemented, an important part of which are sanctions to non-conforming members. The result of monitoring gives a factual, objective basis for a sanction. Should non-compliers persist, a defined conflict-resolution mechanism has to be agreed on and firmly applied.

TABLE 13. Examples of management plan objectives and indicators to address the prioritized issues

	Issues	Operational objectives	Indicators	Target (e.g. in 1 year)	Management measures
Social	Limited access to inputs (seed, feed, capital, etc.)	Increase access to seeds by 20% (all farmers in the area) in two years	Average seed (biomass, numbers, etc.) being bought by farmer per growing cycle	10% increase first year	Build a hatchery for the AMA
Economic	Production losses due to fish diseases	Diminish losses by 30% in two years	Mortality index	20% reduction by second year; continual reduction thereafter	Establish a biosecuirity framework in the area with all relevant procedures
Environmental	Eutrophication of the common area	Diminish eutrophication by 40% in three years	Oxygen, fish kills, chlorophyll-a (Chl-a)	Diminish eutrophication by 20% in the first year	Establish the carrying capacity for nutrients in the area; Reduce total production until meeting maximum allowable according to carrying capacity
	Use of chemicals impacting biodiversity	Use only authorized medication; All medication used under guidance of health specialist	Use of (extent, percentage, biomass, etc.) banned chemicals and medication	Zero use of banned chemicals and medication by year 2	Designation of a common veterinarian; All medication given under supervision and coordinated
Governance	Inadequate monitoring and control	Regular monitoring of performance indicators and compliance of farmers; All farmers in the area management complying to management plan	Number of performance indicators and related th-resholds being recorded	Thorough annual monito-ring of indicators and full report after year 2	Regular monitoring survey with standard analysis and regular reporting and eva-luation
	Lack of institutional capacity	Designated management committee members are knowledgeable, efficient and well trained	Number of key posts filled	All area management posts filled in first year	Training and standard operating procedures on key management measures

That said, the use of incentives for compliance can be a more effective measure than a sanction.

The regular monitoring of management performance may show that the area management plan needs to be adjusted. If current management measures do not seem to be working or are deemed inappropriate, alternative measures need to be introduced. In some cases, some measures may be rendered unnecessary if the issue has been solved. In other cases, changes in issues or priorities could end the relevance of a measure. The management plan should in any case be reviewed periodically, e.g. once a year or every two years according to needs. This underlines the importance of monitoring and evaluation.

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GLOSSARY

Aquaculture licence	A legal document giving officialauthorization to carry out aquaculture. This authorization may take different forms: an aquaculture permit, allowing the activity itself to take place; or an authorization or concession, allowing occupation and/or for aquaculture of an area in the public domain so long as the applicant or holder of the authorization complies with the environmental and aquaculture regulations and other conditions of the authorization (IUCN, 2009).
Aquaculture zone	An aquaculture zone is an area dedicated to aquaculture, recognized by physical or spatial planning authorities, that would be considered as a priority for local aquaculture development (GESAMP, 2001; Sanchez-Jerez, *et al.*, 2016).
Area management plan	A plan for the management of a defined area for aquaculture where the farmers undertake aquaculture in accordance with agreed strategies, management practices and codes of conduct, and manage production in order to reduce and manage risks posed by disease and parasites, including cumulative environmental impacts and social conflict.
Biosecurity	Mitigating the risks and impacts on the economy, the environment, social amenity or human health associated with pests and diseases.
Carrying capacity	Carrying capacity is the amount of a given activity that can be accommodated within the environmental capacity of a defined area. In aquaculture, it is usually considered to be the maximum quantity of fish that any particular body of water can support over a long period without negative effects to the fish and to the environment (FAO, 2009; Ross *et al.*, 2013).
Coastal zone management	The management of coastal and marine areas and resources for the purposes of sustainable use, development and protection (IUCN, 2009).
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their nonliving environment interacting as a functional unit (Millennium Ecosystem Assessment, 2005).
Ecosystem boundaries	The boundaries of a system of complex interactions of ecosystem-linked populations (including humans) between themselves and with their environment.
Evaluation	Evaluation is the systematic examination of a project in order to determine its efficiency, effectiveness, impact, sustainability and relevance of its objectives.

Fallowing	This refers to leaving an aquaculture site empty of fish stock and all removable production structures for a certain period of time. It can be done for environmental or sanitary reasons. For an aquaculture company, fallowing implies having several sites in order to maintain production capacity year-round (IUCN, 2009).
Indicator	Indicator is a parameter, or a value derived from parameters, which points to, provides information about, and describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value (OECD, 2003).
Issue tree	An issue tree, also called a logic tree, is a graphical breakdown of an issue that dissects it into its different components vertically.
Management areas	Management areas are defined geographical waterbody areas where all the operators in the management area agree (coordinate and cooperate) to certain management practices or codes of conduct.
Monitoring	Monitoring is the continuous or periodic surveillance of the physical implementation of a project to ensure that inputs, activities, outputs and external factors are proceeding as planned.
Operational objectives	Operational objectives are measurable production, environmental and additional socioeconomic targets to be achieved within immediate and long-term scales.
Risk assessment	Risk assessment focusing on a variety of ecological attributes in order to protect the environmental, economic, social and cultural values identified by society.
Site selection	Site selection is the process by which various factors indicated are considered to enable one to decide on the right site for a specific culture system, or alternatively, to decide on a culture system that suits the available site (Kutty, 1987; Ross *et al.*, 2013).
Site management	Refers to all the actions involved in maintaining the activity on the site, including the environmental, legal, administrative and managerial aspects of the activity (IUCN, 2009).
Spatial planning	Refers to the methods used by the public sector to influence the distribution of people and activities in spaces of various scales. Spatial planning takes place at local, regional, national and international levels and often results in the creation of a spatial plan. Spatial planning also entails a system that is not only spatial, but one that also engages processes and secures outcomes that are sustainable, integrated and inclusive (FAO, 2013).
Social carrying capacity	Social carrying capacity is the level of development above which unacceptable social impacts would occur.
Stakeholder	Person, group or organization that has a direct or indirect interest in an activity normally initiated by a management authority or other stakeholders or is affected or has an interest in an objective or policies established by such management authority (IUCN, 2009).
Surveillance	Means a systematic series of investigations of a given population

	of aquatic animals to detect the occurrence of disease for control purposes, and which may involve testing samples of a population.
Surveillance zone	Means a zone in which a systematic series of investigations of a given population of aquatic animals takes place.
Targeted surveillance	Means surveillance targeted at a specific disease or infection.
Zone	Means a portion of one or more countries comprising an entire catchment area from the source of a waterway to the estuary, more than one catchment area, part of a catchment area from the source of a waterway to a barrier, or a part of the coastal area, or an estuary with a precise geographical delimitation that consists of a homogeneous hydrological system.
Zoning	Means identifying zones for disease control purposes. (aquatic animal health)
Zoning	Zoning implies bringing together the criteria for locating aquaculture and other activities in order to define broad zones suitable for different activities or mixes of activities. Zoning may be used either as a source of information for potential developers (for example, by identifying those areas most suited to a particular activity); or as a planning and regulating tool, in which different zones are identified and characterized as meeting certain objectives (GESAMP, 2001).

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Annex 1. Binding and Non-Legally Binding International Instruments That Govern Sustainable Aquaculture

Arron Honniball and Blaise Kuemlangan

BINDING INSTRUMENTS

Ramsar Convention on Wetlands of International Importance (Ramsar, 1971). The Ramsar Convention is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

Convention on International Trade on Endangered Species of Wild Fauna and Flora, CITES (Washington, DC, 1973). CITES strives to ensure that international trade in listed specimens of wild animals and plants does not threaten their survival.

Convention on the Conservation of Migratory Species of Wild Animals, CMS (Bonn, 1979). The CMS raises the need to consider aquaculture impacts on listed migratory species, which include various marine mammals and waterbirds.

United Nations Convention on the Law of the Sea, UNCLOS (Montego Bay, 1982). UNCLOS governs all aspects of ocean space and sets out jurisdictional rights and conservation responsibilities relating to marine living resources.

United Nations Framework Convention on Climate Change, UNFCCC (New York, 1992). The UNFCCC has provided a foundation for fostering national mitigation and adaptation commitments to address climate change and ocean acidification. Those commitments have been further elaborated through the Kyoto Protocol (1997) and the Paris Agreement (2015).

Convention on Biological Diversity, CBD (Rio de Janeiro, 1992). The CBD calls upon Member States to conserve and sustainably use biodiversity, and to ensure access and benefit sharing from genetic resources. The CBD supports ecosystem and precautionary approaches and promotes in situ conservation in protected areas.

Cartagena Biosafety Protocol (Cartagena, 2000). The Protocol seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology.

NON-BINDING INSTRUMENTS AND GUIDELINES

Kyoto Declaration on Aquaculture (1976). Adopted at the first FAO organized aquaculture conference, the

Honniball, A. & Kuemlangan, B. 2017. Binding and Non-Legally Binding International Instruments That Govern Sustainable Aquaculture. In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document,* pp. 63–66. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

Declaration placed the spotlight on the absence of an adequate legal basis for aquaculture development in many countries. Governments are urged to enact aquaculture legislation facilitating the establishment of aquaculture industries and enabling the zoning of suitable coastal and inland areas for aquaculture.

Agenda 21 (1992). Chapter 17 of this global action plan for achieving sustainable development urges countries to: provide for an integrated policy and decision-making process, including all involved sectors; promote compatibility and balance of use; implement integrated coastal and marine management plans; apply preventative and precautionary approaches in project planning and implementation; and prepare land and water use and siting policies.

Rio Declaration on the Environment and Development (1992). Adopted at the Rio Conference on Environment and Development, the Declaration sets out 27 principles as sustainable development guideposts. Key principles to be followed at the national level include: intra- and intergenerational equity (principle 3); public participation (principle 10); the precautionary approach (principle 15); and environmental impact assessment (principle 17).

FAO Code of Conduct for Responsible Fisheries (1995). Applying to fisheries but also to aquaculture, the Code encourages States to: develop and maintain appropriate legal and administrative frameworks to facilitate the development of responsible aquaculture; produce and regularly update aquaculture development strategies and plans; establish environmental assessment and monitoring procedures specific to aquaculture; and to integrate aquaculture into coastal area management. States are urged to ensure responsible siting and management of aquaculture activities, which could affect transboundary aquatic ecosystems.

FAO Technical Guidelines for Aquaculture Development (1997). The Guidelines promote the siting of aquaculture activities in locations which: are suitable for sustainable production and income generation; are economically and socially appropriate; prevent or minimize conflicts with other resource users; and respect nature preserves, protected areas and critical or especially sensitive habitats. To ensure that livelihoods of local communities and their access to fishing grounds are not negatively affected by aquaculture, government authorities are encouraged to foster agreements between aquafarmers and fishers to avoid resource conflicts and to subject large-scale aquaculture developments to social and economic assessments.

Bangkok Declaration and Strategy for Aquaculture Development Beyond 2000 (2000). The Declaration emphasizes that aquaculture should be pursued as an integral component of development, contributing through sustainable livelihoods for the poor and enhancing social well-being. The need for national aquaculture policies and regulations to promote economically viable but also environmentally responsible and socially acceptable farming practices is also highlighted. The Strategy notes the importance of integrating aquaculture into coastal area and inland watershed management plans and ensuring aquaculture developments are within local and regional carrying capacities. The Strategy calls for clarifying legal frameworks and policy objectives regarding access and user rights for farmers and developing comprehensive and enforceable laws and procedures that encourage sustainable aquaculture.

International Principles for Responsible Shrimp Farming (2006). The International Principles are aimed at countering inappropriate and unplanned siting of shrimp farms. Guidance is given for farm siting, in particular, not building new shrimp farms above the intertidal zone; ensuring no net loss of mangroves or other sensitive wetland habitats; not locating new shrimp farms in areas already at their carrying capacity for aquaculture; retaining buffer zones between farms and other users; and obeying land use and coastal management plans. The International Principles urge the preparation of integrated coastal area management plans that designate environmentally suitable locations for shrimp farms and other types of aquaculture.

FAO Guidelines on the Ecosystem Approach to Aquaculture (2010). The Guidelines stress the need for integrated planning and management systems and the need to pay more attention to the watershed scale where clusters of farms may have cumulative ecosystem effects. The Guidelines clarify that zoning may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture.

Sustainable Development Goals (2015). Goal 14 of the 2030 Agenda for Sustainable Development is to conserve and sustainably use the oceans, seas and marine resources for sustainable development. Target 14.7 addresses aquaculture and calls for increasing by 2030 the economic benefits from the sustainable use of marine resources including through the sustainable management of fisheries, aquaculture and tourism, to small island developing states and least developed countries.

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Annex 2. Biosecurity Zoning and Compartments, Infected Zones, Disease-Free Zones

David Huchzermeyer and Melba G. Bondad-Reantaso

1. INTRODUCTION

The impact of infectious diseases poses an ever-increasing challenge to aquaculture and marketability of aquaculture products as the farming of aquatic animals increases in intensity to meet growing global demand. Aquaculture and all levels of aquatic resource management play an important role in food security, and may have far reaching effects on rural development, water management, the environment, poverty alleviation, livelihoods, trade, and gender and household nutrition (FAO/RAP, 2003). This chapter details how the concept of biosecurity is used to limit disease transmission in the aquatic environment and how this is applied to zoning in aquaculture.

Aquaculture farming creates large densely stocked populations of aquatic animals that are susceptible to numerous infectious agents. In unstressed populations or where environmental conditions do not favour expression of clinical symptoms, a disease may go undetected. Where a contagious aquatic pathogen is present within a susceptible population of aquatic animals, the expression of disease (morbidity and mortality) will depend on numerous factors, including life stage of the host and environmental and husbandry conditions. Intense aquaculture environments tend to be conducive to expression of diseases that may remain undetected in wild aquatic animals sharing the same waters. Water in which aquatic animals are farmed provides an effective medium for the transfer of these pathogens. Where farmed and wild aquatic animals share a common water source, pathogen transfer may take place not only among the farmed population, but also from farmed-to-wild, and from wild-to-farmed individuals. Furthermore, inadvertent release of infectious agents from aquaculture farms into the natural environment poses serious ecological concerns and has the potential to impact on natural species diversity. Biosecurity zoning and compartmentalization provide a holistic approach to managing the threats posed by such diseases in the aquatic environment with the aim of establishing and maintaining populations of aquatic animals with distinct health status and effectively separating these from populations with a different health status (Zepeda, Jones and Zagmutt, 2008).

Far reaching consequences for both farmed and wild aquatic animals may occur when exotic diseases are introduced, often inadvertently, into the aquatic environment. Changes in the behaviour or distribution of an established endemic disease, or the emergence of a previously unknown disease, may be equally detrimental (Arthur *et al.*, 2005). Disease outbreaks have proved to be one of the major constraints limiting growth and sustainability of aquaculture, and in certain

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instances have resulted in the complete collapse of aquaculture fisheries with serious socioeconomic impact (Bondad-Reantaso *et al.*, 2005; Subasinghe, 2005). There are numerous such examples that in recent years have resulted in tens of thousands of lost jobs, billions of dollars in direct loss, and collapse of economies reliant on aquatic animal production, particularly in developing countries (Brummett *et al.*, 2014). The introduction of the infectious salmon anaemia (ISA) virus into Chilean salmon farms (Asche *et al.*, 2009), the emergence of bacterial disease, such as acute hepatopancreatic necrosis disease (AHPND) in shrimp farms in a number of Asian countries (FAO, 2013) and spread of white spot syndrome (WSS) virus to shrimp farms in two countries bordering the Mozambique channel (World Bank/RAF, 2013; FAO, 2015), underscore the vulnerability of aquaculture farming (Brummett *et al.*, 2014; Oidtmann *et al.*, 2011). Such disease outbreaks have the potential of seriously compromising investment in future aquaculture development. Exotic disease incursions do not only affect aquaculture; they may also pose serious risk to natural fish stocks. The important role of ornamental fish in transmitting disease is well illustrated by epidemics of koi herpesvirus disease in cultured and wild carp populations in Indonesia following introduction of the disease in 2002 (Sunarto, Rukyani and Itami, 2005). Other poorly managed pathways of disease transmission may involve spread from non-native food stocks (live, fresh or frozen material) used in aquaculture as in the case of pilchard herpesvirus that decimated wild Australian pilchard stocks following the introduction of the disease into these waters in the late 1990s (Whittington, Jones and Hyatt, 2005). Wild populations of aquatic animals may harbour diseases and act as reservoirs for infection in cultured stocks. This is particularly relevant to shrimp and marine finfish (Bondad-Reantaso *et al.*, 2005). Interactions between wild and cultured populations are thus of particular concern for aquaculturists and natural resource conservation officers.

Movement of live aquatic animals, within and between countries, associated with aquaculture, marketing of live aquatic animals, and the ornamental fish trade is an increasingly important route of pathogen spread (Oidtmann *et al.*, 2011). Advances in trade in live aquatic animals and the efficiency of modern transportation methods have created opportunities for highly contagious transboundary aquatic animal diseases (TAADs), that have the potential to cause serious socioeconomic impact and to spread rapidly across national borders (Baldock, 2002; Bondad-Reantaso, 2004; Subasinghe, 2005; Rodgers, Mohan and Peeler, 2011). Once a pathogen becomes established within the natural ecosystem, treatment and eradication may become virtually impossible (Hine *et al.*, 2012). In recent years, the emergence of koi herpesvirus, a highly contagious disease of carp (*Cyprinus carpio*); epizootic ulcerative syndrome (EUS), an oomycete infection that affects a wide range of fresh and brackish-water finfish; and ISA, a serious viral disease of Atlantic salmon, have had a major impact on finfish production in various parts of the world where these diseases previously did not occur. Among invertebrate aquatic animals, the emergence of the viral diseases of shrimp: white spot syndrome, yellow head disease and Taura syndrome; and in bivalves: the parasitic disease *Bonamia ostreae* and the ostreid herpesvirus have led to enormous financial losses and socioeconomic disruptions in affected countries (Bondad-Reantaso *et al.*, 2005; Oidtmann *et al.*, 2011).

For aquaculture development to remain sustainable, wherever possible, timeous measures need to be applied to prevent transfer and introductions of aquatic animal pathogens and to limit the consequences of disease outbreaks (Hine *et al.*, 2012). The development and implementation of biosecurity and zoning strategies is increasingly recognized by countries and industries as essential to sustainable growth in aquaculture (Håstein *et al.*, 2008; Hine *et al.*, 2012). One of the strongest incentives for implementing national biosecurity programmes is the ability to move and trade aquatic animals and their products free of specific pathogens (Håstein *et al.*, 2008). This requires international recognition of a country's ability to demonstrate effective biosecurity and zoning strategies, including the ability to maintain zones and compartments of known disease status.

2. DEFINITIONS OF BIOSECURITY, ZONING AND COMPARTMENTS, INFECTED ZONES AND DISEASE-FREE ZONES

2.1 Biosecurity

Biosecurity can be broadly described as a strategic and integrated approach that encompasses both policy and regulatory frameworks aimed at analysing and managing risks relevant to human, animal and plant life and health, as well as associated environmental risks (FAO, 2007a). Biosecurity has direct relevance to the sustainability of aquaculture while ensuring protection of public health, the environment and biological diversity.

The term biosecurity in the context of aquatic animal health is used to specifically describe the measures used to prevent introduction of unwanted biological agents, particularly infectious pathogens, and to manage adverse effects associated with contagious agents. It encompasses both farmed and wild aquatic animals; exotic, endemic and emerging diseases; and is applied from the farm to the ecosystem, and at national and international levels (Scarfe *et al.*, 2009). Subasinghe and Bondad-Reantaso (2006) defined biosecurity in aquaculture as a collective term that refers to the concept of applying appropriate measures (e.g., proactive disease risk analysis) to reduce the probability of a biological organism or agent spreading to an individual, population or ecosystem and to mitigate the adverse impact that may result. Such analysis is done in a way that incorporates best available information on aspects of good husbandry, epidemiology and good science.

Where farming of aquatic animals takes place in open water systems connected to natural waterways, it may be impossible to exclude all infectious diseases. Biosecurity practices provide the procedures that limit the impact of infectious diseases. These include the prevention, control and eradication of diseases (Scarfe *et al.*, 2009). Farmers are increasingly encouraged, and in some cases mandated, to follow sound biosecurity practices. In order to have a predicted outcome, these should be formulated into a structured biosecurity plan that provides the framework for disease management on the farm and is implemented through documented standard operating procedures. Scarfe *et al.* (2009) propose the following essential elements to ensure that the biosecurity plan is effective, justifiable and useful:

- apply to a defined epidemiological unit or area (compartment) or geographical zone;
- identify specific disease hazards (infectious pathogens);
- evaluate the risk of these hazards to the unit;
- evaluate critical points where diseases can enter or leave the unit;
- evaluate and monitor disease status of the unit;
- have contingency plans in place if disease does break out;
- have written records for third-party auditing and certifying, particularly where markets require live animals or their products to be certified as free of disease or specific pathogens; and
- be transparent and credible.

For purposes of disease control, biosecurity principles should be applied to all levels of aquatic animal disease management, from farm to national and regional levels.

Export markets may source aquatic commodities from countries where establishing and maintaining freedom from a particular disease for the entire country may be difficult, or from regions of the world where countries may not have the infrastructure, expertise and resources needed to provide disease-status guarantees on a national level, as required by the importing countries. In such cases, distinct advantages are linked to applying biosecurity principles to subpopulations of aquatic animals restricted to compartments and zones within the country. With application of relevant biosecurity measures to compartments, trade from an individual farm unit becomes possible, even when a country as a whole is unable to provide guarantees of freedom from diseases of relevance.

2.2 Zones

The World Organisation for Animal Health (OIE) defines a zone as a portion of a contiguous water system with a distinct health status with respect to certain diseases (Corsin *et al.*, 2009; OIE, 2016). The recognition of zones is thus based on geographical boundaries (OIE, 2016). A zone may comprise one or more water catchments, from the source of a river to an estuary or lake, or only part of a water catchment from the source of a river to a barrier that effectively prevents introduction of specific infectious agents (OIE, 2016). Coastal areas and estuaries with precise geographic delineation may also comprise a zone (OIE, 2016). The boundaries of zones must be scientifically justifiable, and should not be based on administrative regions or industry/production-related convenience and needs (OIE, 2016). An integral part of a biosecurity strategy is the ability to identify, maintain and effectively manage subpopulations of aquatic animals relative to the presence or absence of disease within defined zones. For official disease control purposes, it is important that diseases restricted to zones are regulated and compulsorily notifiable under relevant legislation of the concerned country (Subasinghe, McGladdery and Hill, 2004).

2.3 Compartments

On a smaller scale, compartmentalization is based on the concept that animals sharing the waters within the same geographical location will share a common exposure risk to pathogens. The factors defining a compartment are based on management and biosecurity practices, and criteria are established by the relevant aquatic animal health services of a country with the objective of facilitating trade in aquatic animals and their products and as a tool for disease management (OIE, 2016). Compartments are epidemiologic units that define both the disease status of the population and the level of risk for entry of new pathogens (Corsin *et al.*, 2009). For the purpose of international trade, a compartment is defined by the OIE as one or more aquaculture establishments under a common biosecurity management system, containing an aquatic animal population with a distinct health status with respect to a specific disease or diseases for which required surveillance and control measures are applied and basic biosecurity conditions are met (Corsin *et al.*, 2009; OIE, 2016). One or more compartments within the same geographic delineation may make up a zone.

2.4 Infected Zones

An infected zone represents a clearly delineated area within a country or region with shared waterways in which a specific disease has been detected or is established as an endemic infection within the population of farmed or wild aquatic animals (Subasinghe, McGladdery and Hill, 2004). Where possible, eradication or control measures may be implemented. A zone will retain its status as infected until eradication of the disease has been proved through appropriate targeted surveillance. If eradication is not possible, an infected zone may be surrounded by a clearly demarcated buffer zone that is subject to targeted surveillance for the disease in order to protect surrounding areas with a disease-free status (Subasinghe, McGladdery and Hill, 2004).

2.5 Disease-Free Zones

Zones free of specific diseases may constitute geographical or hydrological areas within which susceptible aquatic animal populations have been shown, through targeted surveillance and protection from exposure, to be free of a specific infectious disease. Disease-free compartments constitute farms or aquaculture establishments with independent, protected water supplies that meet specific regulated biosecurity and surveillance measures that demonstrate absence of a specific infectious disease and guard against introduction of the disease. For trade purposes, such establishments must be officially registered with the relevant national authority. Facility-based, disease-free compartments may be located within an infected zone or within zones of unknown disease status. The acceptance of disease-free compartments for international trade purposes opens opportunities for aquaculture producers to access international markets from countries where resources, skilled manpower, infrastructure or hydrologic limitations preclude collection of sufficient national surveillance data to prove absence of disease from larger zones.

3. WORLD ORGANISATION FOR ANIMAL HEALTH (OIE) GUIDELINES AND OTHER TECHNICAL GUIDELINES

To meet the aims and needs of modern society, biosecurity systems need to be based on robust and transparent scientific inputs to standard-setting processes, in particular those relating to trade in agricultural products (FAO, 2007a). One of the fundamental principles of the General Agreement on Tariffs and Trade (GATT), established after the end of World War II, ensured that all nontariff barriers to international trade should be prohibited. This was retained in full with the establishment of the World Trade Organization (WTO) in 1995 (Chillaud, 1996). The 1995 WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) aims to minimize the effects of health restrictions on international trade. To achieve this, the animal health measures established by countries to ensure the protection of human and animal life and health are based on international standards, guidelines and recommendations, primarily those developed by the OIE, and the OIE code plays a central role in this process (Chillaud, 1996). The SPS Agreement requires states to not introduce or maintain health measures that result in a higher measure of protection than that advocated by these international standards, unless scientific justification for the need for such measures can be demonstrated (Chillaud, 1996). The SPS Agreement also emphasizes the need for transparency in import health measures that states enforce (Chillaud, 1996). Similarly, the Codex Alimentarius, established by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) of the United Nations in 1963, provides international food standards, guidelines and codes of practice, including those relating to veterinary drug residues that contribute to the safety, quality and fairness of international food trade. Through the SPS Agreement, the Codex also has far reaching implications for resolving trade disputes.

The OIE is recognized by its member countries as the international organization responsible for development and promotion of international animal health standards, guidelines and recommendations affecting safe international trade in live animals and their products. These are documented in the OIE Aquatic Animal Health Code (OIE, 2016) and the OIE Manual of Diagnostic Tests for Aquatic Animals (OIE, 2015). Zoning and compartmentalization, with risk assessment and epidemiological disease surveillance and monitoring, form an essential component of biosecurity and import risk analysis (OIE, 2016). To keep abreast with changing challenges, the input of experts and working groups and the contributions of member countries result in an annual review and update of the Code and the Manual, and authorities should refer to the most recent issue. Central to these documents is a list of diseases that are notifiable to the OIE. Where new outbreaks of these diseases occur, the member states are obliged to report on these outbreaks to the OIE. For a disease to be listed, several standard criteria are applied (OIE, 2016):

- the disease has been shown to cause significant production losses at a national or multinational level;
- the disease has been shown to or scientific evidence indicates that it is likely to cause significant morbidity or mortality in wild aquatic animal populations;
- the agent is of public health concern;
- an infectious aetiology of the disease is proven;
- an infectious agent is strongly associated with the disease, but the aetiology is not yet known;
- likelihood of international spread exists, including via live aquatic animals, their products or fomites;
- several countries or countries with zones may be declared free of the disease based on the general surveillance principles outlined in the Code; and
- a repeatable and robust means of detection/diagnosis exists.

Many countries in the world are members of the OIE, and as such have a commitment to apply the OIE standards through relevant national policy and legislation (Oidtmann *et al.*, 2011). Supernational and political unions, such as the European Union (EU), may apply common policies and legal frameworks to ensure that member countries apply equivalent standards in order to facilitate trade between member states. In the EU, the Council Directive 2006/88/EC (on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals) provides the instrument for the biosecurity framework applied in the EU with an emphasis on promoting prevention of aquatic animal diseases (Oidtmann *et al.*, 2011). The directive is particularly relevant to countries outside of the EU, so-called third countries, wishing to export aquatic animals or their products to the EU. While standardizing aquatic animal health controls across the European Community (EC) to facilitate trade within the EU, it makes provision for protecting areas of higher health status. Such additional animal health control measures applying to certain diseases and areas may include a requirement for specific disease guarantees that will reflect on relevant model animal health certificates required for imports into the country from third countries. For example, England and Wales have import requirements for a number of diseases in addition to diseases considered exotic to the EC (Oidtmann *et al.*, 2011).

The bulk of world aquaculture production takes place in Asia. The Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals, and their associated implementation plan, the Beijing Consensus and Implementation Strategy (FAO, 2000) have been adopted by Asian countries in a regional effort to reduce and manage the risk due to the transboundary movement of live aquatic animals (Mohan, Chinabut and Kanchanakhan, 2008). These guidelines provide a comprehensive framework for dealing with aquatic animal diseases emergencies.

A number of other international guidelines provide technical information on fisheries, aquaculture and biodiversity with information relevant to biosecurity. The FAO Code of Conduct for Responsible Fisheries, adopted by member states on 31 October 1995, applies to both fisheries and aquaculture, and includes principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity (FAO, 2011). Further technical information on health management for the responsible movement of live aquatic animals is provided in the FAO Technical Guidelines for Responsible Fisheries (FAO, 2007b).

Zoning is an important element of a National Aquatic Animal Health Strategy (NAAHS), a broad yet comprehensive strategy to build and enhance capacity for the management of national aquatic biosecurity and aquatic animal health. It contains the national action plans at the short-, medium- and long-term using phased implementation based on national needs and priorities; outlines the programmes and projects that will assist in developing a national approach to overall management of aquatic animal health; and includes an Implementation Plan that identifies the activities that must be accomplished by government, academia and the private sector. It cannot be implemented in isolation and is interlinked with other elements of a NAAHS (FAO, 2007b).

A number of other codes and conventions contribute to standardization of international protocols and responsibilities (Håstein *et al.*, 2008). These include:

- International Council for the Exploration of the Sea (ICES) Code of Practice on the Introductions and Transfers of Marine Organisms;
- International Maritime Organization Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens;
- International Union for the Conservation of Nature Guide to Designing Legal and Institutional Frameworks on Alien Invasive Species;
- European Inland Fisheries Advisory Commission (EIFAC) Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms; and the
- WTO Convention on Biological Diversity.

4. PURPOSE OF ZONING

Zones make distinctions between populations of aquatic animals depending on respective disease prevalence. Zones are therefore used to manage and control the spread of contagious aquatic animal diseases. By establishing zones of known disease status, control measures can be implemented, disease prevalence can be established, and intensity of surveillance can be determined. Zones should not be proposed as administrative regions based on production-related needs or convenience (Corsin *et al.*, 2009).

Zoning is an important procedure for disease control and eradication, and for maintaining international trade opportunities, and control measures should be under the direct control of a competent authority (Zepeda, Jones and Zagmutt, 2008). Where a particular aquatic animal disease posing international risk is present in only part of a country, the establishment and preservation of disease-free zones may allow declarations of freedom from disease, thereby ensuring safe trade from such zones. To provide such declarations, the specified subpopulations of aquatic animals within a zone must become the target of surveillance (Corsin *et al.*, 2009). The identification and traceability of subpopulations within a zone must be clearly defined, and the procedures used to establish and maintain a distinct health status of a zone must be appropriate to the disease, taking into account the epidemiology of the relevant disease, environmental factors, risk of introduction, and establishment of disease and applicable biosecurity measures (OIE, 2016). Disease-specific recommendations for OIE-listed diseases are provided in the OIE Manual of Diagnostic Tests for Aquatic Animals (OIE, 2015). Relevant guarantees applicable to a disease-free declaration, as often required by importing countries, depend on the ability of the exporting country to demonstrate that one or more zones within a country or region do not harbour infected animals and can be kept safe from transfer of the disease from potentially infected zones.

5. PURPOSE OF COMPARTMENTALIZATION

Compartmentalization represents the functional separation of subpopulations of aquatic animals based on disease status through the implementation and documentation of management and biosecurity measures (Zepeda, Jones and Zagmutt, 2008; OIE, 2016). In contrast to a zone, the biosecurity management of a compartment is the responsibility of those in control of compartments (Zepeda, Jones and Zagmutt, 2008). Active surveillance for presence of a specific infectious disease can lead to declaration of freedom of disease where no evidence of infection can be found in a zone or compartment. Such declarations are difficult when dealing with large transboundary watersheds. In such cases, declarations need to be limited to distinct compartments, the smallest compartment being an individual farm and its water source.

The management of a compartment should encompass disease-specific epidemiological factors, a defined aquatic animal species within the compartment, production systems, biosecurity practices, infrastructural components and surveillance (OIE, 2016). Compartments should be clearly documented by the respective competent authority of a country.

Declaration of freedom of a particular disease from a compartment has many advantages relating to trade where the market or the importing country requires disease-status guarantees. Where a country is unable to supply such guarantees on a national or zone level, either through a lack of supportive data or because a zone is infected with a disease, biosecurity and management practices within a compartment may be used to prove negligible disease risk from a subpopulation. To meet the requirements of importing countries, compartments need to be under the responsibility of the competent authority of the country (OIE, 2016). Provided an aquaculture operation meets the required biosecurity standards, compartmentalization offers an internationally acceptable means of providing guarantees.

6. ELEMENTS OF ZONING AND COMPARTMENTALIZATION

6.1 Management of a Compartment or Zone

6.1.1 Physical and Spatial Factors

Where a serious disease has been identified in a country and eradication is not feasible, establishment and maintenance of free zones can limit the impact of a disease on the ability to market products both locally and internationally (FAO, 2007b). Such zones or compartments may be established based on ecological, hydrological and climatological barriers (FAO, 2007b), bearing in mind that numerous pathogens can survive protracted periods in water and have the ability to be transmitted downstream via water and sediments. Fomites, such as fishing equipment, fish transport tanks, people, clothes, boats and vehicles, may aid in the transfer of aquatic animal pathogens and may circumvent natural barriers between infected and noninfected zones. Within watersheds, fish migrations may be accountable for spread of certain pathogens. One example of a pathogen that has spread unexpectedly is EUS, a disease that spreads by the release of infective spores into the water. After the first outbreak of EUS, in the Zambezi River upstream of Victoria Falls in southern Africa in 2006, the disease was found to spread rapidly upstream with its greatest impact in the floodplains of the upper Zambezi, yet few cases were reported downstream of the Falls (Huchzermeyer and Van der Waal, 2012).

Where wild-to-farmed and farmed-to-wild fish interactions favour pathogen transfer, biosecurity measures, including containment and stamping out procedures, may be most successful in farms supplied by a protected water supply (Jeremic, Dobrilla and Radosavljević, 2004). The degree of confidence with which biosecurity and surveillance are applied may be influenced by a number of factors that must be taken into account, as indicated in the OIE Aquatic Animal Health Code (OIE, 2016):

- the disease status of adjacent areas and areas epidemiologically linked to the compartment;
- the location, disease status and biosecurity of the nearest epidemiological units or other epidemiologically relevant premises;
- the distance and physical separation from other aquatic animal populations with different health status in close proximity of the compartment, including wildlife and their migratory routes;
- slaughterhouses or processing plants; and
- fish exhibitions, put and take fisheries, fish markets and restaurants selling live aquatic animals, and any other points where aquatic animals are concentrated.

Functional, structural or natural barriers must ensure that adjacent animal populations with a different health status are adequately separated from a compartment (OIE, 2016). Protected water sources are generally those that contain none of the susceptible species of a particular disease or diseases and are usually a prerequisite for the issue of specific pathogen free (SPF) certification. Spring water and borehole water are considered the safest form of water supply. Compartments utilizing recirculated water systems based on a secure water source preclude the risk of introduction of pathogens via the water supply. Unless such a system is managed as a closed system, pathogens may still enter the system with introductions of aquatic animal stock.

6.1.2 Infrastructural Factors

Where establishing and maintaining a disease-free status throughout an entire country or zone is impossible or difficult, particularly where a specific disease exists in wild aquatic animal species or can cross international borders, recognition of disease status based on biosecurity management of a compartment is possible (OIE, 2016). With the objective to facilitate trade and minimize the impact of disease on aquaculture farms, compartments within countries or zones need to strive for third-party disease-status recognition. All epidemiological factors that affect the disease transmission are taken into account to create disease-specific separation of subpopulations (OIE, 2016). For the purpose of facilitating trade, compartments must be under the control of a relevant competent authority. A compartment should be clearly defined, taking into account physical and special factors that affect the biosecurity of the compartment (OIE, 2016). These include location of its components and related functional units such as broodstock ponds, hatchery, nursery, grow-out facilities, slaughterhouse and processing plants. The effectiveness of the compartment depends on a number of infrastructural aspects, including the following (OIE, 2016):

- water supply, in particular, the degree to which a water supply is regarded safe or protected from disease risks;
- efficacy of physical separation;
- people entry facilities (disinfectant foot baths, protective clothing, etc.) and access control;
- vehicle and vessel access, and washing and disinfection procedures;
- unloading and loading facilities;
- isolation facilities for introduced aquatic animals;
- facilities for the introduction of material and equipment;
- infrastructure for feed and veterinary product storage;
- aquatic animal waste disposal facilities;
- measures to prevent exposure to fomites, mechanical and biological vectors; and
- feed supply and source.

6.2 Biosecurity Plan

The wide diversity of farmed aquatic animal species, the variation in culture methods, environments, intensity of farming and interactions with wild aquatic animals and natural ecosystems make control of aquatic animal diseases challenging. The concept of biosecurity planning, applied from farm to national level, provides an effective means of implementing disease control at multiple levels (Palić, Scarfe and Walster, 2015). At the compartment level, the biosecurity plan provides an auditable process of management procedures that can be evaluated by hazard analysis and critical control point (HACCP) methodologies (Zepeda, Jones and Zagmutt, 2008). Implementation of effective biosecurity programmes requires an integrated approach encompassing epidemiology, pathobiology, clinical and laboratory diagnosis, diagnostic assay interpretation, biosecurity, disease transmission routes, risk analysis, critical control point assessment, auditing, certification and associated ethics and liability, producer goals, and government and trade regulations (Palić, Scarfe and Walster, 2015). Sound epidemiological principles and a logical and sound science-based approach used in formulating a biosecurity plan include the following elements:

- **Hazard identification and prioritization** that involves all diseases that pose a threat to the country or to marketability of export products, and varies depending on the level of application (farm, national, international) (Oidtmann *et al.*, 2011). Routes of introduction and pathways of spread (transport of live animals or animal products, spread via water or fomites) are identified (Oidtmann *et al.*, 2011). Where water connectivity occurs between farmed and wild animals, priority should focus on prevention. In simple terms, the question of "What can go wrong?" needs to be addressed (Arthur *et al.*, 2005).
- **Risk assessment** evaluates the chances of a pathogen carried by an aquatic animal commodity entering a zone or compartment and the chances that wild or farmed animals within the zone or compartment will be exposed to infection. It poses the question, "How likely is it to go wrong?" (Arthur *et al.*, 2005).
- **Critical control point evaluation and remediation** defines the pathways by which critical infectious pathogens may enter a compartment and the measures that can be implemented to control and monitor them, including clinical evaluation and diagnostic testing (Scarfe *et al.*, 2009).
- **Risk mitigation** defines correctable critical control points, including contingency plans that make provision for actions such as isolation, treatment and fallowing. "What can be done to prevent diseases getting in or escaping?" (Scarfe *et al.*, 2009).
- **Disease surveillance** represents the systematic series of investigations of a given population of aquatic animals for the clinical detection of disease occurrence or for detecting the presence or absence of a pathogen within a specified compartment, zone or country and includes monitoring of existing health problems (OIE, 2016). Single surveys seldom provide sufficient evidence to prove absence of a disease. Surveillance therefore encompasses ongoing collection, collation and analysis of information related to animal health. A function of surveillance includes the timely dissemination of information to those that need to know (Corsin *et al.*, 2009). Surveillance activities are usually performed to achieve one or more objectives (OIE, 2016; Corsin *et al.*, 2009; Cameron, 2002):
  - demonstrate absence of disease to facilitate international trade;
  - provide an early warning system of incursion or emergence of disease;
  - identify events that require official notification and action; and
  - determine occurrence and distribution of endemic disease, and changes in incidence and prevalence, to provide information needed for domestic control programmes and for risk assessment by trading partners.

  Surveillance can range from basic passive surveillance systems, relying on the reporting of unusual disease events, to comprehensive targeted programmes to demonstrate absence of a defined disease or infection (Cameron, 2002; OIE, 2016). Passive surveillance systems depend on the ability to recognize and the willingness to report unusual events and require the ability to investigate and identify pathogens when such events are reported. Mortality rates, growth rates, and other health and production benchmarks should be used to alert authorities of a disease outbreak. In countries with limited resources, a range of other information can be sourced for basic surveillance, including anecdotal information, farm records, private and government laboratory reports, certification records, research investigations and fishery stock assessments (Corsin *et al.*, 2009). Active or targeted surveillance follows a structured surveillance design, targeting specified diseases or pathogens often with the purpose of demonstrating the disease status of a defined population (Corsin *et al.*, 2009).

- **Control** measures designed to mitigate the impact of aquatic animal diseases may include containment, eradication, disinfection and fallowing procedures. Control measures should be based on the ability to define epidemiological units. Well-defined sub-populations of aquatic animals can then be managed according to realistic outcomes. Contingency planning makes provisions for the control measures that need to be applied in case of disease outbreaks and are best documented from the animal health management and biosecurity plan at the farm level to national and regional biosecurity strategies. This requires an active commitment from all stakeholders, including farmers, industry leaders, the competent authority and policy makers, with due consideration to differing attitudes and beliefs among role players (Delabbio *et al.*, 2005).
- **Eradication** of the disease may be possible by destroying the stock within an affected epidemiological unit or units, followed by fallowing, in cases where a disease incursion within a compartment or zone has occurred. Eradication and disinfection provide a method of managing the impact of an introduced disease with the possibility of reinstating a disease-free status where effective barriers exist between the farmed and natural environment, and the water supply can be secured. Where a water body in which aquatic animals are farmed is continuous with or connected to the natural aquatic ecosystem, surveillance and early warning critical control points can be used to reduce the economic impact of a disease outbreak by timeous destruction of stock and a period of fallowing followed by reintroduction of SPF stock. This concept has been applied with particular success in the aquaculture of shrimp in a number of countries, and has contributed significantly to a resurgence of sustainable growth in this industry (Lightner, 2011).

An important motivation for aquaculture industries to actively participate in national biosecurity programmes is the ability of a country to compensate for officially ordered destruction of diseased populations and the implementation of enforced fallowing periods (Håstein *et al.*, 2008). In this way, Denmark was successful in eradicating viral haemorrhagic septicaemia (VHS), a highly contagious salmonid disease, from more than 400 endemically affected farms after 45 years of surveillance and stamping out (OIE, 2015). Similar successful eradication of acute incursions of VHS disease has been reported from Norway and the United Kingdom of Great Britain and Northern Ireland (OIE, 2015).

Nations have developed biosecurity strategies to differing levels. Countries such as Australia, Canada, the United States of America and some European countries have developed operational national biosecurity plans in response to several serious diseases (Mohan, Chinabut and Kanchanakhan, 2008). The Aquatic Veterinary Emergency Plan (AQUAVETPLAN) of Australia represents one such effective emergency preparedness and response plan. Many other countries are in the process of developing similar regional and national biosecurity strategies (Bondad-Reantaso, Lem and Subasinghe, 2009).

6.3 Surveillance

Management of aquatic animal diseases on a farm, national, regional and international level requires relevant knowledge about the occurrence of disease. Surveillance activities provide the information on the occurrence of important aquatic animal diseases within compartments, zones and countries. It is important to prioritize the diseases to be included in a surveillance system. This may depend on the need to provide disease-status assurances for trade purposes, the financial and socioeconomic impact of the threat that a disease poses, the importance of an industry-wide disease-control programme within a country or region, and the resources of a country (OIE, 2016).

Surveillance is the systematic ongoing collection, collation and analysis of information related to animal health and the timely dissemination of information to those who need to know so that action can be taken (Cameron, 2002; Corsin *et al.*, 2009). For purposes of disease surveillance, farmed and wild populations and subpopulations of aquatic animals are managed as epidemiological units. An epidemiological unit represents a defined population or subpopulation of aquatic animals that share the same chance of exposure to a pathogen within a defined location in which infectious diseases can be transmitted, but that is separated from other populations by some means (Corsin *et al.*, 2009; OIE, 2016). An epidemiological unit may represent a population of wild aquatic animals inhabiting a distinct geographic location or be as small as a single pond or cage on an aquaculture farm. Where management practices cannot preclude a common exposure route in a shared environment, the epidemiological unit becomes larger and will apply to all the ponds or cages on a farm or even to an entire waterway or catchment.

Surveillance programmes can be implemented once epidemiological units have been defined. As a minimum, this is based on comprehensive general surveillance activities aimed at establishing the extent of endemic disease situations and as an early warning system for outbreaks of new or exotic diseases (Subasinghe, McGladdery and Hill, 2004). More detailed information about the status of a defined disease is gathered through targeted surveillance aimed at a specific disease or infection (OIE, 2016).

Countries have a number of responsibilities to ensure effective disease surveillance (Subasinghe, McGladdery and Hill, 2004). These include:

- support national surveillance schemes by ensuring that relevant diagnostic capacity is available, and that field and laboratory personnel are sufficiently trained in disease recognition, reporting and accurate rapid pathogen identification;
- develop standardized field and laboratory surveillance methodologies, and training and reference manuals;
- ensure that surveillance data are entered into a national database from which the data can be rapidly accessed; and
- ensure that adequate finances are available to support active surveillance schemes.

Surveillance is usually performed to achieve one or more clear objectives, including the ability to demonstrate absence of infection needed to facilitate domestic and international movement of aquatic animals and their products, provide an early warning of the incursion of a new or exotic disease, describe occurrence and distribution of diseases relevant to official disease control measures, and assess progress in control or eradication of selected diseases (Corsin *et al.*, 2009; Subasinghe, McGladdery and Hill, 2004). Surveillance provides information on disease control programmes that is valuable to trading partners for import risk assessment and for the justification of import health certification requirements and to substantiate absence of disease claims required for export certification (Subasinghe, McGladdery and Hill, 2004; FAO, 2007b).

Implementing biosecurity practices and the systematic approach to gathering information on occurrence and distribution of diseases provides aquaculture farmers with the most effective means of disease prevention (Subasinghe, 2005). Aquatic animal health services require meaningful reports on disease status of zones and compartments that depend on well-designed surveillance programmes to support risk analysis and to support the rapid implementation of contingency programmes for eradication or containment of serious introduced diseases (Subasinghe, McGladdery and Hill, 2004; FAO, 2007b).

Where infrastructural development or diagnostic capacity is insufficient for national-level surveillance programmes supporting the creation of zones, surveillance of the health status of a compartment may provide sufficient information for export purposes. Once surveillance data on the prevalence of diseases within a zone or compartment become available, steps can be taken to either:

- limit the impact of an infectious disease if present;
- eradicate the disease if present; or
- ensure that an infectious disease is not introduced if found to be absent.

Aquatic Animal Disease Surveillance and the Trade in Live Aquatic Animals and Their Products

Domestic and international trade in live aquatic animals and products may be dependent on the ability of a producer to provide guarantees of freedom from diseases. For transboundary movement of live aquatic animals and their products, it is the importing country that states the guarantees required, usually as a condition of an import permit. Importing countries require such guarantees in order to appropriately protect the health status of aquatic animal populations within the importing country. For farmers to access transboundary markets, they need to be in a position to meet the importing country's demands. For this purpose, surveillance of zones and compartments, at the very least at the farm level, is a prerequisite. Such demands may appear restrictive to farmers, but by adopting and adhering to the management practices required to meet strict biosecurity demands, the reduction in risk of disease outbreaks and associated cost bears substantial advantages to animal production systems.

6.4 Diagnostics

Diagnostics play two essential roles in aquatic animal health management and disease control, i.e. (1) to screen healthy animals to ensure that they are not carrying infection at subclinical levels by specific pathogens; and (2) to determine the cause of unfavourable health or other abnormality (such as spawning failure, slow growth, behaviour, etc.) in order to recommend mitigating measures applicable to that particular condition. The former, commonly done on stocks or populations of aquatic animals destined for live transfer from one area or country to another, reduces the risks on two fronts: (1) risk of animals carrying opportunistic pathogens which may proliferate during shipping, handling or change in environment; and (2) risk of resistant or tolerant animals transferring a significant pathogen to a population which might be susceptible to infection. The latter is the most immediate and clearly recognized role of diagnostics in aquatic animal health biosecurity (Bondad-Reantaso *et al.*, 2001).

Diagnosis of aquatic animal diseases is a specialized field and laboratories that traditionally have dealt with terrestrial animal diseases may need to develop specialized expertise and materials to deal with aquatic animal diseases. Many of the components of the terrestrial animal disease diagnostic laboratory can, however, be applied to aquatic animal diseases. The pathology, histopathology, bacteriology and virology components of the terrestrial diagnostic laboratory are relevant to many, but not all aquatic animal diseases. Few aquatic animal diseases show pathognomonic macroscopic signs of infection by which a definitive diagnosis can be made. Morphological pathology, including direct light microscopy, histopathology and electron microscopy, is therefore an important and essential component of the diagnostic investigation of aquatic animal diseases. Standard laboratory culture methods are applied to viral, bacterial and mycotic pathogens, particularly those of finfish. Increasingly, molecular techniques are applied for detailed identification of pathogenic organisms and provide the possibility of a more rapid diagnosis. Virus isolation is still the gold standard for the diagnosis of many aquatic viral infections of finfish. These methods are often disease specific, and laboratories need to develop the tests appropriate to the aquatic animal health needs of their country. The laboratory isolation of finfish viruses is done on pathogen-specific tissue cell lines. An appropriate variety of tissue cell lines need to be sourced by laboratories intending to offer virus isolation tests. Relevant viruses for positive controls need to be sourced and maintained as well as the respective antisera.

The type of sample material depends on the species, life stage and size of the target animal, and the epidemiological situation. It is influenced by the objective of the diagnostic testing, whether for the detection of overt disease or for targeted sampling (OIE, 2015). A large amount of information can be gleaned from histological examination, and this technique is often recommended as an initial screening method and where abnormal disease or mortality occurs (OIE, 2015). Electron microscopy and molecular techniques may be needed to confirm pathogen identity.

Details of relevant diagnostic methods for the OIE-listed diseases of aquatic animals are regularly updated in the OIE Manual of Diagnostic Tests for Aquatic Animals (OIE, 2015), and laboratories should consult the recommended diagnostic techniques for specific pathogen confirmation and disease surveillance. The manual also provides important information on the quality management in veterinary laboratories and the principles and methods of validation of diagnostic assays for infectious diseases (OIE, 2015). Diagnostic techniques employed for the examination of material from the three major groups of OIE-defined aquatic animals, finfish, crustaceans and bivalves, differ somewhat. Crustacean viruses are not routinely isolated, limiting the use of virus-culture-based assays in the diagnosis of viral diseases of crustaceans. Antibody-based tests are precluded from both crustacean and molluscan diagnostic techniques due to the inability of crustaceans and molluscs to produce antibodies (OIE, 2015).

Diagnostic techniques appropriate to OIE-listed finfish diseases include (OIE, 2015):

- virus isolation on tissue cell cultures;
- serology;
- direct microscopy;
- histological techniques;
- electron microscopy; and
- molecular techniques for confirmatory testing and diagnosis.

Diagnostic techniques appropriate to OIE-listed crustacean diseases include (OIE, 2015):

- gross and clinical signs;
- direct bright-field, phase-contrast or dark-field microscopy with whole stained or unstained tissue wet mounts, tissue squashes and impression smears; and wet mounts of faecal strands;
- histology of fixed specimens;
- bioassays of suspect or subclinical carriers using a highly susceptible host (life stage or species) as the indicator for the presence of the pathogen;
- transmission or scanning electron microscopy;
- antibody-based tests for pathogen detection using immune sera polyclonal antibodies or monoclonal antibodies; and
- molecular methods (including sequencing where appropriate for strain determination).

Diagnostic techniques appropriate to OIE-listed bivalve diseases include (OIE, 2015):

- macroscopic examination;
- histological techniques;
- transmission electron microscopy; and
- molecular methods.

6.5 Emergency Response

Emergencies can arise rapidly with the incursion of an exotic disease, a change in prevalence or behaviour of an endemic disease, or the emergence of a previously unknown disease (Arthur *et al.*, 2005). The well documented devastating impacts of diseases, such as koi herpesvirus and EUS in fish, the shrimp diseases (white spot syndrome and Taura syndrome) and abalone viral mortality, highlight the need for emergency preparedness (Mohan, Chinabut and Kanchanakhan, 2008). Emergency response is a critical element of risk management taking into account farm-level actions, transboundary movement of pathogens, misuse of chemicals, food safety, and compliance with regional and international obligations (Mohan, Chinabut and Kanchanakhan, 2008). To deal with an emergency, relevant policy, procedures and regulations must be in place, and adequate human, infrastructural and financial resources must be available. The roles and responsibilities of relevant stakeholders must be specified, and operational procedures should be clearly defined, taking into account relevant risk analysis principles (FAO, 2007a). Where there is limited capacity to deal with an aquatic animal emergency within a country, links need to be established to international consultants and organizations that have the relevant expertise. For example, after the first outbreak of EUS in Southern Africa in 2006, both private consultants (Andrew *et al.*, 2008) and an FAO emergency response team (FAO, 2009) were tasked by the affected countries to help investigate and advise on the outbreak. A similar emergency task team of relevant specialist consultants, organized by the World Bank, assisted during the devastating outbreak of white spot syndrome in Mozambique during 2011 (World Bank/RAF, 2013). In 2002, an Emergency Disease Control Task Force organized by the Network of Aquaculture Centres in Asia and the Pacific (NACA) investigated a suspected koi herpesvirus disease outbreak in Indonesia (Bondad-Reantaso, Sunarto and Subasinghe, 2007). More recently, a Rapid Deployment Team through the FAO's Crisis Management Centre-Animal Health (CMC-AH), in 2011, made a quick assessment of an unknown disease (later identified as AHPND) affecting cultured shrimp of the Mekong Delta provinces of Vietnam (FAO, 2013).

A rapid and timely response can reduce the potential catastrophic impacts of disease incursions and can create strong awareness on the importance of early detection and rapid response to aquatic animal epizootics both at national and regional levels (Subasinghe and Bondad-Reantaso, 2008).

National emergency reporting systems should be in place for suspected and confirmed outbreaks of disease and should constitute an important component of a biosecurity plan. The flow of critical information to national authorities tasked with aquatic animal disease control is essential to the successful implementation of early warning systems, contingency planning, and the ability to mount an effective early response, all of which are vital to the outcome of an emergency disease situation.

6.6 Reporting

Close collaboration between neighbouring countries is essential in managing aquatic animal disease risks. The rapid and transparent sharing of information on new disease occurrences, the spread of existing epidemic diseases to areas with shared waterbodies, and information relating to control measures can provide valuable early warning to allow countries to implement an appropriate response (Subasinghe, McGladdery and Hill, 2004). Reporting of disease status and outbreak events should be transparent and include risk communication strategies that facilitate an open and active interchange of information among all stakeholders, with the aim of promoting public trust and confidence in regulatory decisions and control measures (FAO, 2007a). Such information should be shared among respective competent authorities, responsible government agencies, local, district, provincial or regional management offices, laboratories and scientific research institutions, and industry associations (Subasinghe, McGladdery and Hill, 2004). Membership of international and regional intergovernmental organizations with a mandate for aquatic animal health management obliges countries to report surveillance data on occurrence and prevalence of regulated and emerging aquatic animal diseases timeously, accurately and conscientiously, as appropriate (Subasinhge, McGladdery and Hill, 2004).

To ensure transparency of aquatic animal disease situations on a global basis, OIE member countries undertake to report on aquatic disease outbreaks and to notify the presence or absence of OIE-listed diseases. Submission of data to the OIE is performed through the World Animal Health Information System (WAHIS), and submitted official information is made immediately available to member countries through the World Animal Health Information Database (WAHID) Interface (www.oie.int/wahid). On a regional basis, there are a number of other international reporting systems. Asia-Pacific countries report to the Network of Aquaculture Centres in Asia-Pacific (NACA)/FAO and the OIE Quarterly Aquatic Animal Disease Reporting System. North Atlantic countries report to ICES. European countries report to EIFAC (Subasinghe, McGladdery and Hill, 2004). Documented field observations, research data, scientific publications and other sources of information are used to complement surveillance data. Reports to the OIE are usually prepared by the national competent authority of each country and are submitted to the OIE by the national delegate (usually the chief veterinary officer) of the OIE member country. The OIE Aquatic Code obliges member countries to submit notifications to the OIE within 24 hours of confirmation of any of the following events:

- a first occurrence or recurrence of any OIE-listed disease in a country or zone of the country if the zone or country was previously believed to be free of that particular disease;
- an OIE-listed disease that has occurred in a new host species;
- an OIE-listed disease that has occurred with a new pathogen strain or in a new disease manifestation;
- there is potential for international spread of an OIE-listed disease;
- an OIE-listed disease has a newly recognized zoonotic potential; or
- if in the case of an emerging disease or pathogenic agent not listed by the OIE, there should be findings that are of epidemiological significance to other countries.

Monthly reports summarizing the disease situation are submitted until the disease has been eradicated, or the situation has been brought under control.

FAO's Quarterly Early Warning Bulletin, a result of a collaboration between the Emergency Prevention System (EMPRES) for transboundary animal and plant pests and diseases and food safety threats, the Global Information and Early Warning System (GIEWS) and the Food Chain Crisis Management Framework (FCC) (www.fao.org/food-chain-crisis/early-warning-bulletin/en/), integrates information on threats to the food chain and food security for the three months ahead. Aquatic diseases are included in the bulletin.

6.7 Documentation

Information on aquatic animal diseases may be documented in many formats, ranging from handwritten farm records to local, regional and national computerized databases that can be managed by linking various relevant government agencies and diagnostic laboratories (Subasinghe, McGladdery and Hill, 2004). The competent authority of a country is responsible for documentation of data that is regulatory in nature and is required for the establishment and maintenance of zones for diseases of national and trade concern. Surveillance data should be regularly updated on a country's national database where the data can be accessed by policy makers, the competent authority and other stakeholders (Subasinghe, McGladdery and Hill, 2004). It is in the public interest that information relating to biosecurity hazards and their management is made available by competent authorities on an ongoing basis (FAO, 2007a). Nonregulatory data may be documented in scientific research papers, industry newsletters and in farm records from where relevant industry stakeholders can access the information. It is essential that farming operations document data relevant to disease incidence and prevalence as part of the farm-level biosecurity plan. Where third-party guarantees on disease status are required, this forms an important component of the auditing process (Palić, Scarfe and Walster, 2015). Under certain circumstances, disease prevalence reporting may be seen as confidential by industry stakeholders. In such cases, the confidentiality of individual and corporate client information may need to be respected where such information falls outside of regulatory requirements.

6.8 Aquatic Animal Health Services

The confidence that trading partners place in a country's aquatic animal health status and the ability of a country to provide guarantees required by international animal health certificates is a reflection of the aquatic animal health services of a country. The quality of a country's aquatic animal health services depends on a number of factors, including the fundamental principles of an ethical, organizational, legislative, regulatory and technical nature to which OIE member countries have an obligation to conform, regardless of the political, economic or social situation of their country (OIE, 2016). Details of these fundamental principles are presented in the OIE Aquatic Animal Health Code (OIE, 2016). Each OIE member country has the right to request an evaluation of the quality of another member country's aquatic animal health services where an initiating country is an actual or prospective importer or where a review of sanitary measures relating to trade from the exporting country is a component of a risk analysis process (OIE, 2016). Such evaluations follow procedures established by the OIE.

6.9 Role of the Private Sector

Official aquatic animal health services provided by state veterinarians and technologists encompass the surveillance and regulatory aspects of aquatic disease management. The provision of aquatic veterinary services is a specialized field, as is the provision of official regulatory services, and effective biosecurity management in some instances requires both official and private-sector expertise (Palić, Scarfe and Walster, 2015). To ensure effective management of aquatic biosecurity, aquaculture farmers should be encouraged to make use of both private and official aquatic animal health services. In countries with limited resources or where official aquatic animal health services are poorly developed, private-sector aquatic animal health specialists can play an important role in supporting the competent authorities tasked with biosecurity zoning. By applying sound biosecurity plans to compartments and zones within a country, private-sector specialists are able to provide a significant advantage to aquaculture farmers while at the same time creating a favourable environment for third party or official auditing and certification. Farmers need to realize that disease and infectious hazards change and evolve over time. An effective biosecurity plan needs to be regularly revised to remain up to date with relevant diseases and to remove procedures that may have become obsolete. Unless the official veterinary services of a country have the expertise and capacity to provide this service, aquaculture farmers should make provision to fund private-sector specialists to assist with the task.

Application of Zoning and Compartmentalization

Zoning and compartmentalization are an integral part of biosecurity measures implemented by countries and aquaculture industries to contain, control and eradicate contagious diseases. They can be applied in many facets, but the implementation requires development of appropriate diagnostic, surveillance and reporting capabilities within a specific regulatory framework (FAO, 2007b). In the case of an outbreak or suspicion of an outbreak of a disease for which control measures are in place, zones or compartments define the geographic area to which restrictions to the movement of aquatic animals and other control measures are applied. Within the framework of zoning and compartmentalization, certification of disease status and freedom from specific pathogens provide further measures to prevent spread of disease (Håstein *et al.*, 2008). Where eradication is not possible or practical, containment and control within zones provides an alternative means of limiting the impact of a disease (FAO, 2007b). Establishment of free zones, based on ecological, geographical, hydrological and climatological barriers and meeting the specific technical requirements for disease control, as defined by the OIE Aquatic Animal Health Code (OIE, 2016), will restrict the impact of disease to infected zones and allow unhampered movement of aquatic animals from free zones.

Effective management of zones requires that animals may be moved only from zones where the same or fewer pathogens are present than in the receiving zone, or between zones where none of the specified diseases occur. Restrictions are justified to prevent movement from zones where diseases occur that are absent from the receiving zone (FAO, 2007b). Where zones based on entire river systems and coastal areas involving more than one country are affected by a contagious disease, neighbouring countries will benefit from regional zoning (FAO, 2007b).

In the case of salmonids, the breeding cycle of rainbow trout in the Northern Hemisphere is offset by six months from that of the Southern Hemisphere. South Africa, for example, has a salmonid industry that dates back to early colonial days, and trout hatcheries have traded in live salmonid ova with the Northern Hemisphere for many decades, culminating with the annual export of over 40 million eyed ova during the latter part of the last century. As the breeding cycle of salmonids in the Southern Hemisphere is six months apart from that of the Northern Hemisphere, it is beneficial for farmers in both hemispheres to supplement their production through an additional stocking of young fish during the time of year when in the respective hemisphere hatchery stock would be unavailable. Trout farmers in South Africa, to this day, import their so-called summer eggs from Northern Hemisphere farms, and the Northern Hemisphere provides a good market for ova produced in the Southern Hemisphere. South Africa has had effective legislation governing the introduction of exotic salmonid diseases. The importation of eyed salmonid ova is only permitted where guarantees of freedom from specific salmonid diseases can be provided by the authorities of the exporting country. As an additional measure, official sampling of imported ova takes place at the port of entry. Such imports remain under quarantine and are traceable until the results of the testing have become available. Over this long time span, serious salmonid diseases have not been introduced into South Africa despite the frequent importation of eyed salmonid ova.

The production of SPF trout ova for international trade provides an example of the implementation of the concept of compartmentalization. South Africa, for example, has no national surveillance data on the prevalence of OIE-listed salmonid diseases. Yet a number of rainbow trout hatcheries in this country are registered as export hatcheries with the country's competent authority. Export hatcheries, managed as a compartment, need to comply with biosecurity measures reflecting the requirements of the importing country and stipulated by the relevant competent authority tasked with issuing the disease-status guarantees for export. In this manner, relevant disease-status guarantees that meet the requirements of importing countries can be provided by the competent authority allowing export of salmonid ova from South Africa to countries such as those in the European Union.

For a competent authority of a country to provide guarantees of freedom from specific diseases, the source population of aquatic animals needs to be subjected to disease surveillance testing. Such testing must be done at a statistically relevant level of confidence. The OIE recommends working at the statistical 95 percent confidence level of detecting a disease agent with a prevalence of 2 percent or lower (OIE, 2016). This principle has been applied to trout hatcheries exporting ova. In the case of South Africa, depending on the relevant province, implementation of the farm biosecurity plan and collection of surveillance samples is done either by a state veterinarian with aquatic animal disease knowledge or jointly by a state veterinarian and a private-sector aquatic animal health specialist appointed by the hatchery owner. The laboratory testing of the samples is performed by an accredited national laboratory. Provided the hatchery has been approved by and is registered by the competent authority, the issuing of export certificates reflecting disease-status guarantees is done by the state veterinarian responsible for the hatchery.

The koi industry in South Africa has been affected by koi herpesvirus with frequent outbreaks among the koi collections of hobbyists and farmers since 1998. Most of these go unreported. As South Africa has no official surveillance data on either koi herpesvirus (KHV) or rhabdovirus carpio, the causative agent of spring viraemia of carp (SVC), koi producers wishing to export fish to certain international markets need to provide SPF certification to meet the requirements of the importing country. Koi farms based on protected water supplies and conforming to the requirements for registration of export farms can be managed as a compartment in order to export SPF fish (Huchzermeyer and Colly, 2015). Such farms need to maintain a closed population of fish, with introductions being allowed only from sources with a certified disease-free status of equivalent or higher standard. The fish population on such a farm is subjected to a statistically valid level of testing for KHV and rhabdovirus carpio for a mandatory of four tests at six-month intervals (OIE, 2016). After the initial two-year testing period, the competent authority is able to issue guarantees of freedom from KHV and SVC, and fish can be exported. In the absence of wider surveillance, and establishment of KHV and SVC free zones, the routine of six-month testing continues as long as a farm remains registered as an export facility and continues selling SPF fish. As in the case of trout export hatcheries, both the state veterinarian and a private-sector aquatic animal health specialist jointly implement, maintain and monitor the biosecurity measures relevant to the conditions for approval and registration of an export fish farm. In the case of koi, the private-sector specialist is responsible for collection of surveillance samples. The accredited national laboratory in South Africa is only able to test for SVC, and a private-sector accredited laboratory is used for analysing the KHV samples. Provided all tests are negative and all the conditions of the importing country have been met, the relevant state veterinarian will issue the disease status guarantees.

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Annex 3. Aquaculture Certification and Zonal Management

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ABSTRACT

There has been concern among academia, consumers and nongovernmental organizations (NGOs) that certain forms of aquaculture, mainly high-value species for export, are environmentally unsustainable, socially inequitable, raise issues of animal welfare and have issues about food safety. Certification schemes addressing the sustainability of aquaculture production have emerged to address these concerns. However, these certification schemes deal with single production units, and have not, until recently, developed mechanisms to validate the performance of groups of farmers or the management of zones of farms.

As aquaculture continues to grow to meet global demand, governments and production industries must address the need to effectively manage the key resources that aquaculture relies upon, most notably water, and minimize the risk of disease impacts. In order to maintain supplies, improve food safety, increase traceability and develop greater social equity, it is in the interest of the market to promote mechanisms to encourage this resource-level governance. Managing the risk of disease transfer between farms and developing mechanisms to control the spread of disease are key components of emerging zonal management certification. Early industry-led examples of coordinated action from Scotland, the United Kingdom of Great Britain and Northern Ireland and Surat Thani province in Thailand are discussed. Group certification and zonal management certification both enshrine the development of management bodies as a core component. These producer organizations or zone managers carry the burden of compliance on behalf of producers, but also guide and support them to better overall performance. The need for certification approaches that more effectively engage small-scale producers in supply chains is also briefly discussed.

NOTE ON SCOPE AND DEFINITION

This document is a chapter in a wider document on aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture and should be read in that context. The term "zonal management" is used in this chapter because it is the terminology that certification developers and the supply chain use to refer to the need to introduce and deliver aquaculture management at the resource level. Zonal management currently includes processes to develop effective industry institutions and voluntary and compulsory management of shared water resources, disease risks and feed supplies. At present, the market has not introduced into zonal management the social licence consideration included in the ecosystem approach to aquaculture; also the term "area

1 The views expressed in this annex are those of the authors and do not necessarily reflect the views or policies of FAO or the World Bank Group.

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management" under "the ecosystem approach to aquaculture" and "zonal management" are generally interchangeable.

INTRODUCTION

Future projections for demand for aquaculture products predict that there is a need to double production before 2030. This is an opportunity for aquaculture producing countries that requires both government and private investments in aquaculture management systems. The investments can be used for aquaculture production infrastructure and operations, for enterprises along the value chain (supplying inputs such as seed and feed and delivering product to markets), and for supporting services, processes and institutions at the sector level. Future demand for aquatic products is expected to provide business opportunities across the sector, but risks within the framework in which producers operate must be effectively governed. Opportunities for the continued (and increasing) involvement of small-scale producers in these supply chains need to be developed.

AQUACULTURE CERTIFICATION

The rapid expansion of aquaculture production and the change from being mainly locally produced and consumed towards internationally traded products have raised concern among academia, consumers and NGOs that certain forms of aquaculture, mainly shrimp and marine finfish production (with salmon as the one species in particular focus), are environmentally unsustainable and socially inequitable, and that products are not safe for consumers (Corsin, Funge-Smith and Clausen, 2007).

Certification is understood to be the procedure by which a body or entity gives written or equivalent assurance that the activity under consideration conforms to the relevant standards. Impartial certification based on an objective assessment of relevant factors provides assurance to buyers and consumers that a product comes from an operation (or operations) that conforms to the certification standards. Both national and voluntary certifications currently focus on farm-level performance only, with limited consideration of zonal management elements. To date, the only zonal requirement has been for salmon farms wanting Aquaculture Stewardship Council (ASC) certification to engage in area management systems if one exists (ASC, 2012). However, some examples specifically focused on zonal management are starting to develop, as discussed below.

There are a number of international, regional and national certification schemes that focus on confirming responsible management by individual farms. In Asia, most of the main exporting countries, including China, Indonesia, Malaysia, Singapore, Thailand and Vietnam, have their own national schemes, as well as producers who comply with international certification schemes. Certification schemes are a way for consumers and retailers in developed markets in Europe, the United States of America, Japan and larger Asian cities such as Singapore, Hong Kong and some capitals of the countries that are members of Association of Southeast Asian Nations (ASEAN) to communicate their demands to producers in other regions. There is a need for certification schemes to understand both consumer concerns and requirements, and at the same time ensure that producers are able to produce sufficient volumes at the quality demanded. Sometimes a knowledge gap exists between what consumers know about the production and what they ask for. The certification schemes are not only created or driven by consumers, but they are often used by retailers to differentiate among themselves (Belton and Little, 2009; Belton *et al.*, 2010).

Whereas the international certification schemes have high confidence among consumers but perhaps are seen as a burden by the producers, the regional and national certification schemes or the good aquaculture practices (GAPs) and better management practices (BMPs) are more focused on communicating the current good practices by producers, and working with producers first and secondarily looking at consumer concerns. In some cases, these national schemes are seen as validating the performance of producers in a way that allows them to meet their bottom line rather than encouraging change in response to customer requirements.

VIETGAP—An example of a current national certification programme.

The overall strategic principles of the aquaculture VietGAP are that aquaculture must ensure quality and food safety by complying with the current standards and regulations of the state and the provisions of the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO). Aquaculture must ensure aquatic animal health and living conditions for farmed animals by creating the best conditions for health, reducing stress, limiting the risk of disease, and maintaining good farming environments in all stages of the production cycle. Additionally, aquaculture activities should be done according to detailed plans and limit negative environmental impacts, according to the regulations of the state and international commitments. There must be an evaluation of the impact on the environment of the planning, development and implementation of aquaculture.

VietGAP looks not only at the production steps of the aquaculture value chain, but also looks at the other links in the value chain (e.g., breeding facilities, processing), and is therefore one of the ASEAN national programmes that takes a value chain approach; most other member states only look at the production steps.

The VietGAP programme, together with other certification programmes and a general focus on prudent use of veterinary drugs to treat aquatic animal diseases, managed to bring down the use of antibiotics and improve aquatic disease management practices, greatly reducing the number of antimicrobial alerts from the main importing markets in the period from 2004–2013 (RASFF—the EC Rapid Alert System for Food and Feed, 2016). In particular, the larger, more commercial farms that gained certification quickly managed to reduce the use of antimicrobials. However, in the period from 2013 through the end of 2015 there was a dramatic increase in the number of alerts, which could be related to the increased problems with diseases. It might be that focusing on individual farm certification is not enough for the industry, but that a wider focus on zonal management and certification is needed to limit and prevent the spread of diseases (for more information on VietGAP, see www.quacert.gov.vn).

According to Bush *et al.* (2013), only 4.6 percent of the world aquaculture production is currently certified. This is, given the huge attention certification schemes are given, quite a low number, but the number is increasing. It is easier for larger-scale, better capitalized production units to deal with infrastructure, record keeping and administrative requirements demanded by certification. It is often observed that smallholder farmers are excluded from markets that require certification, even when external support such as donor-funded projects, governments or NGOs have tried to increase their involvement. It has been suggested that cluster certification systems or group certification that specifically addresses problems of smallholders can increase their likelihood of participation (Kassam, Subasinghe and Phillips, 2011), although the market is only starting to utilize these approaches as the supply from larger farms becomes limiting. One way of including more of the production in certification schemes could be to include zonal management in more of the schemes.

Kassam, Subasinghe and Phillips (2011) also mention the need for an international certification that recognizes risk reduction by smallholder farmers, something the world is still waiting for. However, progress is being made on the certification of aquaculture zones, which makes sense not only from a social point of view, potentially increasing market accessibility for small-scale farmers, but also makes good sense from an environmental and production point of view. In particular, in Asia, by far the majority of aquaculture production comes from smallholders, and the accumulated environmental impact from this production is largely unknown, especially since many smallholder farms are not licensed. If certification recognized and rewarded local efforts to introduce carrying capacity-based measures for establishing production volumes for both new and existing areas, or if aquatic animal health programmes encouraged farms to coordinate management and treatment approaches and openly report disease incidence, improvements to overall sustainability would benefit all producers, increasing market access and reducing risk for smallholder farmers. The challenge in this approach is who would take on the role of "zone manager."

ZONAL MANAGEMENT

There are some examples of industry taking a lead in the development of good management approaches at the farm and zonal levels, often in response to external pressure, but also to respond to disease challenges faced by the industry. The Scottish salmon industry developed a Code of Good Practice that is adhered to by 95 percent of the industry, verified through audits, and has become a requirement for membership of producer organizations. Compliance with the code is not demanded by the market, although it was developed in part to demonstrate to the market the responsible approaches taken by the sector. It also includes requirements to be active in area management processes (see www.thecodeofgoodpractice.co.uk), something not typically included in current voluntary standards. The Surat Thani Shrimp Club developed disease notification processes and local groupings of farmers in the hope of reducing disease risk. Success has been mixed, but is widely recognized as a leading example of voluntary coordinated action between producers (Boromthanarat and Nissapa, 2000; Yamprayoon and Sukhumparnich, 2010).

The Sustainable Fisheries Partnership has been working on a bottom-up zonal management approach in several Southeast Asian countries and in China that has shown that there is significant positive value in farmers developing both formal and informal communication and representation mechanisms within a zone or group (www.sustainablefish.org and www.hntsa.org). Building trust among producers strengthens internal management of the industry, but an effective multistakeholder entity that involves feed companies, processors, hatcheries and technical support/input suppliers can also speak with more confidence when representing a unified industry with outside stakeholders from government, other industries or the market. Having such a producer organization also enables the market to communicate market requirements more effectively to a whole industry, meaning changes can happen more quickly, benefiting everyone once trust has been built. These projects have had varying degrees of market support and are discussed in more detail as examples elsewhere in this publication.

These examples highlight the value of the private sector initiating collaboration among multiple industry stakeholders. The added value of these processes was the strengthening of producer groups to become effective representative organizations that can guide members and engage with governments, NGOs and other stakeholders. But the aquaculture sector has been short on such examples and to answer the concern about irresponsible aquaculture production, governments and markets developed farm-level certification requirements for food safety and aquatic animal health, subsequently adding environmental and social issues. Some of these processes have been government driven, whereas others have been market driven, but all have focused on improving performance on individual farms.

GROUP CERTIFICATION

Two different approaches to certification are currently considered within the area of zonal management. As a proxy for full zonal management, the market is engaging in group certification, particularly as a mechanism to bring more products from small-scale producers into the market without the need for changes to the overall sector management regime required in zonal management—or the need to develop a standard at a simpler level that would address the reduced risks typically posed by small-scale producers. Many of the standards are developing group certification mechanisms, following on from GLOBALG.A.P., which was the first international standard and which also delivered pilot projects, for example, with pangasius producers in Viet Nam. GLOBALG.A.P. has had great success with its group certification processes for agricultural crop farmers. The Global Aquaculture Alliance (GAA) is finalizing a group certification standard and ASC is in the late stages of drafting a standard. At the heart of group certification, there is still a need for each farm to fully comply with individual farm-level certification requirements. There is an additional obligation for an internal quality control process within the group to ensure each farm is in compliance, which reduces the requirement for every farm in the group to be visited by an auditor in each certification period, and therefore reduces overall auditing costs for the group. The auditor will instead look for evidence that the internal control system is operating effectively and will visit a sample number of farms each time certification is renewed, eventually visiting all farms over a number of renewal cycles. In group certification, the farms do not all have to be located in the same area, although they have to be within reasonable travelling distances to be effectively managed. Groups also do not need to be constituted from all the farmers within a specific area. This is an important distinction from zonal management, because although increased collaboration between farms is a requirement of zonal management, group certification does not require those farms to be in geographically contiguous zones or for a majority of farmers from a specific zone to be involved. So far, for aquaculture group certification, the groups are dispersed suppliers to particular processors that become the certification applicant, whereas in agriculture the certification applicant is more commonly a farmer cooperative. Details of what is required for effective group certification are available from the standard demanded by the market.

ZONAL MANAGEMENT CERTIFICATION

Zonal management certification, however, requires the industry to look at aquaculture management from a different perspective, taking into account the need for resource-level management, not just multiples of farm management. At the request of the market, the GAA is currently leading the development of a new zone management standard and certificate that it plans to offer under its Best Aquaculture Practice (BAP) certification programme (Global Aquaculture Advocate, 2014). BAP is already widely recognized for a range of standards covering farms, processing plants, feed plants and hatcheries. Other international voluntary aquaculture standards including ASC and GLOBALG.A.P. are involved in the multistakeholder zonal management standard development process. The standard will initially focus on biosecurity area management, but it is expected that environmental and social components will be added to the standard as market demand increases. At the heart of the standard is the need for a "zone manager"—an entity or a person who will take responsibility for ensuring that a zone management system is developed and followed by all producers within the zone. A competent disease control specialist, likely a veterinarian, needs to validate that the scale of the zone proposed and the measures to be followed by farms offer effective disease control. The programme requires that the majority of farms within the zone are active participants in the zone management process and follow farm-level requirements within that process, but not all farms need to be individually certified to all the requirements of current farm-level certifications. This means that small-scale producers can more easily be part of the programme. The programme will provide business-to-business reassurance. The zonal programme is in the pilot-testing phase, working with producers in Canada, Chile, China, Honduras, Ireland, Thailand and the United States of America where interest has been shown. Producers in Canada, China and Honduras are furthest in the process. There are some indications that these zonal certification programmes will significantly lower the risk for the aquaculture industry in these zones and hence make aquaculture more attractive to the large amount of investors who are looking for suitable investment opportunities within the aquaculture industry (Hatanaka, Bain and Busch, 2005).

It is important that a zonal certification module or programme is in compliance with the FAO technical guidelines on aquaculture certification and addresses environmental, aquatic animal health, animal welfare and socioeconomics (WWF, 2007 and FAO, 2011). By covering these management requirements at the resource (zone) level rather than just at the farm level, certification should be more confident in making claims of verifying sustainable management—rather than the current approach of claiming "responsible" management.

CHALLENGES AND OPPORTUNITIES FOR ZONAL MANAGEMENT CERTIFICATION

Aquaculture certifications are typically market-driven approaches that certify the performance of particular producers. The underlying assumption in most certifications is that the legal framework takes care of the issues considered in zonal management (and the ecosystem approach to aquaculture). However, in most countries, the legal framework has not been based on approaches like carrying capacity and epidemiology, and the industry is often not effectively pulled together and represented by producer organizations. In fisheries management certification, the validation of the effectiveness of the legal framework to manage fisheries is a specific requirement. For fisheries management certification, the legal framework is understood to be vital to the long-term availability of products and therefore of critical interest to the market. Aquaculture continues to supply increasing volumes of products to the market despite many countries not having effective zonal management regimes. The challenge will come once supplies are limited because the regulatory framework is not ensuring sustainable management at the resource level (e.g., when production crashes because of uncontrolled disease outbreaks or when water quality rapidly deteriorates causing mass fish kills). The dialogue around aquaculture, however, continues to talk of substantial production growth even with a "business as usual" approach to regulation and management. This is placing a dangerous reliance on good performance at the (multiple) individual farm levels rather than the much needed improvements in resource-level governance. The market, through the use of mechanisms such as zonal management certification, should drive the necessary improvements before—not once—supplies become severely constrained or reputations are at risk. But governments and larger-scale producers must also take action nationally, now, to protect their rapidly developing industries from the inevitable collapses that come from intensified production practices that are reliant on natural resources severely lacking in effective management (Hall *et al.*, 2011). The burden cannot be put on the shoulders of small-scale producers alone through group or zonal management certification.

Developing effective industry associations (whether part of a group or zonal certification) will also have a benefit for the wider social acceptance of aquaculture. Effective guidance and management of multiple producers to deliver responsible practices will enhance the overall understanding of non-aquaculturists to the value of producing food this way. Effective producer organizations also provide the industry with a coherent voice to counter criticism. A confident industry, within a well-regulated environment, is also more likely to positively engage with detractors and regulators rather than retreat into defensive positions that further distance opposing views.

The formation of groups and the internal control systems that are demanded by these certifications enable improvements in traceability and food safety. Full zonal management can provide the market with further confidence around traceability and food safety when all producers within any given zone are licensed—and therefore identifiable—and all operating according to best practice that means no single farm is posing an unmanaged risk to all its neighbours; this should significantly reduce the need for unnecessary and non-prudent use of chemicals to treat disease outbreaks, leading to safer food for consumers. Where emergency disease response plans are developed and a clear plan of action is agreed upon between producers, regulators and scientists, there is increased likelihood of further reductions in the unnecessary use of chemicals, improving food safety, environmental quality and industry reputation (World Bank, 2014). A coordinated demand from an industry for sustainable feed ingredients also helps to drive improvements in traceability of marine ingredients from legal, regulated and managed sources.

CONCLUSIONS

Zonal management within the context of both regulation and certification schemes has not previously received much attention. The focus on farm-level best practices and the established certification processes that validate performance at the farm level offers a challenge to zonal management and zonal certification to demonstrate long-term value to an ever-increasing aquaculture industry.

Group certification and zonal management certification offer mechanisms to enable small-scale producers to enter more formal supply chains at a potentially lower price, but it still requires them to commit to what is usually an improved level of performance. It also requires neighbours to collaborate. Both group certification and zonal management certification are opportunities for smallholders, but it is important to emphasize that the standards for these schemes are as stringent as for individual certification schemes. There is still space in the market for a specific standard aimed at recognizing the lower levels of risk reduction needed from small-scale producers, therefore keeping them as suppliers to the ever-growing demand for certified seafood.

A key component of group and zonal management certifications is the formation of management bodies that coordinate performance among member farms. These producer organizations carry the burden of conformity on behalf of the producers, but still require best practices at the farm level. The idea of strong producer organizations should be adopted across the industry as a mechanism for improving the reputation of the industry, reducing disease risk and environmental impacts, and increasing food safety and traceability—whether or not it is part of a certification process.

Group certifications have developed in part because it has become increasingly difficult for the market to source all products they need from larger already individually certified farms. It is also increasingly obvious to the market and producers that certified farms are often connected through shared resource use to uncertified producers who pose risks such as disease transfer or water supply quality reduction that cannot be addressed through current farm-level certifications. An approach that addresses risks at the resource (zonal) level is needed, especially as aquaculture production is forecast to grow significantly to fulfil market demand. Sustainable intensification or blue growth will require action from governments and demand from markets for resource-level management.

A continued push for scaling-up production as rapidly as possible with an almost-exclusive focus on farm-level best practices will bring continued disease and environmental challenges that affect the reputation of aquaculture, negatively impact the livelihoods of millions of people, disrupt supply chains, increase prices and slash national productivity. There is an urgent need for better governance mechanisms within the private sector as well as a government that acts on the realization that farms do not operate in isolation.

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Annex 4. Tools and Models for Aquaculture Zoning, Site Selection and Area Management

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BACKGROUND AND OBJECTIVES

Decision makers, faced with data and output from spatial tools, often lack a basic understanding of spatial modelling technologies, including their limitations and strengths and the kinds of questions that can be addressed by them that would allow for operational use and informed decisions. The same range of understanding is required to decide on the level of adoption of additional tools and models that are needed to analyze and address aquaculture zoning, site selection and area management options. Expanding awareness and realizing the analytical potential of tools and models of all types are key to making better informed decisions.

Success in application of tools and models depends on the assessment required, applications available, finances applied and capacity of users to apply them appropriately. With regard to the latter, capacities vary among and within countries, so there is a need to match training and technical support to the capacity to absorb them. The range of tools and models is relatively large and growing, including overall governance approaches, spatial analysis and modelling, and ecosystem and site specific models; and vary from very simple to complex in application. Some require purchase and others can be obtained for free (Open Source). In essence, analytical techniques should be designed and delivered to match the need, and capacity of the users to apply the tools and models appropriately.

Investment on governance approaches, spatial tools, ecosystem and site specific tools and models should be made with a clear understanding of what should be accomplished with such application and in particular on the decision-support needs involved and the variety of stakeholder requirements that the tools can fulfil. Application of tools and models is part of the overall ecosystem approach to aquaculture (EAA), which in turn is primarily about people and collective interest to develop aquaculture in an environmental and people-friendly way. It is entirely up to aquaculture competent authorities, decision makers and analysts, as potential EAA implementers, to make sure that tools and models are used responsibly, in an appropriate manner that makes their application useful and effective.

The main objective of this annex is to provide an overview of tools and models that are applicable to aquaculture

1 The views expressed in this annex are those of the authors and do not necessarily reflect the views or policies of FAO or the World Bank Group.

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zoning, site selection and area management, of relevance to developing and developed countries.

This annex should be considered as a brief introduction and a reference. Additional reading and references have been selected under each subsection in this annex to allow for more thorough investigation on specific topics. It is not designed specifically to be read in sequence, and the reader is able to select the parts of interest, gain a brief understanding of the techniques, tools or models available, and undertake further reading where necessary. That specific tools, models and approaches are listed here and others not should not be taken as an endorsement or condemnation of a specific tool, model or product. The reader is advised to seek professional support where needed.

OVERVIEW OF THIS ANNEX

Chapter 2 of the handbook of this publication identifies a number of spatial tools and models to support aquaculture zoning, site selection and area management. Table 4, in particular, lists a substantive number of tools that can aid development of zoning for aquaculture, assist in the selection of appropriate sites, and support the design of area management plans. Such activities and tools can be carried out over different spatial scales: from regional, national areas, including exclusive economic zones (EEZs), local and site scale; and different temporal scales: from single production cycles, through multiple cycles, to long-term sustainable development for future generations.

In Annex 4, a brief description is given of some overall governance approaches that should be implemented to ensure aquaculture is developed in a sustainable manner using the EAA, supported by other tools and models, that help achieve the required aims of site zoning, site selection and area management. Under each subsection further reading is provided to support understanding, which may lead to further examples.

The annex is divided into three parts.

Part 1 includes a table that summarizes each of the ten case studies in this publication (detailed reports are available in Annex 5) to highlight the tools and models that have been applied within each. Each case study has a brief introduction on the background and context for the application of aquaculture zoning, site selection and/or area management, and a description of some of the approaches, spatial tools and models used to implement the zoning, area management and site selection activities undertaken.

Part 2 summarizes some of the critical requirements that will achieve good overall governance of aquaculture development. It includes short sections on strategic planning for aquaculture; the need for aquaculture specific laws and regulations; developing codes of conduct, codes of practice or best management practices; the application of spatial planning under the EAA and marine spatial planning. Use of the environmental impacts assessment and evaluation of carrying capacity are not strictly related to governance, but nonetheless provide the means by which site specific decisions are made by regulators when locating aquaculture farms, and are therefore included.

Part 3 provides a brief description of some of the tools and models used for aquaculture zoning, site selection and area management, and includes brief descriptions for some of the available cross-cutting computer models developed for this purpose, including the use of geographic information systems (GIS). This part also describes some of the tools and models listed in the case study table and some from the list in Table 4 in Chapter 2 of the handbook. It is not, however, an exhaustive listing of all available techniques, tools and models available worldwide.

Useful Definitions

Before reading this section, there are two useful definitions that require clarification. In this document:

Tool — has a very wide definition, and is considered as any legislative instrument (laws, regulations, guidelines), process (such as stakeholder engagement), computer model application (such as GIS, or computer models to assess impacts of aquaculture), or other approaches that can be used or be implemented to help and support the development of aquaculture; and the gathering, analysis and presentation of data to aid decision making.

Model — is considered a predictive tool, mainly developed by modelling specialists, using state-of-the-art equations to describe specific actions (e.g., fish growth), interactions (e.g., cage aquaculture wastes into the environment), and consequences (e.g., setting of local carrying capacity) of aquaculture. Models provide information to enable understanding of sometimes complex activity and interactions that would otherwise not be possible.

Outputs from models, by definition, cannot provide definitive "answers", but do support decision making by giving outcomes (e.g., species growth, aquaculture waste deposition, changes to water quality from aquaculture activity) that improve understanding. Models generally require calibration to local conditions and validation through data collection.

PART 1. CASE STUDY SUMMARIES

Spatial planning following the ecosystem approach for aquaculture is in the early stages of development internationally and reflects the need for this guidance document. Annex 5 of this document includes ten case studies, presented by the authors at the workshop in Izmir, Turkey, in 2015. These case studies provide an invaluable insight into the spatial planning development stage in each country, and include scoping, zoning, site selection and/or area management examples, focusing on the spatial planning processes and identifying the tools and models used as part of that development activity.

Table A4.1 summarizes the activity undertaken and the reasons behind the work undertaken, and identifies tools and models used in that development. The case studies summarized in Table A4.1 provide evidence that systematic assessment and activities that lead to a more coordinated spatially driven approach for aquaculture is gaining traction globally. Aquaculture expansion has often developed naturally, but in an uncoordinated way, such that environmental and other limitations have not been considered systematically to enable the appropriate allocation of zones for culture of fish and other species. Uncoordinated expansion is, by definition, unsustainable. Zoning, site selection and area management are not simply the "giving" of space for aquaculture. They require a systematic approach, including collection, analysis and mapping of data; and the use of models are increasingly being used to determine the best locations for aquaculture development that means aquaculture will be sustainable in the long term. Unrestricted aquaculture development has the potential to damage the environment, which is counter to the ecosystem approach.

The case study summaries describe the spatial planning activities undertaken in each country. Although the activities described are not necessarily examples of precise best practices, they do illustrate the application of systematic approaches to scoping, aquaculture zoning, site selection and/or area management, so that production can occur with the least impact on the environment while maintaining ecological and social carrying capacity. The processes implemented, however, offer a variety of means to achieve this.

TABLE A4.1. Summary of the tools and models used in ten case studies described in this document.

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
Brazilian aquaculture parks—fish farming and mariculture Zoning example	This case study is based on development of tilapia production in cages in aquaculture parks in the Castanhão Dam in the State of Ceará; and oyster and mussel production in marine aquaculture parks along the coast of the State of Santa Catarina. Aquaculture parks are designated areas for aquaculture cultivation in water owned by the federal state. Allocation of zones for aquaculture is conducted under Presidential Decrees and Inter-Ministerial Normative Instructions (INIs) that outline ministerial roles and responsibilities, guidelines for establishment of aquaculture parks, and procedures for implementation and issuing of concessions. Rules vary depending on whether an investor requests the development in a specific location or whether the government undertakes an assessment and makes suitable areas available.		
	Demarcations of aquaculture parks were designed using GIS to map exclusion areas, particularly environmentally sensitive sites, areas of port activity, other impediments planned by management plans, etc.; study of potential environmental conflicts as well as mapping of infrastructure, logistics (such as roads/market access) and local community organization analysis.	Mapping application of collected data through GIS (type unspecified), with data layers combined using a multi-criteria evaluation to determine best management areas and best locations within these areas to locate fish farms.	
	Impacts of aquaculture on physico-chemical parameters were assessed against defined standards and local water quality testing, with assessment of impacts on water quality in freshwater systems using a well-developed, but non-aquaculture specific model to evaluate water residence time and changes in phosphorus specifically.		Conservative application of a modified Dillon-Rigler model for use in reservoirs is used for freshwater environments to calculate carrying capacity. Allocation of a proportion of the overall phosphorus loading allocated to aquaculture (and for other uses and natural phosphorus loading) to retain the reservoir below an overall maximum concentration. It thus defines a maximum annual production of fish, the maximum daily amount of feed given, and the maximum daily load of phosphorus to the water column.
	Sites require an environmental permit, which is deemed difficult and complex to obtain, due to the time and costs involved. In general, permits are requested by small farmers who often lack sufficient funds to complete the process effectively.	Applied specifically developed social, environmental, economic and institutional sustainability indices, combined to give an overall index score, which determines overall sustainability of the site. Area is managed through a management committee comprising state, local and fish farmer officials.	

2 The full case study reports are in Annex 5.

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
Chile: The spatial planning of marine cage farming—salmon Area management example	In the early 1990s, after the establishment of salmon production, appropriate areas for aquaculture (called AAAs) were established, for 12 of the 15 states. These were established through dialogue at national and local levels but with no formal assessment on suitability. Since then, a rationalization process for AAAs has occurred, with improved digital mapping and the application of GIS to assess user and use conflicts, for example, and boundaries redrawn.		
	Following an outbreak of infectious salmon anaemia in 2007, work was undertaken to evaluate the mechanisms behind disease transfer, including hydrodynamic assessment using hydrographic models to evaluate water movement, risk analysis (disease risk analysis in particular, including epidemiological studies of disease transfer mechanisms), which lead to the establishment of aquaculture management areas (AAAs or AMAs; also referred to as neighbourhoods). Each AMA contains a number of group concessions for specific areas within the AMA, and each farm within the group concession area is licenced. AMA's coordinate treatment for disease (e.g., sea lice), has defined fallowing period when fish cannot be produced and limits on stocking density, for example.	The application of digital mapping and collation of data through a GIS system (unspecified), using a multi-criteria evaluation that establishes zones for specific activity and/or multi-use where the uses do not conflict, and maps potential user and use conflicts. AAAs are presented in the map viewer of SUBPESCA (www.subpesca.cl) supported by datumWGS-84, SAD-69, PSAD-56 or local datum graphics.	Application of hydrographic modelling and epidemiological studies over larger areas to define disease risk.
	In reality, often the AMAs are in close proximity, so the Chilean authorities undertook further hydrographic assessment and created macrozones for the specific purpose of containing disease outbreak. Each macrozone contains a number of AMAs, and a minimum distance of 5 km between macrozones is applied, set to create the disease break.	Macrozones are presented in the map viewer of SUBPESCA (www.subpesca.cl) supported by datum WGS-84 graphics. Neighborhoods, not available in the SUBPESCA map viewer, but for internal purposes of the authority they are presented supported by datum WGS-84 graphics. Licenses are presented in the SUBPESCA (www.subpesca.cl) map viewer supported by datum WGS-84. Uses GIS (type unspecified), to conduct regional assessments of use and user conflicts (fishing areas, ports, shipping movements, areas off-limits due to navy requirements or conservation requirements, etc.) to define suitable AMAs.	

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
		AMA management structure is established as a forum for overall management of the AMA. Within AMAs there is coordination of activities, including stocking and disease management.	
	Sites are established following an environmental impact assessment (EIA) procedure, including stakeholder and public consultation. Licencing is based on an assessment of carrying capacity, and specifically maintaining positive oxygen condition on the seabed, which is subsequently evaluated through monitoring.	Site development requires application of regulatory tools such as EIA procedures, which define what assessment of impacts needs to be carried out. The focus is on reporting seabed conditions, likely changes resulting from the aquaculture proposal (especially oxygen), then evaluation through monitoring. Minimum distances between farms is required (1.5 nautical miles).	
Zonal aquaculture management in China and Indonesia Area (or zonal) management example	Zonal management has been applied through the application of aquaculture improvement projects in China and Indonesia. **China:** Pond, dam and cage culture of tilapia in three counties of the Haikou region in Hainan province, southeast China.		
	Focused principally on farmer and stakeholder engagement to improve the use of water as a shared resource, better understanding of environmental and disease issues, a shift to developing appropriate best practice and capacity building through training. Development has included the funding of the Hainan Tilapia Sustainability Alliance, which includes seed, feed, technical suppliers, farmers and processors, providing a local complement to existing trade associations at the provincial and national level. Stakeholders include government departments and the local university to improve scientific understanding of the impacts of aquaculture, use of resources, and reporting of data on production, water quality and others.	Stakeholder engagement and facilitation.	

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
	Eventually, this will lead to cooperative development of the industry. One of the key present activities is the development of a localized code of practice based on those developed in more technically proficient sectors, including salmon.	Application of code of practice.	
	Indonesia: Shrimp production in Eastern Java.		
	A similar type approach has been applied through stakeholder engagement, although the reasoning is different; it is focused primarily on East Java maintaining its early mortality syndrome (EMS)-free status, implementation of responses to disease risks, developing codes for the zonal response to disease and quality issues. It is also focused on developing the East Java shrimp industry towards international certification standards on the quality of production and products.	Application of code of practice.	
	Web site developed as a means to engage, report and support local farmers with news, technical support and information.	Development of web resources and information-sharing.	
Spatial planning of marine finfish aquaculture facilities in Indonesia	This case study is based on the management of aquaculture zoning and site selection in bays in Bali, Batam and Pulau Seribu, under Indonesia's general desire to increase aquaculture production and local employment while protecting the environment.		
Zoning and site selection example	Since 2008, the bays concerned have been analyzed as to their aquaculture layout, design and development, deriving the best locations for aquaculture, and specific site selection through a series of tasks undertaken to identify each system's carrying capacity, identify the best areas based on defined characteristics, and identify management areas and relocation of existing farms based on the results.	Primary data collection through on-site measurements of seawater and sediments for a number of physical parameters, including water depth, water currents, salinity and dissolved oxygen, chemical analysis for dissolved ammonia, nitrate and phosphate, and concentrations of chlorophyll, particulate organic phosphorus and nitrogen, RedOx and sulphide. Data also collected via remote sensing using TOPEX and SAR satellite data, including temperature and chlorophyll measurements, and verified through on-site measurements.	Development and application of simulation models based on freely available modelling packages, to assess wave height, water flows and water quality (including dissolved oxygen). Adoption of general strategies for the set up and application of models for sites with scarce data typical to South-East Asia. Freely available bathymetric data from existing databases are combined with data from remote sensing and ocean forecast systems, enabling the development and application of simulation models.

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
	A scoping exercise identified land, coastal and water uses (such as navigation routes, fishery areas, national parks, tourism, protected areas and so on), verified through on-site inspection, and used to define management areas. Data presented through GIS and zones or management areas identified.		Results of simulation models based on freely available modelling packages in terms of water levels, current velocities and waves.
	This was followed by site selection, applying a multi-criteria evaluation with GIS layers accounting for a number of criteria, including physical, chemical and bottom sediment properties. Included within this were wave height, water flows, and water and sediment quality, and the application of remote sensing data defined through hydrodynamic and depositional models.	Application of collected data through GIS (ArcGIS), with data layers used to determine management areas and best locations within these areas to locate fish farms. SYSMAR module used to facilitate site selection. Thematic maps based on *in situ* measurements, simulation models and zoning schemes are prepared and imported to the decision support system. Templates built using ArcGIS. Overlay of templates generates suitability maps for marine finfish aquaculture.	Application of simulation models for flow, waves, water quality and sediment deposition.
	Sites identified through the application of a decision-support system that included fish growth models, site selection based on likely deposition of wastes, and site and overall carrying capacity set by applying a limit to this sediment deposition.	Specific site selection was done with SYSMAR that contained modules on fish growth, site selection based on best flushing, protection to hazards and farm operation. Site and cumulative carrying capacity limits to production set to comply with water quality and sediment environmental quality standards, validated through on-site sampling underneath existing fish farms.	
	Biosecurity framework using real-time polymerase chain reaction (PCR) to ensure that seeds are specific pathogen free (SPF). This is combined with the establishment of quarantine offices for monitoring fish diseases. As disease outbreaks are also associated with sudden changes in water temperature, an operational system for monitoring of water temperature is in place.	Operational sensors of water temperature transmit data in quasi-real time to a control station near the site in the northwest of Bali. Early warnings are delivered to farmers via SMS.	

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
Shrimp farming in Mexico Zoning example	Specific analysis was conducted in the State of Nayarit in Mexico, in a region that already grows shrimp in marine ponds, expanded through unregulated development.		
	As a land-based but marine system of production, the areas of shrimp farming come under the auspices of two federal directorates: CONAPESCA, responsible for aquaculture and fisheries in all federal waters, and SEMARNAT, responsible for the development of aquaculture on land. Many ponds were already located in the area under investigation. The study identified how overall management could be improved through zoning.	Government directorates established with distinct responsibilities.	
	The case study does not define legislative and policy documents, but notes that the area generally does not comply with the federal requirements due to ignorance of frameworks, high cost of conforming, lack of technical support and general difficulties in achieving required permits and licences. Farmers set up a local association to increase awareness and as a forum to discuss requirements.	Legislative and policy requirements exist, but implementation within the area is limited. Web resources set up to support farmers: www.acuasesor.conapesca.gob.mx/index.php.	
	As part of the scoping study, characteristics of the location were undertaken through a literature search for data on the area, surveys of aquaculture production units (APUs) and participatory stakeholder discussions.		
	Spatial analysis was undertaken with defined thresholds for soil types, hydrology, geomorphology, topography and slope, localities and population, roads, electricity, and natural protected areas, evaluated together through GIS. No carrying capacity assessment is undertaken as yet.	Mapping introduced through the application of ArcGIS version 10 to define distribution of APUs in relation to water body, marsh area, towns and roads to define the study area. The application of digital mapping and collation of data through ArcGIS, using a multi-criteria evaluation to establish zones of low, medium and high potential for aquaculture, mapped against existing UPAs.	

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
Aquaculture site selection and zoning in Oman Scoping example	Development of fish cage culture in the Gulf of Oman and Arabian Sea coast of Oman, and for on-shore prawn production. A number of the 11 governorates have been identified as suitable for either on-shore aquaculture or marine cage aquaculture, or both, by the Ministry of Agriculture and Fisheries, Directorate of Aquaculture Development, in 2010.	Application of ArcGIS for mapping of zones, based on analysis of collected and remotely sensed data (e.g., temperature, chlorophyll-a, land characteristics) that resulted in an atlas of areas suitable for aquaculture.	
	The Ministry of Agriculture and Fisheries developed a strategy for aquaculture development in 2011, covering the years 2011 to 2030. Legislative norms apply, combining general laws on sea fishing and biological wealth (including aquaculture) and on conservation of the environment, supported by three regulations, including development of a by-law on aquaculture and quality control in 2012.	Legislative and regulatory requirements are established, under more general legislation, plus regulations on aquaculture activities and operations as well as the application of environmental impact assessment (EIA) and discharge of waste requirements. Monitoring guidelines have been developed for environmental, disease and product quality monitoring.	
	Specific case study relates to assessment aquaculture potential and suitability in Musandam Governorate, which started in 2014. At an early stage, the project will include spatial analysis, such as other use and uses of both marine and land systems (e.g., marine transport, fishing areas and landing sites, combined with water quality criteria, current speeds, and other physio-chemical characteristics of local marine fjord-like systems (called *khawrs*) with application and analysis through GIS. Carrying capacity is to be assessed using modelling (but not defined).	Application of spatial and criteria analysis using ArcGIS (GIS) and ENVI (remote sensing).	

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
Mariculture parks in the Philippines Area management example	The Bureau of Fisheries and Aquatic Resources (BFAR) has, for ten years, promoted the development of communal mariculture zones and parks, and developed 67 of them. Parks are seen as a way to promote responsible and sustainable development of coastal cage aquaculture to provide livelihoods to local communities and contribute to food security. Parks use shared infrastructure, resources and security; and use a systematic approach to assessment and monitoring in setting up the parks. Parks are set up following a distinct sequence of activity defined in Fisheries Office Order No. 317 (2006), including surveys prior to establishing the park, consultation, environmental monitoring of water and sediment quality in compliance with established environmental protocols, conducting carrying capacity and economic studies, and giving training and ongoing research. Management of the parks is through a joint agreement between the local government unit and BFAR, operated through development of a Mariculture Park Operations Manual.	Application of developed government-defined environmental requirements and certification scheme. Each park is operated through an operations manual that lays out the requirements for operation, defining the critical policies and regulations consistent to the principles of good aquaculture practice standards. Application of aquaculture specific regulations, including the Fisheries Office Order No. 317 (2006), on setting up aquaculture parks, and the Fisheries Code enacted in 1998, which establishes requirements for large and small investors, and rules on the control of such areas as stocking density and feeding rates.	
	Work to set up a mariculture park includes a rapid assessment of the existing habitats, mapping critical habitats and setting of buffer zones to protect habitats. Undertake large consultation exercises and mapping. Baseline data including hydrographic assessment of tides, currents and bathymetry are used as the basis for zoning and development. Assessment of impacts from the parks is assessed using a particle tracking model, which serves a number of purposes including zoning of sites, support to environmental governmental certification requirements and as part of the EIA.	Critical habitats defined through mapping using Google Earth. Application of EIA. Environmental certification scheme.	TROPOMOD particle tracking model to define benthic impacts based on species to be produced, with mariculture park layout defined by least impact in the model output. Application of hydrodynamic model.

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
Aquaculture zoning, site selection and area management in Scottish marine finfish production Area management example	The case study area in Scotland, the United Kingdom of Great Britain and Northern Ireland concerned the development of zones/ management areas for cage culture of Atlantic salmon.		
	Management areas/zones in Scotland were developed out of a need to control infectious salmon anaemia infection in 1989/90, to limit movement of stock across areas, and to remove cross-infection potential across large areas: denoted as disease management areas (DMAs). Also, industry defined farm management areas (FMAs), where companies coordinate stocking, disease treatment and harvesting, etc. FMAs and DMAs are often the same, and within FMAs all Atlantic salmon sites are often managed by the same company. Large areas of Scotland (e.g., entire east coast) are off limits to aquaculture development. Minimum distances are applied between fish and shellfish production in Shetland, and may be applied elsewhere, though not regulated.	DMAs defined through disease management area model, which evaluates disease dispersal potential based on a complex hydrographic model. FMAs, managed through area management agreements, to coordinate activities such as disease treatments, and includes stakeholder meetings between companies and other area stakeholders and water users who meet regularly to discuss issues.	
	In zones where aquaculture is permitted there is further subdivision, with specific fjordic embayments defined as category 1, 2 or 3 for "no development," "some limited development potential is possible," and "development potential is possible," respectively.		Categorized waterbodies as 1, 2 or 3 was through the application of the Equilibrium Concentration Enhancement (ECE) model, estimating changes in water quality concentrations from different levels of aquaculture against allowable thresholds to define carrying capacity. Latest developments include enhancements and extensions of the original ECE model, with two new models (ACExR and L-ESV models) in development.
	Individual site selection and licence application completed through site suitability assessment, EIA and the application of waste dispersion and benthic impacts model, assessing deposition of wastes to the seabed, including likely concentration of in-feed sea lice treatments, set against defined environmental quality standards to define a maximum biomass limit for the site. Latest developments include assessment of inshore and offshore carrying capacity through the application of more sophisticated models.	Planning permission is given as a licence to produce. Licence is also required to discharge wastes (as a controllable substance) through the Scottish Environment Protection Agency, following the use of AutoDEPOMOD model. Approval is also required from Marine Scotland, in relation to disease control issues.	

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
	Marine aquaculture is managed through aquaculture specific regulations, A Marine Fish Farm Manual is available online (www.sepa.org.uk/regulations/water/aquaculture/fish-farm-manual/), it provides the policies and regulations to be adhered to, as well as specific guidance and other resources to ensure site evaluation and monitoring protocols are complied with.	Regulatory tools, such as code of conduct, licencing and EIA procedures, disease control requirements (European Commission directives, laws and regulations) are applied and enforced. Specific aquaculture legislation has been enacted (e.g., 2013 Aquaculture and Fisheries Act (Scotland)) to provide overall control and management by government. Online fish farm manual is available as a farmer resource.	Application of AutoDEPOMOD model.
	All information is made publicly available through a government-developed Web site: http://aquaculture.scotland.gov.uk. The majority of companies belong to trade organizations, including the Scottish Salmon Producers Organisation, British Trout Association and Association of Scottish Shellfish Growers, who have each developed codes of conduct for members.	Web portals and resources using desktop ArcGIS (shifting to QGIS), and online services through ArcGIS online and use of GeoServer, including site applications, mapping of existing site locations and approved licences, are available for public scrutiny.	
Mariculture parks in Turkey Zoning example	This case study focuses on mariculture zones in Gulluk Bay, where 55 percent of total marine aquaculture production occurs. Conflict with other coastal zone stakeholders (especially tourism) prompted a new regulation from the Ministry of Environment and Urbanization. In 2008, new regulations for Gulluk Bay led to the definition of two mariculture zones through consultation with stakeholders.		
	Legislative component is well developed with specific laws on fisheries and environmental protection, and regulations covering aquaculture development, EIA, monitoring and water pollution.	Regulatory tools, licencing and EIA post-development monitoring procedures are applied and enforced.	
	Zone selection carried out on potential areas using criteria, including water depth, net depth to water depth ratio, distance from coast, current speed and use of the TRIX eutrophication index to delimit areas unsuitable for aquaculture. It was combined with what was known about tourism areas, marine transport routes, and application of buffer zones around vulnerable marine communities (e.g., *Posidonia* beds) to further define unsuitable areas using mapping software.	Digitization of maps undertaken. Application of GIS (MapInfo) for mapping. Application of TRIX index.	

Case Study/Spatial Planning Category	Brief Description of Background to Zoning, Site Selection and Area Management Activity	Tools	Models
	TRIX index was applied with mapping software to interpolate TRIX measures taken at eight locations across the whole bay to provide a forecast of whole bay conditions. Water conditions were combined with mapping of unsuitable areas to then select suitable locations for fish farm activity.	Application of TRIX index.	
	Site selection within demarcated zones carried out on potential areas by applying the similar criteria to zonal work (i.e., water depth, net depth to water depth ratio) and application of minimum distances between sites and limits on the number of sites allowed within the zones. Monitoring undertaken to ensure compliance with minimum water quality requirements for dissolved oxygen, chlorophyll-a and dissolved inorganic nitrogen and total phosphorus, defined through the TRIX index.	Physical characteristics of the sites used to determine where sites could be placed within zones. Monitoring determines impacts of cage culture with measurement of physio-chemical parameters and application through the TRIX index.	
Aquaculture parks in Uganda Scoping example	Current production stems from family-owned and widely spread small farms growing tilapia and African catfish. Zoning case study relates to development of aquaculture parks through clustering of pond farms (land based) or cage farms (lake based) in suitable areas of high potential determined through a mapping study on site suitability against defined criteria for pond culture and for lake culture in cages. No aquaculture zones have been allocated as yet.	The application of digital mapping and collation of site selection data through GIS (ArcGIS and ArcMap), using a multi-criteria evaluation that establishes suitable zones for specific pond culture, and cage aquaculture in lakes.	
	Legislative component is well developed with specific laws and policy documents related to fish farming, social, environmental components and the need for EIA. Specific policy for aquaculture parks has been developed, but not yet fully implemented.	Developed the National Aquaculture Parks Policy in 2012 to complement the National Fisheries Policy (2004) and Fish (Aquaculture) Regulations (2003). Other non-aquaculture specific legislation needs to be taken into account.	
	Development of parks follows a number of reviews and development of an aquaculture strategy. Parks will be public-private enterprises, aimed to be self-sustaining after initial government financial support.	A national aquaculture strategy has been developed.	
	Regulations require each park to undergo licencing procedure, evaluation through impact assessment and subsequent monitoring. Individual park carrying capacity assumes a maximum stocking density for ponds and cages, and needed evaluation through EIA, without specific modelling requirements being specified.	Regulatory tools, licencing and EIA procedures and monitoring requirements defined.	

PART 2. OVERARCHING TOOLS FOR GOOD AQUACULTURE GOVERNANCE

The following are a broad category of tools that can and should be used for aquaculture development and overall good governance. Most are tools (also called instruments or approaches) to ensure the overall strategy for a country's aquaculture development is managed in a coherent way at the national and local level. Other tools ensure the siting and zoning of aquaculture are done systematically and with due consideration of the environmental and social context. All tools can be used to ensure the long-term sustainability of aquaculture using the ecosystem approach.

Stakeholder Engagement as a Tool

The Food and Agriculture Organization of the United Nations (FAO) has developed the ecosystem approach to fisheries (EAF) toolbox, which contains a description of the four steps to implementation: (i) initiation and scope; (ii) identification of assets, issues and priorities; (iii) development of a management system; and (iv) implementation, monitoring and performance review. Within each of these steps, tools and advice are available to enable each of the steps to be carried out, with supporting documents for particular activities. Although this is for fisheries, much of the information present is useful for the development of aquaculture. An ecosystem approach to aquaculture (EAA) toolbox is in development by FAO. The key activity defined in the toolbox relates to stakeholder engagement means and methods as approaches for action research which stimulate data gathering through engagement and observation.

Rapid rural appraisal (RRA) and participatory rural appraisal (PRA) are two such techniques of stakeholder engagement. Often used in developing countries, much of the basic information needed for decision makers to understand a local situation is provided by these methods, including through structured interviews, questionnaires, working and focus groups, and other forms of stakeholder engagement; and also for the understanding of how aquaculture is facilitated in an area, how zoning may help or hinder production and development, and how these and siting issues might help support rural livelihoods. The reader is recommended to review RRA, PRA and other tools in the FAO EAF toolbox and further reading in its application.

On general principle, stakeholder engagement is critical in the assessment of zoning, site selection and area management under the EAA approach, and active participation of stakeholders is encouraged for all facets of the necessary activity needed to achieve quality and sustainable aquaculture production.

Web Resources

See EAF toolbox (www.fao.org/fishery/eaf-net/toolbox/en).

Further Reading

Ahmed N. 2009. The sustainable livelihoods approach to the development of fish farming in rural Bangladesh. *Journal of International Farm Management*, 4(4): 1–18.

Barman, B. K., Little, D. C. & Edwards, P. 2002. Small-scale fish culture in Northwest Bangladesh: A participatory appraisal focusing on the role of tilapia. In P. Edwards, D. C. Little & H. Demaine, eds. *Rural Aquaculture*. UK, CABI Publishing. 233 pp.

Pido, M. D., Pomeroy, R. S., Garces, L. R. & Carlos, M. B. 1997. A rapid appraisal approach to evaluation of community level fisheries management systems: Framework and field application at selected coastal fishing villages in the Philippines and Indonesia. *Coastal Management*, 25(2): 183–204.

Tiller, R. & Richards, R. 2015. Once bitten, twice shy: Aquaculture, stakeholder adaptive capacity, and policy implications of iterative stakeholder workshops; the case of Frøya, Norway. *Ocean & Coastal Management*, 118(B): 98–109.

Townsley, P. *Rapid rural appraisal, participatory rural appraisal and aquaculture*. FAO Fisheries Technical Paper No. 358. Rome, FAO. 1996. 109 pp. (also available at www.fao.org/docrep/006/W2352E/W2352E00.htm#TOC).

Developing Strategic Planning for Aquaculture Development

Strategic planning in aquaculture results in the production of a document that outlines the overall vision, goals and guiding principles for how the aquaculture sector should develop within a country. Such a document should cover all forms of aquaculture following a systematic assessment. In outline, the document produced should contain the legislative background to the development of aquaculture; an analysis of the strengths, weaknesses, opportunities and threats to its development; should provide vision on how such activity will be implemented; and provide a clear plan on when it will happen through a set of clearly defined objectives and priorities. Such a document will also evaluate the linkage between research and production and sustainability for the long-term development and promotion of aquaculture products. Responsibility for strategic planning lies with national governments, who should undertake to review and update the plan at defined intervals once produced to ensure it takes into account recent developments and is current.

The strategic plan will allow regional and local authorities to understand government priorities and approach to aquaculture development; and will also allow developers/investors to understand the context within which their applications for fish farm sites are being made. This will ensure they comply with the overall master plan and for all parties to make environmentally and economically sustainable decisions when it comes to developing aquaculture zones and management areas. At the farm site level, the strategic plan should include the evaluation of applications, issuing of licences, monitoring of environmental impacts, managing facilities; and, more generally, developing aquaculture in an efficient and environmentally sustainable and socially acceptable manner.

Main sources of information (general and example plans):

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 pp. (also available at www.fao.org/docrep/012/i1601e/i1601e00.pdf).

EU Commission. 2012–2016. Multiannual national strategic plans for the promotion of sustainable aquaculture. In: *European Commission Fisheries* [online]. Brussels. [Cited 12 January 2017]. http://ec.europa.eu/fisheries/cfp/aquaculture/multiannual-national-plans/index_en.htm.

European Commission. 2013. *Strategic guidelines for the sustainable development of EU aquaculture. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions*. Brussels. COM (2013): 229 final. (also available at http://ec.europa.eu/fisheries/cfp/aquaculture/official_documents/com_2013_229_en.pdf).

FAO. 2010. *Aquaculture development. 4. Ecosystem approach to aquaculture.* FAO Technical Guidelines for Responsible Fisheries No. 5, Suppl. 4. Rome, FAO. 53 pp. (also available at www.fao.org/docrep/013/i1750e/i1750e00.htm).

FAO. 2016. *Regional strategy and action plan for sustainable intensification of aquaculture in the Asia-Pacific region.* Bangkok, Thailand (also available at: www.fao.org/3/a-i546 6e.pdf).

Fisheries and Oceans Canada. 2010. *National Aquaculture Strategic Action Plan Initiative (NASAPI) 2011–2015*. An initiative of the Canadian Council of Fisheries and Aquaculture Ministers (CCFAM). 20 pp. (also available at: www.dfo-mpo.gc.ca/aquaculture/lib-bib/nasapi-inpasa/Report-eng.pdf).

Ministry of Agriculture and Fisheries Secretariat of State for Fisheries. 2012. *Timor-Leste National Aquaculture Development Strategy 2012–2030.* [online]. Timor-Leste. [Cited 12 January 2017]. http://pubs.iclarm.net/resource_centre/WF_3602.pdf.

Ministry of Food and Agriculture, Fisheries Commission. 2012. *Ghana National Aquaculture Development Plan* [online]. Ghana. [Cited 12 January 2017]. http://faolex.fao.org/docs/pdf/gha149443.pdf.

NOAA Fisheries. 2016. *USA Marine Aquaculture Strategic Plan 2016–2020*. (also available at

www.nmfs.noaa.gov/aquaculture/docs/aquaculture_docs/noaa_fisheries_marine_aquaculture_strategic_plan_fy_2016-2020.pdf).

The Use of Strategic Environmental Assessment

Strategic Environmental Assessment (SEA) is a systematic, analytical and participatory approach that aims to integrate environmental considerations into policies, plans and programmes, and evaluates the interlinkages with economic and social considerations. SEA confers specific requirements on national and local governments to consider the environmental implications, alternatives and measurable targets related to large and complicated infrastructural developments, for example. In an aquaculture context, the application of SEA forms part of the principles of applying the ecosystem approach to aquaculture by considering how any development activity fits into a country's needs from a legislative, business, social, economic and environmental perspective.

SEA should be carried out in order to ascertain the impact of legislative and regulatory systems and practices on aquaculture development. This should be evaluated fully to identify where aquaculture-related legislation might be enacted, if appropriate. The SEA provides a clear context for development of the industry, having evaluated not only the regulatory framework but also the institutional capacity; existing and new market potential both internally and internationally; needs in terms of research, training, infrastructure and financial/business opportunities; opportunities in terms of food security and quality assurance; compliance with international Codes of Conduct, such as that issued by FAO for sustainable fisheries (including aquaculture); and an evaluation of social and economic requirements. More broadly, it will provide an overall framework for the development of the aquaculture industry, with an outcome of SEA being to support the completion of a strategic plan for aquaculture (see above). SEA can consider the cumulative impacts of more than one project or activity on the same environmental component.

SEA follows a similar path to environmental impact assessment (see below) in undergoing a scoping exercise to establish the requirements and encourage stakeholder engagement; screening to determine what areas will be considered and investigated; an analysis, covering those areas outlined above; and decision making based on that assessment, including development of the strategic plan. Some examples of the application of SEA to aquaculture development are included in the further reading.

Web Resources

Application of SEA to aquaculture development in South Africa (http://aquasea.csir.co.za/sea-process).

European Union with guidance on the application of SEA (not aquaculture-specific) (http://ec.europa.eu/environment/eia/sea-support.htm).

Environmental impact professionals (SEA and EIA) (www.iaia.org/index.php).

Further Reading

Adi Associates Environmental Consultants Ltd. 2012. *Strategic Environmental Assessment on Malta's Aquaculture Strategy.* Environmental report. San Gwann, November 2012; viii + 112 pp. + 1 appendix. (also available at https://agriculture.gov.mt/en/fisheries/Documents/Final%20Environmental%20report%20%20Aquaculture%20Strategy%20Oct%202013%20post%20public%20c.pdf).

Department of Agriculture, Food and the Marine. 2015. *Strategic Environmental Assessment: SEA statement—National Strategic Plan for sustainable aquaculture development in Ireland.* 76 pp. (also available at www.agriculture.gov.ie/media/migration/seafood/marineagenciesandprogrammes/nspa/NSPASEAstatement181215.pdf).

Hutchings, K., Porter, S., Clark, B. M. & Sink, K. 2011. *Strategic Environmental Assessment: Identification of potential marine aquaculture development zones for fin fish cage culture.* 65 pp. (also available at www.anchorenvironmental.co.za/Documents/Pdfs/SEA%20MADZ/Draft%20SEA%20Report%20for%20web.pdf).

Loughs Agency. 2010. *Strategic Environmental Assessment (SEA) of the Aquaculture and*

Shellfisheries Management Strategy. Environmental report, Loughs Agency. 92 pp. (also available at www.balticlagoons.net/artwei/wp-content/uploads/2011/04/SEA-of-aquaculture-in-TWs-of-Ireland.pdf).

Rosário Partidário, M. do. 2012. *Strategic environmental assessment better practice guide: methodological guidance for strategic thinking in SEA*. 76 pp. (also available at http://ec.europa.eu/environment/eia/pdf/2012%20SEA_Guidance_Portugal.pdf).

Aquaculture Legislation and Regulations

Laws are written legislative acts of national government that set out the standards, procedures and principles that must be followed. They are enforceable through the judicial system whereby failure to comply can result in prosecution in court. Regulations are the tools that ensure that a law is put into effect with details about how this should be done, providing more detail about the activities to be undertaken or not undertaken to comply with the legal requirements.

There are probably many laws that are of general application to aquaculture without being aquaculture specific. A few examples include those on food safety and environmental protection, for example. Legislation and regulations developed specifically for aquaculture and aquaculture development are critical tools in correctly planning for and aiding the development of aquaculture at the national level. As a general rule, countries that have a well-developed aquaculture sector tend to have aquaculture specific legislation and regulations that have helped to support their well-developed sector.

Legislation tends towards having a general law for aquaculture development. Regulations tend towards relaying specific rules about specific subjects, such as environmental impact assessment, fish safety and welfare, use of drugs and other chemotherapeutants, and other aquaculture-specific areas of relevance.

Internationally, there are a number of binding instruments (e.g., the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Ramsar, others) and nonbinding instruments (e.g., FAO codes of conduct, millennium goals and others) that govern sustainable aquaculture development, including spatial planning for aquaculture. Please refer to Annex 1 for a more detailed list.

Web Resources

See FAO. 2016. *National Aquaculture Legislation Overview (NALO) Fact Sheets*. [online]. Rome. [Cited 12 January 2017]. www.fao.org/fishery/nalo/search/en.

These National Aquaculture Legislation Overviews (NALOs) exist for 61 countries on this Internet site.

Further Reading

Abate, T. G., Nielsen, R. & Tveterås, R. 2016. Stringency of environmental regulation and aquaculture growth: A cross-country analysis. *Aquaculture Economics and Management*, 20 (2): 201–221.

Hishamunda, N., Ridler, N., Bueno, P., Satia, B., Kuemlangan, B., Percy, D., Gooley, G., Brugere, C. & Sen S. 2010. Improving aquaculture governance: What is the status and options? In R. P. Subasinghe, J. R. Arthur, D. M. Bartley, S. S. De Silva, M. Halwart, N. Hishamunda, C. V. Mohan & P. Sorgeloos, eds. *Farming the waters for people and food*. Proceedings of the Global Conference on Aquaculture 2010, Phuket, Thailand. 22–25 September 2010. FAO, Rome and NACA, Bangkok.

Sanchirico, J. N., Eagle, J., Palumbi, S. & Thompson Jr, B. H. 2010. Comprehensive planning, dominant-use zones and user rights: A new era in ocean governance. *Bulletin of Marine Science*, 86(2): 273–285.

Developing Codes of Practice, Codes of Conduct and Best Management Practices

In recognition that laws and regulations need to be followed and complied with, and in areas where aquaculture is well developed, industry has tended to develop a non-mandatory set of guiding principles, often referred to as codes of practice (CoP), codes of conduct (CoC) and best management practices (BMPs). These are non-mandatory in a legal sense, as CoCs/CoPs/BMPs are generally voluntary schemes, often issued by aquaculture trade associations, certification schemes and other stakeholders, and provide a set of operating principles that "members" must comply with to be a "member" or achieve certification, for example. Compliance with CoCs/CoPs/BMPs can be laid down in aquaculture licences in some countries.

CoCs/CoPs/BMPs are useful tools to harmonize the operation of aquaculture production activities. These codes outline the standards of operation expected of the producer, designed to describe the best practices that should be undertaken. The ultimate aim is to provide reassurance to consumers on seafood products, that production conducted by those complying with the codes meet safety and environmental protection standards, have been produced ethically and use sustainable techniques.

Often CoCs/CoPs/BMPs at this higher-level result in aquaculture producers producing their own company-specific versions that detail the methods of operation for specific activities (i.e., standard operating procedures (SOPs) for farm workers to adhere to, providing an overall chain of good conduct. To give two examples: (i) in certain countries, such as the mariculture parks set up in the Philippines, (see case study summary in Table A4.1 and full case study in Annex 5), each park has a manual of operating procedures to which all operators within the park comply; and (ii) in Scotland, the United Kingdom of Great Britain and Northern Ireland (and in other European countries also), the trade body (Scottish Salmon Producers Organisation—SSPO) has issued a code of practice for Scottish salmon farmers, implementation of which is required for membership. The code is based on one produced at European level by the Federation of European Aquaculture Producers (FEAP). Each company has then developed its own code and standard operating procedures for on-site activity and management.

At a broad scale, guiding principles for sustainable production of aquaculture products have been issued by FAO, through the Code of Conduct for Responsible Fisheries (FAO, 1995), that define a number of articles that, if implemented, will lead to improved sustainability of aquaculture (and fisheries) production. This has been augmented by the EAA (FAO, 2010), a strategy for the integrated management of land, water and living resources that promotes conservation, sustainable use and a fair and equitable sharing of the benefits of aquaculture development.

It should be noted that compliance with CoCs/CoPs/BMPs issued by FAO or others as guidelines does not implicitly provide "certification" to aquaculture organizations. Certification is different in that it requires compliance with specific standards, which are not generally presented in guideline documents produced by FAO (Environmental Law Society, 2012).

Overall, codes of practice, codes of conduct and best management practices are management tools that aim to improve overall quality in production—not just in the final product, but in every activity undertaken to produce that aquatic product.

Further Reading

Aqvaplan Niva. 2008*. Better Practice Guidelines (BPGs) for marine pen and cage farmers for responsible and sustainable production.* (also available at http://aquaculture.asia/files/online_03/PHILMANAQ%20Better%20Practice%20guidelines.pdf).

Arevalo, N. B., Donaire, T. C., Ricohermoso, M. A. & Simbajon, R. Undated. *Better Management Practices for seaweed farming of* Eucheuma *and* Kappaphycus *(in the Philippines)*. [online]. NACA. [Cited 12 January 2017]. http://library.enaca.org/bmp/manuals/seaweed-culture-bmp-manual.pdf.

Environmental Law Society. 2012. *Seafood certification based on FAO guidelines and code of conduct: a credible approach?* [online]. Environmental Law Institute. [Cited 12 January 2017]. www.eli.org/sites/default/files/docs/seafood-certification-july-2012.pdf.

FAO. 1995. *Code of conduct for responsible fisheries.* Rome. 41 pp. (also available at www.fao.org/docrep/005/v9878e/v9878e00.htm).

FAO. 2010. *Aquaculture development. 4. Ecosystem approach to aquaculture*. FAO Technical Guidelines for Responsible Fisheries No. 5, Suppl. 4. Rome. 53 pp. (also available at www.fao.org/docrep/013/i1750e/i1750e00.htm).

FAO. 2011. *Technical guidelines on aquaculture certification. Directives techniques relatives à la certification en aquaculture. Directrices técnicas para la certificación en la acuicultura*. Rome/Roma. 122 pp. (also available at www.fao.org/docrep/015/i2296t/i2296t00.htm).

FEAP. Undated. *Code of conduct for European aquaculture*. Federation of European Aquaculture Producers. 8 pp. (also available at www.feap.info/shortcut.asp?FILE=1180).

Kusumawati, R. & Bush, S. R. 2015. Co-producing Better Management Practice standards for shrimp aquaculture in Indonesia. *Maritime Studies*, 14: 21. doi:10.1186/s40152-015-0039-4.

Maine Aquaculture Association. Undated. *Code of Practice for Aquaculture in Maine*. [online]. Sustainable Solutions for Maine's Growing Future. [Cited 12 January 2017]. http://maineaquaculture.com/Code_of_Practice_v1.pdf.

National Marine Fisheries Service. Undated. *A Code of Conduct for responsible aquaculture development in the U.S Exclusive Economic Zone*. 44 pp. (also available at www.nmfs.noaa.gov/trade/AQ/AQCode.pdf).

SSPO. 2015. *Code of Good Practice for Scottish Finfish Aquaculture*. Scottish Salmon Producers Organisation. [online]. Perth, Scotland. [Cited 12 January 2017]. http://thecodeofgoodpractice.co.uk/chapters.

Spatial Planning for Aquaculture under the Ecosystem Approach to Aquaculture

Around the globe, the availability of and access to aquaculture zones and sites with favourable characteristics, including those areas that minimize interactions and conflicts with other activities, represent constraints for the expansion of the sector. The selection of the spatial area designated for aquaculture development and careful selection of farm sites are essential first steps to ensure the success and sustainability of aquaculture. They should be carried out in accordance with the FAO Code of Conduct for Responsible Fisheries and the ecosystem approach to aquaculture.

Spatial planning for aquaculture zoning, site selection and the design of aquaculture management areas should consider the social, economic, environmental and governance objectives of sustainable development. This is especially relevant when aquaculture takes place in common properties such as shared water resources. The Code of Conduct for Responsible Fisheries encourages the concept of sustainability in aquaculture planning and management. It urges states to produce and regularly update aquaculture development strategies and plans to ensure that aquaculture development is ecologically sustainable

Further Reading

Aguilar-Manjarrez, J., Kapetsky, J. M. & Soto, D. 2010. *The potential of spatial planning tools to support the ecosystem approach to aquaculture.* FAO/Rome. Expert Workshop. 19–21 November 2008, Rome, Italy. FAO Fisheries and Aquaculture Proceedings No.17. Rome, FAO. 176 pp. (also available at www.fao.org/docrep/012/i1359e/i1359e00.htm).

FAO. 2010. *Aquaculture development. 4. Ecosystem approach to aquaculture*. FAO Technical Guidelines for Responsible Fisheries No. 5, Suppl. 4. Rome. 53 pp. (also available at www.fao.org/docrep/013/i1750e/i1750e00.htm).

FAO. 2013. *Applying spatial planning for promoting future aquaculture growth*. Seventh Session of the Sub-Committee on Aquaculture of the FAO Committee on Fisheries (COFI). St Petersburg, Russian Federation, 7–11 October 2013. Discussion document: COFI:AQ/VII/2013/6. (also available at www.fao.org/cofi/43696-051fac6d003870636160688ecc69a6120.pdf).

FAO. 2016. *Report of the FAO workshop launching the Blue Growth Initiative and implementing an ecosystem approach to aquaculture in Kenya*. Mombasa, Kenya, 27–31 July 2015. FAO Fisheries and Aquaculture Report No. 1145. Rome. (also available at www.fao.org/3/a-i5997e.pdf).

Sanchez-Jerez, P., Karakassis, I., Massa, F., Fezzardi, D., Aguilar-Manjarrez, J., Soto, D., Chapela, R., Avila, P., Macias, J. C., Tomassetti, P., Marino, G., Borg, J. A., Franičević, V., Yucel-Gier, G., Fleming, I. A., Biao, X., Nhhala, H., Hamza, H., Forcada, A. & Dempster, T. 2016. Aquaculture's struggle for space: the need for coastal spatial planning and the potential benefits of Allocated Zones for Aquaculture (AZAs) to avoid conflict and promote sustainability. *Aquaculture Environment Interactions*, 8: 41–54. (also available at www.int-res.com/articles/aei2016/8/q008p041.pdf).

Marine Spatial Planning

There are many definitions of marine spatial planning (MSP). A useful one is the one given by Douvere and Ehler (2009), who describe MSP as "a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process." MSP can be considered as a strategic planning process, undertaken through a consistent and agreed upon framework that enables integrated, future looking and consistent decision making on the spatial use of the sea.

Marine spatial planning considers and systematically integrates all uses and users of selected space, while retaining and improving ecological services provided by habitats, species and the environment, through coordinated management, planning and implementation. An overall spatial plan for a large area allows for development of regional, national, subnational and local spatial plans through a participatory and coordinated approach.

Marine spatial planning, specifically, supports zoning for aquaculture in the marine environment through an evaluation of appropriate locations in marine space, taking account of environmental and social suitability and other use, users and sectorial interests while resolving or minimizing conflicts. There is a direct link between having an overall strategic plan for aquaculture, as defined above, and the implementation of this in a systematic way through good spatial planning.

Zoning is one of the main management measures used in implementing MSP, with virtually all marine spatial plans containing zoned areas and maps for specific activities. However, MSP is not just the production of maps, or a plan or zoning—as well as these, it is the development of a longer-term strategic process and management system whose aims are to best develop the marine area for the benefit of all.

Marine spatial planning as a tool is a defined methodological process of investigation, data collection, stakeholder engagement, analysis and decision making that provides zones and management areas for marine development, including aquaculture along with other important sectors that use land and marine space. MSP is a large subject that cannot be elaborated here in detail, but further reading is recommended below.

An atlas of potential areas for aquaculture is an example of "spatial planning for aquaculture (or aquaculture spatial planning)" in which the analysis is primarily focused on aquaculture, whereas marine spatial planning is a cooperative approach that integrates all marine users in identifying issues, opportunities and challenges to securing the sustainable use of marine space. Clearly, aquaculture spatial planning contributes to MSP, and likewise other stakeholder groups such as the military, navy and navigation authorities might have their own spatial plans all of which contribute to development of MSP and the overall marine spatial plan.

Further Reading

Douvere, F. & Ehler, C. 2009. Ecosystem-based marine spatial management: an evolving paradigm for the management of coastal and marine places. *Ocean Yearbook,* 23: 1–26.

Meaden, G. J., Aguilar-Manjarrez, J., Corner, R. A., O'Hagan, A. M. & Cardia, F. 2016. *Marine spatial planning for enhanced fisheries and aquaculture sustainability—its application in the Near East.* FAO Fisheries and Aquaculture Technical Paper No. 604. Rome, FAO. (also available at www.fao.org/3/a-i6043e.pdf).

The second document, in particular, contains an annex with a comprehensive listing of additional information about MSP, including worldwide examples where MSP has been applied under varied local conditions at highly variable geographic scales.

Use of Environmental Impact Assessment

Environmental impact assessment (EIA) can be defined as "The process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made" (IAIA, 1999). In an aquaculture context, EIA is a process that occurs typically at the individual site level, but increasingly so at the area and zonal level.

EIA is a systematic assessment of the proposed aquaculture development in terms of infrastructure to be deployed, production and growth cycles of species to be placed on site; an evaluation of the outputs, in terms of solid and dissolved wastes and chemical use (e.g., plans for treating disease), for example; and an assessment of impacts of farm activities on the ecosystem, local environment and on relevant biodiversity. Often, EIAs will contain a summary of the economic impacts, including summaries of likely local employment and contribution of the development to the local economy.

EIA, as a tool, generally follows a distinct sequence of activities: (i) screening to determine whether an EIA is needed; (ii) scoping to determine what should be evaluated; (iii) undertaking environmental studies; and (iv) writing an environmental impact statement that aims to show possible impacts and how these will be prevented, offset or otherwise mitigated using a precautionary approach to reduce any negative impacts from the aquaculture development. Activities (iii) and (iv) often require collection of primary and secondary data (e.g., baseline conditions in the local environment), and the application of computer models to determine the likely impacts and engagement with local stakeholders and the public. The EIA should aim to address public concerns about the development. This is followed by statutory and non-statutory stakeholder consultation and feedback to the competent authority, and overall consideration of the merits of the development by the competent authority, who makes a final decision to approve the EIA or not. EIA is generally part of the wider licencing procedures, and approval of the EIA leads to the issuance of a licence to produce. Other licence requirements (e.g., planning, municipality approval, licence to discharge wastes) may also be required before final approval is given, however.

The application of EIA at the site level implements a thorough assessment of all likely significant impacts that an aquaculture site, or mariculture park, will have on the local ecosystem, and should indicate the risks and mitigation of those risks. EIA should be implemented prior to the site being given permission to operate. The site or park should be monitored subsequently to ensure the impacts of the site or park are not any worse than what was predicted in the EIA. Post-operational monitoring is a critical phase in the EIA process.

Further Reading

Corner, R. A., Siriwardena, S. N. & Fersoy, H. 2013. *Guidelines on the application of the environmental impact assessment procedure in aquaculture in the Central Asia and Caucasus region*. FAO, Ankara. 71 pp.

FAO. 2009. *Environmental impact assessment and monitoring in aquaculture*. FAO Fisheries and Aquaculture Technical Paper No. 527. Rome. Includes a CD-ROM containing the full document. 648 pp. (also available at www.fao.org/docrep/012/i0970e/i0970e00.htm).

IAIA, International Association for Environmental Assessment. 1999. *Principles of environmental impact assessment best practice*. 4 pp. (also available at www.iaia.org/uploads/pdf/principlesEA_1.pdf).

Evaluation of Carrying Capacity

The evaluation of carrying capacity for aquaculture is a relatively new area of activity within aquaculture, and has the aim of assessing the maximum limits on aquaculture production in a given area based on environmental limitations and social acceptability.

Carrying capacity is most typically evaluated through modelling owing to the multifactorial nature of the environment, where there is a need to consider hydrodynamics (water current flows and speeds, tidal changes and waves), impacts on water quality and waters ability to assimilate dissolved wastes, impacts on sediment quality and its ability to assimilate particulate wastes, impacts on wild species, and cultured species growth, and culture practices. These incorporate the environmental changes brought about by the cultured and wild species (biological component) and changing chemical processes as a result of the addition of nutrients to the environment (chemical component), and establishing the spatial extent of impacts through water movement (physical component). The extent to which each component has an effect on limiting capacity is to some extent dependent on the local environmental conditions and on the species being grown, so there is no single approach that is typical of the models developed. Also, models developed as a general application will often require local calibration and validation before use.

It is worth noting that no aquaculture production is "zero impact." Carrying capacity assessment carries with it a social component through adoption of acceptable limits of impact and the development of environmental quality standards, for example. The development of integrated multi-trophic aquaculture (IMTA) has the potential to offset some of the nutrient loading from fish culture by growing extractive species, such as shellfish, algae and deposit feeders. Nutrients added to the environment by fish production are used by the other aquaculture species for growth, lowering the overall environmental load. It is, however, unlikely that the introduction of IMTA would reduce the net nutrient load to zero.

Most activity and model development has focused on assessing carrying capacity for specific individual sites in open marine environments. This has primarily been done for species with the highest production internationally, such as salmon and sea bream, mussels and oysters. There has also been some evaluation of carrying capacity for tilapia and carp in freshwater cage production systems. Carrying capacity estimation for pond systems is less critical; except when water is released to the environment into rivers, lakes or the sea during harvest activity, which can have negative consequences for the receiving ecosystem. This is not to say that carrying capacity assessment in freshwaters is any less important than for marine systems. It is perhaps more important, especially for reservoirs and lakes, given the fragility of many freshwater ecosystems and the additional resources they provide (power, drinking water, water for crops and so on); it is especially so in lakes that have a long water residence time.

There are a number of models that assess carrying capacity for individual sites, and further details on some of these are elaborated below for reference. There are only a few examples of models that assess carrying capacity at the area and zonal scale and these are also highlighted below. The use of geographic information systems (GIS) (see section below on GIS) in assessment of site suitability at various geographic scales is widely used, but not ubiquitous, and development of GIS capacity and use in aquaculture development is encouraged.

Ultimately, assessment of carrying capacity is a significant undertaking conducted by specialists in the field and requires time and money: to collect needed field data, to develop the model or models, and for calibrating and validating these before results from the modelling are used. Fundamentally, however, the assessment of carrying capacity is the ultimate tool that will determine the overall production potential, and assessment of carrying capacity will provide for the long-term sustainability of the aquaculture sector.

Further Reading

Byron, C. J. & Costa-Pierce, B. A. 2013. Carrying capacity tools for use in the implementation of an ecosystems approach to aquaculture. In L. G. Ross, T. C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez, eds. *Site selection and carrying capacities for inland and coastal aquaculture.* FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 46 pp. Includes a CD–ROM containing the full document. 282 pp. (also available at www.fao.org/docrep/018/i3322e/i3322e.pdf).

Campuzano, F. J., Gutiérrez, J. M., Senabre, T., Mateus, M. D., Perán, A., Belmonte, A., Aliaga, V. & Neves, R. 2015. A modelling approach to estimate the environmental and productive carrying capacity for a Mediterranean coastal marine culture park. *Journal of Aquaculture Research and Development*, 6: 373. doi:10.4172/2155-9546.1000373.

Cubillo, A. M., Ferreira, J. G., Robinson, S. M. C., Pearce, C. M., Corner, R. A. & Johansen, J. 2016. Role of deposit feeders in integrated multi-trophic aquaculture—a model analysis. *Aquaculture*, 453: 54–66. doi:10.1016/j.aquaculture.2015.11.031.

David, G. S., Carvalho, E. D., Lemos, D., Silveira, A. N. & Dall'Aglio-Sobrinho, M. 2015. Ecological carrying capacity for intensive tilapia (*Oreochromis niloticus*) cage aquaculture in a large hydroelectrical reservoir in Southeastern Brazil. *Aquacultural Engineering*, 66, 30–40.

Ferreira, J. G., Grant, J., Verner-Jeffreys, W. & Taylor, N. G. H. 2013. Carrying capacity for aquaculture, modelling frameworks for the determination of. In P. Christou, R. Savin, B. Costa-Pierce, I. Misztal & B. Whitelaw, eds. *Sustainable Food Production*, pp. 417–448.

Ferreira, J. G., Hawkins, A. J. S., Monteiro, P., Moore, H., Service, M., Pascoe, P. L., Ramos, L. & Sequeira, A. 2008. Integrated assessment of ecosystem-scale carrying capacity in shellfish growing areas. *Aquaculture*, 75: 138–151.

Ferriss, B. G., Reum, J. C. P., McDonald, P. S., Farrell, D. M. & Harvey, C. J. 2016. Evaluating trophic and non-trophic effects of shellfish aquaculture in a coastal estuarine foodweb. *ICES Journal of Marine Science*, 73 (2): 429–440. doi: 10.1093/icesjms/fsv173.

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.

Ross, L. G., Telfer, T. C., Falconer, L., Soto, D., Aguilar-Manjarrez, J., Asmah, R., Bermúdez, J., Beveridge, M. C. M., Byron, C. J., Clément, A., Corner, R., Costa-Pierce, B. A., Cross, S., De Wit, M., Dong, S., Ferreira, J. G., Kapetsky, J. M., Karakassis, I., Leschen, W., Little, D., Lundebye, A.-K., Murray, F. J., Phillips, M., Ramos, L., Sadek, S., Scott, P. C., Valle-Levinson, A., Waley, D., White, P. G. & Zhu, C. 2013. Carrying capacities and site selection within the ecosystem approach to aquaculture. In L. G. Ross, T. C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez, eds. *Site selection and carrying capacities for inland and coastal aquaculture*, pp. 19–46. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 282 pp. (also available at www.fao.org/docrep/018/i3322e/i3322e.pdf).

Soto, D., ed. 2009. *Integrated mariculture: a global review*. FAO Fisheries and Aquaculture Technical Paper No. 529. Rome, FAO. 183 pp. (also available at www.fao.org/docrep/012/i1092e/i1092e00.htm).

There are a number of approaches to evaluate carrying capacity; too many to mention here. A useful means to gain further information is to conduct a Web search for "aquaculture carrying capacity." Some tools and models are detailed below.

PART 3. SUMMARY OF SPATIAL TOOLS AND MODELS IN USE FOR AQUACULTURE ZONING, SITE SELECTION AND AREA MANAGEMENT

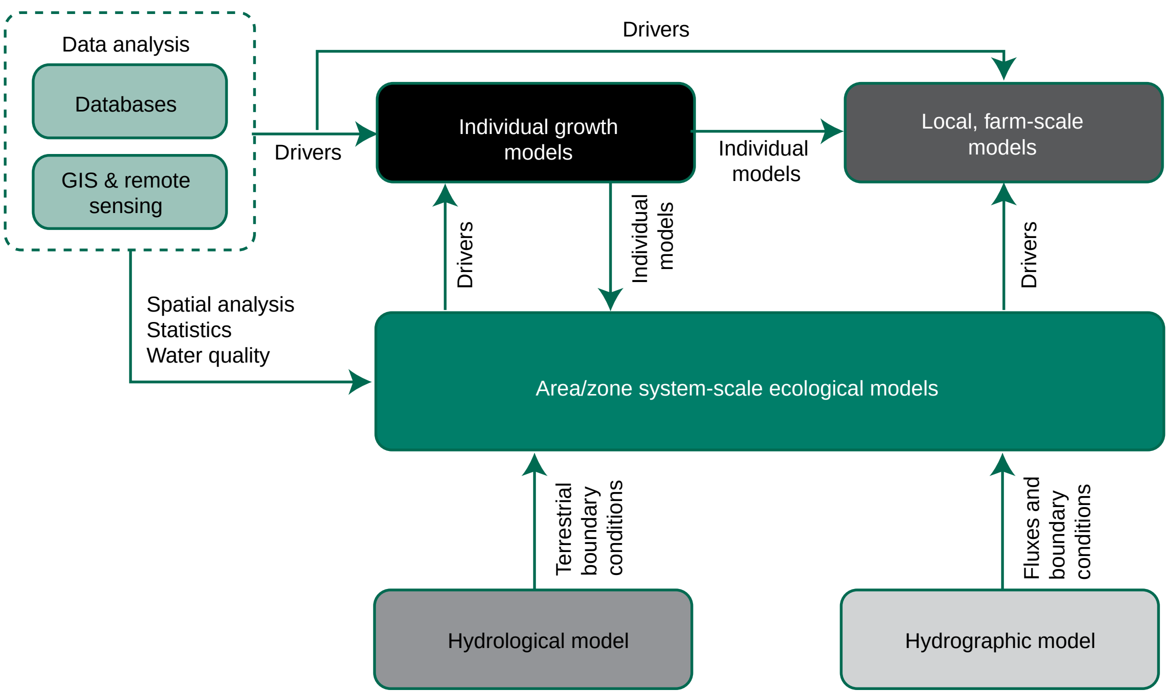
This part starts with a subsection on spatial data types, quality and sources to highlight the importance of using good data and information for aquaculture zoning, site selection and area management. Although high-quality primary and secondary data requirements are highlighted under a subsection on "Spatial data types, quality and sources" below, the requirements for good data apply equally to development of all tools and models.

Subsequent subsections provide a summary of a few of the available tools and models. The development of aquaculture zoning, site selection and area management often results from the application of cross-cutting tools and models, with a capability to deal with varying spatial scales. Often, the outputs from small scale models can be used at the larger scale, as indicated by the modelling framework in Figure A4.1.

Some of the farm scale and ecosystem models selected tend to reflect the fact that the majority of such development has taken place in Europe and North America, except perhaps for the application of GIS, remote sensing and freshwater modelling, which have a more global application.

Given the vast range of tools and models, only some of the main ones are listed in this document. Occasionally, tools and models are developed for aquaculture for zoning, site selection and area management, but are not identified by a distinct "name" (of the model), which makes them difficult to identify and highlight. Occasionally, a suite of tools is developed but the literature refers to them only as being part of a general "decision support tool" used in a particular location, which again makes them difficult to include here. Other models contribute in a smaller way, such as models that simulate fish and shellfish growth, which provide useful information, but do not in themselves contribute to zoning, site selection

FIGURE A4.1. Generic framework that shows how various tools and models can be used to provide the drivers, boundary conditions or fluxes into larger scale models and *vice versa.* Good quality data at each stage are vital.



and area management activity. There is no doubt the development and application of GIS, remote sensing and dynamic models, in particular, will increase over time as aquaculture develops and expands further.

This section generally covers the tools and models used within the case studies (Annex 5) mentioned in Table A4.1 or selected for inclusion by the authors.

Table A4.2 also identifies a non-exhaustive list of projects, where tools and models are being developed or used in the application of aquaculture zoning, site selection and area management, that will stimulate investigation. Each subsection, however, also contains a reading list, generally covering more recent publications and Web resources, where applicable. There is

TABLE A4.2. Selection of recent international collaborative research projects where tools and models were applied to aquaculture zoning, site selection and area management.

Name	Thematic Area	Web Resources
Aquabest	Developing responsible aquaculture in the Baltic Sea region (dedicated work package on spatial planning)	www.aquabestproject.eu
Aquaculture Zones project	Developing aquaculture zones in designated areas selected for its suitability for a specific aquaculture sector	www.fish.wa.gov.au/Fishing-and-Aquaculture/Aquaculture/Aquaculture%20Zones/Pages/default.aspx
Aquapods	Spatial Planning and Bio-Economic Analysis for Offshore Shrimp Aquaculture in Northwestern Mexico	www.bren.ucsb.edu/research/documents/aquapods_report.pdf
AquaSpace	Ecosystem approach to making space for sustainable aquaculture	www.AquaSpace-H2020.eu
BlueBRIDGE	Building research environments fostering innovation, decision making, governance and education to support Blue Growth	www.bluebridge-vres.eu/about-bluebridge
Co-Exist	Sustainable integration of aquaculture and fisheries	www.coexistproject.eu
ECASA	Ecosystem approach for sustainable aquaculture	www.ecasa.org.uk
Lake Volta	Planning for improved and sustainable cage aquaculture in Lake Volta, Ghana	www.aquaculture.stir.ac.uk/GISAP//Ghana/index
NASO maps	NASO aquaculture map collection	www.fao.org/fishery/naso-maps/country-initiatives/en/
PHILMINAQ	Zoning and site selection in the Philippines	www.aquaculture.asia/pages/15.html
ROSA	Risks and opportunities for sustainable shellfish aquaculture	www.rosa-marine.uk/home
ShellEye	Improving shellfish aquaculture through satellite monitoring	www.shelleye.org/
SISQUONOR	Spatial Information System for Aquaculture in Normandy and Norway	www.forskningsradet.no/prognett-fns/Nyheter/Norwegian_technology_to_help_French_ shellfish_production/1253990751393/p1226994063847
TAPAS	Tools for assessment and planning of aquaculture sustainability	www.tapas-h2020.eu/

also a short additional reading section at the end of this Annex.

Spatial Data Types, Quality and Sources

Data are facts and statistics collected together for reference or analysis. There are two key types: (i) primary data; and (ii) secondary data. Primary data include information collected directly through measurement, or otherwise collected directly for a specific purpose. Primary data would include on-site measurements of water quality, for example, or stakeholder feedback through project questionnaires. Secondary data are data that have been collected by someone else, or the primary data that have been processed in some form (e.g., through statistics, or input into GIS, or a model) with the outputs constituting secondary data. Although primary data are available via remote sensing, such data are generally a good example of secondary data, for example, collected via satellite imagery with measurement and processing completed by the collecting organization (e.g., through NASA or other similar agencies) and sold or made available free as databases for use by third parties (such as GIS specialists or modellers).

Any tool or model applied is only as good as the data that are used to develop and then apply that tool or model. The old adage "poor data in = poor information out" should be heeded, and people applying tools and models should make every effort to incorporate high-quality and relevant data for the tool or model applied. The main factors influencing data quality are the money, time and effort that are put into data collection.

Data quality is largely scale dependent, whereby if data were collected for a small-scale (large area) project, then the use of the same data for a large-scale project would almost certainly be inappropriate because the resolution of the data would be insufficient. Any scaling done needs to be certain that the tool or model remains valid. In developing and applying a fish growth model covering the whole production cycle for a 1 kg fish, the data used for model calibration and validation also need to cover this size, and not simply scaling measured data for juvenile stages up to 100 g and assuming this will be sufficient. Data quality must also take into consideration: (i) the accuracy of data used and to their precision (how precisely has a measurement been recorded); (ii) standardizing the methods used for data collection; (iii) the use of appropriate classification systems and thematic categories; (iv) the timeliness of the data; and (v) possible sources of error in any data collected (Meaden and Aguilar-Manjarrez, 2013).

Sources of data are many and varied, and the extent of available data depends on the location, previous work done and on their application. Increasingly, there are a large number of databases that are becoming freely available on climate, from remote sensing and for mapping purposes, for example. If not freely available, then such data can also be purchased for a fee. Good data sources come from the refereed literature: journals that present the results from years of research conducted by universities, research institutions, and others globally. Governments will often maintain a large body of data for their country. FAO maintains large databases on fisheries and aquaculture production globally through its FIGIS database, comprising strategic data, information, analyses, and reviews of issues and trends on a broad range of fisheries subjects. It is important that any data used come from a reliable source with appropriate vetting to ensure the key requirements on data quality outlined above are met. In the end, if data are not available, then the only alternative is direct data collection, remembering that this form of data collection is probably the most expensive and time consuming to carry out.

There are many online sources of spatial data. Each data set is usually described and categorized so that the user can understand what the data set contains and represents—this information is known as metadata. An example of a metadata portal is the United Nations Environment Programme online portal of environmental data sets (http://geodata.grid.unep.ch). Hosted data are searchable by keywords, and can be filtered by thematic category, priority issue and geographic region, etc.

For a more thorough review of data types and sources specific for application through GIS, see Meaden and Aguilar-Manjarrez (2013). The Web site http://gisinecology.com/gis_data_sources.htm also provides some examples of data sources available.

Web Resources

FAO. 2016. *GeoNetwork—The portal to spatial data and information*. [online]. Rome. [Cited 12 January 2017]. www.fao.org/geonetwork/srv/en/main.home

FAO. 2016. Global aquaculture production 1950–2014. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. [Cited 12 January 2017]. www.fao.org/figis/servlet/TabLandArea?tb_ds=Aquaculture&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY

UNEP. 2016. Environmental data explorer. In: *United Nations Environment Programme* [online]. Geneva. [Cited 12 January 2017]. http://geodata.grid.unep.ch

Further Reading

Aguilar-Manjarrez, J., Kapetsky, J. M. & Soto, D. 2010. *The potential of spatial planning tools to support the ecosystem approach to aquaculture*. FAO/Rome. Expert Workshop. 19–21 November 2008, Rome, Italy. FAO Fisheries and Aquaculture Proceedings No. 17. Rome, FAO. 176 pp. (also available at www.fao.org/docrep/012/i1359e/i1359e00.htm).

Meaden, G. J. & Aguilar-Manjarrez, J., eds. 2013. *Advances in geographic information systems and remote sensing for fisheries and aquaculture. Summary version*. FAO Fisheries and Aquaculture Technical Paper No. 552. Rome, FAO. 98 pp. Includes a CD–ROM containing the full document. 425 pp. (also available at www.fao.org/docrep/017/i3102e/i3102e00.htm).

Geographic Information Systems

The application of geographic information systems (GIS) has a long history, carried out by GIS practitioners. GIS is a spatial tool that uses geospatially referenced information to visualize, question, analyse and interpret data to understand the relationships, patterns and trends in the data at various geographic scales, within or across administrative or ecosystem boundaries. Common outputs include maps that highlight the data analysis undertaken, along with underlying information about the geospatially referenced area under investigation. Digital maps can come from a number of sources and include topographic mapping, digital elevation model data and satellite imagery, for example. Mapping the bathymetry (water depth) of the sea is slightly more specialized, with maps available from the National Oceanic and Atmospheric Administration (NOAA) (https://ngdc.noaa.gov/mgg/bathymetry/maps/nos_intro.html) and the General Bathymetric Chart of the Oceans (GEBCO, www.gebco.net), among others.

Aquaculture zoning and site selection are often evaluated through a multi-criteria evaluation (MCE) model that incorporates layers of information (attributes) within the GIS. These include, for example, digital maps; physical, chemical and biological attributes, such as water depth (bathymetry), wave height, distance to port and population centres (markets); application of remote sensing data (e.g. water temperature and chlorophyll concentration); identification of other water uses (fisheries, oil extraction, navigation routes and aggregate dredging, to name a few); and areas that are off limits for other reasons (tourism areas and marine protected areas, for example), often verified through field surveys (called ground truthing). These data are used collectively to then define areas suitable for aquaculture development and map out suitable aquaculture zones and sites. At a simple level, the MCE overlaps layers and identifies areas where conflicting use is low. More typically, the MCE weighs the importance of each element in the overall scheme, to then determine areas suitable for aquaculture identified by a higher overall score and those not suitable for a range of reasons achieving a lower score. There are various ways in which that weighting can be completed.

As well as providing information in its own right, GIS can also integrate a range of other data and information for presentation, including, for example, hydrographic information on waves, tides and currents, which can form a further layer in the technical understanding of finding the best locations for aquaculture development to take place.

The majority of the case studies in Table A4.1 have used GIS as part of their respective zoning, site selection and/or area management activity and thus GIS is a critical tool in the development of aquaculture. It is not possible in the available space, however, to outline all possible uses and applications to aquaculture, or indeed to describe how GIS works.

For a more thorough review of how GIS can support aquaculture development, the publications by Kapetsky and Aguilar-Manjarrez (2005), Aguilar-Manjarrez, Kapetsky and Soto (2010), and Meaden and Aguilar-Manjarrez (2013) are recommended. GIS is often the first tool to be applied in zoning and site selection before the application of more specific local area and farm-scale models are applied, which assess likely impacts from a specific level of production at a site or within an area.

Table A4.3 provides a list of popular GIS software available. Also, there are a number of aquaculture inventory initiatives (i.e., Web mapping applications) already being undertaken by many countries; see FAO's National Aquaculture Sector Overview (NASO) map collection compilation at www.fao.org/fishery/naso-maps/country-initiatives/en.

Web Resources

The reader is also recommended to investigate:

FAO GISFish publications database (www.fao.org/fishery/gisfish/index.jsp), which provides a large resource of information on the application of GIS, remote sensing and mapping for aquaculture and fisheries.

The Institute of Aquaculture in Scotland, the United Kingdom of Great Britain and Northern Ireland, is a rich source of research information focused on GIS, remote sensing and spatial applications for resource management for aquaculture (www.aquaculture.stir.ac.uk/GISAP/gis-group).

TABLE A4.3. Popular general-use GIS software.

Name	Publisher	Software Licence/Cost	Description	Complexity Rating
Desktop GIS software				
QGIS	QGIS	Open Source $	Desktop analysis and cartography	■■
GRASS	Open Source Geospatial Foundation (OSGeo)	Open Source $	Desktop analysis and visualization	■■
Manifold	Manifold	Commercial $	Desktop analysis and cartography	■
IDRISI	Clark Labs	Commercial $$	Desktop analysis and cartography	■
ArcGIS	ESRI	Commercial $$$	Industry standard GIS tools with additional disaster templates and disaster response information support Free ArcGIS Explorer data viewer available	■■
Web GIS software				
GeoServer	Open Source Geospatial Foundation (OSGeo)	Open Source $	Geospatial Web service (Web map) provider	■■■
MapServer	Open Source Geospatial Foundation (OSGeo)	Open Source $	Geospatial Web service (Web map) provider	■■■
ArcGIS Server	ESRI	Purchase $$$	Geospatial Web service (Web map) provider	■■■
ArcGIS Online	ESRI	Purchase $$$	Hosted online Web maps	■

Notes: Cost rating: $$$ > US$5 000; $$ ≤ US$5 000; $ = free. Complexity rating: ■ = beginner user, training manuals; ■■ = expert user, good documentation; ■■■ = expert user.

Further Reading

Aguilar-Manjarrez, J. & Crespi, V. 2013. *National Aquaculture Sector Overview map collection. User manual/Vues générales du secteur aquacole national (NASO). Manuel de l'utilisateur.* Rome, FAO. 65 pp. (also available at www.fao.org/docrep/018/i3103b/i3103b00.htm).

Aguilar-Manjarrez, J. & Nath, S. S. 1998. *A strategic reassessment of fish farming potential in Africa.* CIFA Technical Paper No. 32. Rome, FAO. 170 pp. (also available at www.fao.org/docrep/w8522e/w8522e00.htm).

Aguilar-Manjarrez, J., Kapetsky, J. M. & Soto, D. 2010. *The potential of spatial planning tools to support the ecosystem approach to aquaculture.* FAO/Rome. Expert Workshop. 19–21 November 2008, Rome, Italy. FAO Fisheries and Aquaculture Proceedings No. 17. Rome, FAO. 176 pp. (also available at www.fao.org/docrep/012/i1359e/i1359e00.htm).

Ashok, K., Nayak, D. P., Kumar, P., Mahanta, P. C. & Pandey, N. N. 2014. GIS-based aquaculture site suitability study using multi-criteria evaluation approach. *Indian Journal of Fisheries*, 61(1): 108–112

Brigolin, D., Lourguioui, H., Taji, M. A., Venier, C., Mangin, A. & Pastres, R. 2015. Space allocation for coastal aquaculture in North Africa: Data constraints, industry requirements and conservation issues. *Ocean and Coastal Management*, 116: 89–97.

Falconer, L., Hunter, D-C., Scott, P. C., Telfer, T. C. & Ross, L. G. 2013. Using physical environmental parameters and cage engineering design within GIS-based models of site suitability for coastal and offshore aquaculture. *Aquaculture Environment Interactions*, 4: 223–227. doi: 10.3354/aei00084.

FAO. 2016. Aquaculture mapping and monitoring. In: FAO. 2016. *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all*, p. 111. Rome, FAO. 200 pp. (also available at www.fao.org/3/a-i5555e.pdf).

FAO. 2016. *National Aquaculture Sector Overview (NASO) map collection.* [online] Rome. [Cited 12 January 2017]. www.fao.org/fishery/naso-maps/naso-home/en.

FAO/Regional Commission for Fisheries. 2013. *Report of the regional technical workshop on a spatial planning development programme for marine capture fisheries and aquaculture.* Cairo, the Arab Republic of Egypt, 25–27 November 2012. FAO Fisheries and Aquaculture Report No. 1039. Rome. 127 pp. (also available at www.fao.org/docrep/017/i3100e/i3100e00.htm).

Ferreira, J. G., Falconer, L., Kittiwanich, J., Ross, L. Caurel, C., Wellman, K., Zhu, C. B. & Suvanachai, P. 2014. Analysis of production and environmental effects of Nile tilapia and white shrimp culture in Thailand. *Aquaculture*, 447: 23–36.

Gimpel, A., Stelzenmuller, V., Grote, B., Buck, B. H., Floeter, J., Nunez-Riboni, I., Pogoda, B. & Temming, A. 2015. A GIS modelling framework to evaluate marine spatial planning scenarios: Co-location of offshore wind farms and aquaculture in the German EEZ. *Marine Policy*, 55: 102–115.

Hossain, M. S. & Das, N. G. 2010. Geospatial modelling for aquaculture sustainability in Noakhali, Bangladesh. *World Aquaculture Society magazine*, 41(4): 25–29.

Jenness, J., Dooley, J., Aguilar-Manjarrez, J. & Riva, C. 2007. *African water resource database. GIS-based tools for inland aquatic resource management. 1. Concepts and application case studies.* CIFA Technical Paper No. 33, Part 1. Rome, FAO. 167 pp. (also available at www.fao.org/docrep/010/A1170E/A1170E00.HTM).

Kapetsky, J. M. & Aguilar-Manjarrez, J. 2005. *Geographical information systems in aquaculture development and management from 1985 to 2002: an assessment.* Proceedings of the Second International Symposium on GIS in Fisheries and Spatial Analyses. University of Sussex, England. 3–6 September 2002. Fishery GIS Research Group, Saitama, Japan.

Kapetsky, J. M. & Aguilar-Manjarrez, J. 2007. *Geographic information systems, remote sensing and mapping for the development and management* *of marine aquaculture*. FAO Fisheries Technical Paper No. 458. Rome, FAO. 125 pp. (also available at www.fao.org/docrep/009/a0906e/a0906e00.HTM).

Kapetsky, J. M. & Aguilar-Manjarrez, J. 2010. Geographic information systems, remote sensing and mapping for the development and management of marine aquaculture. In: FAO. *The State of World Fisheries and Aquaculture,* pp. 150–154. Rome, FAO. (also available at www.fao.org/docrep/013/i1820e/i1820e00.htm).

Kapetsky, J. M., Aguilar-Manjarrez, J. & Jenness, J. 2013. *A global assessment of potential for offshore mariculture development from a spatial perspective.* FAO Fisheries and Aquaculture Technical Paper No. 549. Rome, FAO. 181 pp. (also available at www.fao.org/docrep/017/i3100e/i3100e00.htm).

Lovatelli, A., Aguilar-Manjarrez, J. & Soto, D., eds. 2013. *Expanding mariculture farther offshore—technical, environmental, spatial and governance challenges*. FAO Technical Workshop. 22–25 March 2010. Orbetello, Italy. FAO Fisheries and Aquaculture Proceedings No. 24. Rome, FAO. 73 pp. Includes a CD–ROM containing the full document. 314 pp. (also available at www.fao.org/docrep/018/i3092e/i3092e00.htm).

Meaden, G. J. & Aguilar-Manjarrez, J., eds. 2013. *Advances in geographic information systems and remote sensing for fisheries and aquaculture. Summary version*. FAO Fisheries and Aquaculture Technical Paper No. 552. Rome, FAO. 98 pp. Includes a CD–ROM containing the full document. 425 pp. (also available at www.fao.org/docrep/017/i3102e/i3102e00.htm).

Miceal, J., Costa, A. C., Aguiar, P., Medeiros, A. & Calado, H. 2015. Geographic information system in a multi-criteria tool for mariculture site selection. *Coastal Management*, 43: 52–66. (also available at www.tandfonline.com/doi/abs/10.1080/08920753.2014.985178).

Moreno Navas, J., Telfer, T. C. & Ross, L. G. 2011. Spatial modelling of environmental vulnerability of marine finfish aquaculture using GIS-based neuro-fuzzy techniques. *Marine Pollution Bulletin*, 48(8): 1786–1799. doi:10.1016/j.marpolbul.2011.05.019.

Radiarta, I. N., Saitoh, S-I. & Yasui, H. 2010. Aquaculture site selection for Japanese kelp (*Laminaria japonica*) in southern Hokkaido, Japan, using satellite remote sensing and GIS-based models. *ICES Journal of Marine Science*, 68(4): 773–780.

Ross, L. G., Telfer, T. C., Falconer, L., Soto, D. & Aguilar-Manjarrez, J., eds. 2013. *Site selection and carrying capacities for inland and coastal aquaculture. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland*. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 46 pp. Includes a CD–ROM containing the full document. 282 pp. (also available at www.fao.org/docrep/017/i3099e/i3099e00.htm).

Silva, C., Ferreira, J. G., Bricker, S. B., Del Valls, T. A., Martin-Diaz, M. L. & Yaenz, E. 2011. Site selection for shellfish aquaculture by means of GIS and far-scale models, with an emphasis on data-poor environments. *Aquaculture*, 318: 444–457.

Ssegane H., Tollner, E. W. & Veverica, K. 2012. Geospatial modeling of site suitability for pond-based tilapia and *Clarias* farming in Uganda. *Journal of Applied Aquaculture*, 24(2): 147–169. (also available at http://dx.doi.org/10.1080/10454438.2012.663695).

Yucel-Gier, G., Pazi, I. & Kucuksezgin, F. 2013. Spatial analysis of fish farming in the Gulluk Bay (Eastern Aegean). *Turkish Journal of Fisheries and Aquatic Sciences*, 13: 737–744.

There are a number of resources, technical papers and journal publications on the application of GIS for aquaculture site selection and zonal management; too many to mention here. A useful means to gain further information is to conduct a Web search for "GIS aquaculture site selection, zone management" or variations thereof.

TABLE A4.4. Commonly used satellite remote sensing software applicable to aquaculture.

Name	Publisher	Licence/Cost	Description	Complexity Rating
Satellite remote sensing				
ILWIS	52°North Open Source Software Initiative	Open Source $	Free integrated raster + vector GIS and remote sensing software	■■
Sentinel Toolboxes	European Space Agency	Open Source $	Free open source toolboxes for the scientific exploitation of the Sentinel missions	■■■
IDRISI	Clark Labs	Commercial $$	GIS tool set with over 300 analytical tools, primarily oriented to raster data	■
ENVI	Exelis Visual Information Solutions	Commercial $$$	Software to process and analyse all types of imagery	■■
ERDAS Producer Suite	Hexagon Geospatial	Commercial $$$	Software to process and analyse all types of imagery	■■
Geomatica	PCI Geomatics	Commercial $$$	Software to process and analyse all types of imagery	■■
SEADAS	NASA	Open source $	Software to process ocean colour	■
Unmanned aerial vehicles				
Pix4d Mapper Pro	Pix4d	Commercial $$$	Software to process and analyse UAV data	■■
Agisoft Photoscan	Agisoft	Commercial $$$	Software to process and analyse UAV and photogrammetry data	■■

Notes: Cost rating: $$$ > US$5 000; $$ ≤ US$5 000; $ = free. Complexity rating: ■ = beginner user, training manuals; ■■ = expert user, good documentation; ■■■ = expert user.

Satellite Remote Sensing

Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites where sensors detect energy reflected from the earth's surface, using either passive means (such as sunlight) or active means (such as lasers). The most often used remote sensing information for aquaculture comes from satellites, which are able to measure sea surface temperature and chlorophyll concentration, detect harmful algal blooms and sea surface height, and provide wind data over large areas; the information can then be analysed using GIS.

Satellite data generally consist of raster images, with associated data in each pixel of the image. Image pixels represent areas of sea (or land) at different spatial scales depending on the system used; they can have a vast range of spatial resolutions, ranging from a very high resolution, such as 1 m × 1 m, or low resolution, such as 1 000 m × 1 000 m per pixel, which is generally too large for specific site selection activity, but is useful for larger spatial scales considered for zoning. Raw data are generally referred to as Level 1 information and constitute the primary data received from the images. Conversion using GIS, for example, into mapped images and then model outputs represent secondary data that can, through the GIS applications outlined above, provide useful information on areas of interest for aquaculture based on the parameters measured and any other criteria used in the assessment.

Table A4.4 provides a summary of the commonly used remote sensing software, and for an overview of how remote sensing can support aquaculture development, please see Dean and Popolus (2013).

Further Reading

Dean, A. & Popolus, J. 2013. Remote sensing and GIS integration. In G. J. Meaden & J. Aguilar-Manjarrez, eds. *Advances in geographic information systems and remote sensing for fisheries and aquaculture*. CD–ROM version. FAO Fisheries and Aquaculture Technical Paper No. 552. Rome, FAO. 425 pp. (also available at www.fao.org/docrep/017/i3102e/i3102e00.htm).

Dean, A. & Salim, A. 2013. Remote sensing for the sustainable development of offshore mariculture. In J. M. Kapetsky, J. Aguilar-Manjarrez & J. Jenness. *A global assessment of offshore mariculture potential from a spatial perspective*, pp. 123–181. FAO Fisheries and Aquaculture Technical Paper No. 549. Rome, FAO. 181 pp. (also available at www.fao.org/docrep/017/i3100e/i3100e00.htm).

Kapetsky, J. M. & Aguilar-Manjarrez, J. 2007. *Geographic information systems, remote sensing and mapping for the development and management of marine aquaculture*. FAO Fisheries Technical Paper No. 458. Rome, FAO. 125 pp. (also available at www.fao.org/docrep/009/a0906e/a0906e00.htm).

Kapetsky, J. M. & Aguilar-Manjarrez, J. 2010. Geographic information systems, remote sensing and mapping for the development and management of marine aquaculture. In: FAO. *The State of World Fisheries and Aquaculture,* pp. 150–154. Rome, FAO. (also available at www.fao.org/docrep/013/i1820e/i1820e00.htm).

Meaden, G. J. & Kapetsky, J. M. 1991. *Geographical information systems and remote sensing in inland fisheries and aquaculture*. FAO Fisheries Technical Paper No. 318. Rome, FAO. 262 pp. (also available at www.fao.org/docrep/003/t0446e/t0446e00.htm).

Platt T., Shah, P., George, G., Menon, N., Mohammed, N., Thottan, M. P. & Sathyendranath, S. 2015. *Use of remote sensing in the context of cage aquaculture*. 5th International Symposium on Cage Aquaculture in Asia. (also available at http://eprints.cmfri.org.in/10588/1/CAA5%20Souvenir_Grinson.pdf).

Saxena, M. R., Gangulya, K., Sunder, B. S., Rani, P., Rao, A. & Shankar, G. R. 2014. *Monitoring land use with reference to aquaculture in Chinna Cherukuru village of Nellore District, Andhra Pradesh, India—A remote sensing and GIS based approach.* The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Services, Volume XL-8, 2014. pp. 927–931. (also available at www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-8/927/2014/isprsarchives-XL-8-927-2014.pdf).

Travaglia, C., Kapetsky, J. M. & Profeti, G. 1999. *Inventory and monitoring of shrimp farms in Sri Lanka by ERS SAR data.* FAO Environment and Natural Resources Working Paper No. 1. 34 pp.

Travaglia, C., Profeti, G., Aguilar-Manjarrez, J. & Lopez, N. 2004. *Mapping coastal aquaculture and fisheries structures by satellite imaging radar: case study of the Lingayen Gulf, the Philippines.* FAO Fisheries Technical Paper No. 459. Rome, FAO. 45 pp. (also available at www.fao.org/docrep/007/y5319e/y5319e00.htm).

Valentini, E., Filipponi, F., Xuan, A. N., Passarelli, F. M. & Taramelli, A. 2016. Earth observation for maritime spatial planning: measuring, observing and modelling marine environment to assess potential aquaculture sites. *Sustainability*, 8(6), No. 519. doi:10.3390/su8060519.

Wijenayake, W. M. H. K., Gunaratne, A. B. A. K., De Silva, S. S. & Amarasinghe, E. S. 2014. Use of geographical information system and remote sensing techniques for planning culture-based fisheries in non-perennial reservoirs of Sri Lanka. *Lakes and Reservoirs Research and Management*, 19(3): 183–191.

Risk Mapping, Including Climate Change

Management of aquaculture operations, even in normal times, is complex because of the range of factors that can affect production. All the segments of the aquaculture production and supply chain are vulnerable to disaster events, a situation which makes the tasks of disaster risk reduction, emergency response, and recovery and rehabilitation particularly demanding in the aquaculture sector.

Aquaculture is practised in varied environmental and physical settings, but several factors (many of which are linked to location) affect vulnerability:

1. Many aquaculture sites are relatively exposed compared with other industries owing to competition for coastal resources and production locations.
2. Many aquaculture sites are situated in fragile ecosystems that can be affected by hydrometeorological changes.
3. Conditions for cultured species easily deteriorate with changes in temperature, precipitation, and other water quality parameters. The cultured species are often sensitive or have low tolerance to these changes.
4. Aquaculture is often the "last user" of freshwater and usually accorded low priority in its allocation.
5. In many countries, aquaculture is mostly carried out by small-scale and resource-poor farmers with weak resilience and adaptive capacity to disasters.

The use of spatial tools and models is increasingly prevalent in society. Spatial tools acquire, manage and analyse data that have geographic or geospatial context. This includes remote sensing technology, including satellites images, aerial surveys, global positioning systems (GPS), GIS and information and communications technology (ICT) tools more broadly, such as mobile communication devices, and other data gathering sensors such as meteorology sensors. Some tools and models are explicitly targeted to disaster management and/or the aquaculture sector.

Changes in climate will affect aquaculture in freshwater and marine systems as a consequence of increased air and water temperatures, the lack of or change in resources, particularly affecting rainfall and freshwater availability in certain regions, changes in ocean acidification, changes in frequency and intensity of storms and harmful algal blooms, among others, which will impact aquaculture stocks, infrastructure and livelihoods. The extent of impact will vary regionally and requires the application of GIS and remote sensing to establish likely risks.

Web Resources

See Climate Change Vulnerability Index (www.natureserve.org/conservation-tools/climate-change-vulnerability-index) for plant and animal species vulnerable to climate change impacts.

See ClimateWizard (www.climatewizard.org) for a summary of global temperature and precipitation change expected in the mid and end of the twenty-first century.

Further Reading

Risk Mapping

Brown, D. & Poulain, F. 2013. *Guidelines for the fisheries and aquaculture sector on damage and needs assessments in emergencies*. FAO, Rome. 114 pp. (also available at www.fao.org/3/a-i3433e/index.html).

Cattermoul, B., Brown, D. & Poulain, F. 2014. *Fisheries and aquaculture emergency response guidance*. Rome, FAO. 167 pp. (also available at www.fao.org/3/contents/64f74d96-3323-4795-880d-0c9399e6f049/i3432e00.htm).

Joyce, K. E., Wright, K. C., Samsonov, S. V. & Ambrosia, V. G. 2009. Remote sensing and the disaster management cycle. Advances in geoscience and remote sensing. G. Jedlovec, ed. *InTech*, pp. 318–346. (also available at www.intechopen.com/books/advances-in-geoscience-andremote-sensing/remote-sensing-and-the-disaster-management-cycle).

Climate Change

De Silva, S. S. & Soto, D. 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto & T. Bahri, eds. *Climate change implications for fisheries and aquaculture: overview of current scientific knowledge,* pp. 151–212. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome, FAO.

Hamdan, R., Othman, A. & Kari, F. 2015. Climate change effects on aquaculture production performance in Malaysia: an environmental performance analysis. *International Journal of Business and Society*, 16(3): 364–385.

Handisyde, N. T., Lacalle, D. S., Arranz, S. & Ross, L. G. 2013. Modelling the flood cycle, aquaculture development potential and risk using MODIS data: a case study for the floodplain of the Rio Paraná, Argentina. *Aquaculture*, 422–423: 18–24.

Handisyde, N. T., Ross, L. G., Badjeck, M.-C. & Allison, E. H. 2014. *The effects of climate change on world aquaculture*: *a global perspective*. Technical report. University of Stirling and Department for International Development, UK. 152 pp.

Handisyde, N., Telfer, T. C. & Ross, L. G. 2016. Vulnerability of aquaculture-related livelihoods to changing climate at the global scale. *Fish and Fisheries.* doi:10.1111/faf.12186 (also available at http://onlinelibrary.wiley.com/doi/10.1111/faf.12186/abstract).

Lebel, L., Lebel, P. & Lebel, B. 2016. Impacts, perceptions and management of climate-related risks to cage aquaculture in the reservoirs of Northern Thailand. *Environmental Management*, 58(6): 931–945.

Liu, Y., Saitoh, S.-I., Igarashi, H. & Hirawake, T. 2014. The regional impacts of climate change on coastal environments and the aquaculture of Japanese scallops in northeast Asia: case studies from Dalian, China, and Funka Bay, Japan. *International Journal of Remote Sensing*, 35: 4422–4440.

There are a number of journal publications on climate change and aquaculture; too many to mention here. A useful means to gain further information is to conduct a Web search for "aquaculture climate change zoning site selection" or variations thereof.

Mapping Aquaculture Facilities to Improve the Effectiveness of Planning and Management

Inventories and monitoring of aquaculture facilities provide decision makers with important baseline data and trends on production, area boundaries, size distribution of farms, environmental conditions and impacts, and spatial risks to the ecosystem and to the farming systems, and so on. Mapping facilities improves the effectiveness of planning and management interventions to increase production, improve emergency preparedness (including for diseases) and reduce risks in general.

The mapping of aquaculture facilities can be performed accurately, regularly (i.e., days, months or years) and at selected spatial scales by remote sensing. Remote sensing—using satellites, aircraft, drones or fixed sensors—enables observations of large and often remote or inaccessible areas at a fraction of the cost of traditional surveys. It provides a large range of observation data that complement and extend data acquired from *in situ* observations to support aquaculture management.

FAO has been assisting countries in recording the location and type of aquaculture structures so they can improve their aquaculture zoning, site selection and area management. The work of FAO by Travaglia *et al.* (1999) and Travaglia *et al.* (2004) has demonstrated the mapping of coastal aquaculture and fisheries structures using radar satellite images in Sri Lanka and the Philippines.

Aquaculture structures and their evolution can be assessed against locations of sensitive ecosystems and habitats to highlight potential impacts, and they can be used to assess spatial risks to aquaculture. They can also be linked to the licencing process to identify unregistered or illegal facilities and to land tenure issues. FAO's National Aquaculture Sector Overview (NASO) map collection (www.fao.org/fishery/naso-maps/naso-home/en) provides a spatial inventory of aquaculture with attributes, including species, culture systems and production (FAO, 2016). Based on Google Earth/Maps technology, its aim is to develop ways to assist developing countries, and so to encourage them to conduct their own inventories, at minimal cost, as part of their strategic planning for sustainable aquaculture development.

Google Earth is a good starting point for spatial inventories of aquaculture, as it makes high-resolution data (e.g., satellite images or historical aerial photographs) freely available to the general public without requiring any remote-sensing expertise.

More advanced approaches based on image analysis require the use of GIS or remote-sensing software and access to satellite images in their original format. For example, images from the Sentinel-1A satellite are being used to monitor aquaculture in the Mediterranean (ESA, 2016).

Further Reading

Aguilar-Manjarrez, J. & Crespi, V. 2013. *National Aquaculture Sector Overview map collection. User manual/Vues générales du secteur aquacole national (NASO). Manuel de l'utilisateur.* Rome, FAO. 65 pp. (also available at www.fao.org/docrep/018/i3103b/i3103b00.htm).

Aguilar-Manjarrez, J., Zhou, X. & Luce, J. B. 2016. Managing aquaculture from space. *FAO Aquaculture Newsletter,* No. 55: 46–49. (also available at www.fao.org/documents/card/en/c/578da08b-8c74-4bf2-a7e3-e70e6f0386c8).

ESA (European Space Agency). 2016. Sentinel-1 counts fish. In: European Space Agency. *Observing the earth*. [online]. Paris. [Cited 12 January 2017]. http://m.esa.int/Our_Activities/Observing_the_Earth/Sentinel-1_counts_fish.

FAO. 2016. Aquaculture mapping and monitoring. In: FAO, 2016. *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all*, 111 pp. Rome, FAO. (also available at www.fao.org/3/a-i5555e.pdf).

FAO. 2016. NASO aquaculture maps collection. In: *FAO* [online]. Rome. [Cited 12 January 2017]. www.fao.org/fishery/naso-maps/naso-maps/en.

Travaglia, C., Kapetsky, J. M. & Profeti, G. 1999. *Inventory and monitoring of shrimp farms in Sri Lanka by ERS SAR data.* FAO Environment and Natural Resources Working Paper No. 1. 34 pp.

Travaglia, C., Profeti, G., Aguilar-Manjarrez, J. & Lopez, N. 2004. *Mapping coastal aquaculture and fisheries structures by satellite imaging radar: case study of the Lingayen Gulf, the Philippines.* FAO Fisheries Technical Paper No. 459. Rome, FAO. 45 pp. (also available at www.fao.org/docrep/007/y5319e/y5319e00.htm).

Trujillo, P., Piroddi, C. & Jacquet, J. 2012. Fish farms at sea: the ground truth from Google Earth. *PLoS ONE* 7(2): e30546. doi:10.1371/journal.pone.0030546.

Application of Models and Indices—Introduction

Table A4.5 provides a summary of models and indices used in the case studies and additional models of relevance to aquaculture zoning, site selection and area management. Descriptions of each of these models and indices are provided below. Other models and indices are available.

Models for Freshwater Environments

The largest impact in freshwater lake systems is most likely eutrophication potential, with the addition of nutrients from waste feed, faeces and dissolved wastes, increasing algal growth (i.e., higher chlorophyll and, in extreme cases, phytoplankton blooms) and reducing oxygen availability, especially when the phytoplankton die and are consumed by bacteria. This limits productivity in aquaculture, but more fundamentally damages the ecosystem for wild species and other uses. The primary limiting factor for phytoplankton growth in freshwater systems is phosphorus, which is generally added in excess to fish feeds because fish lack phytase to be able to process phosphorus efficiently. When released to the environment, this increases the concentration so that algal growth is no longer restricted. The most common approach to assess freshwater lake systems and aquaculture is application of the Dillon-Rigler mass-balance model. At larger river basin scales, the SWAT model is also used, and described here. Other models provide more generic assessment of freshwater environments at system scales (e.g., see Panuska and Kreider, undated), and for classification of estuarine systems (e.g., see www.eutro.org).

Dillon-Rigler Model

Lakes are generally sensitive waterbodies, where shifts in trophic status and the potential for eutrophication affect the likely uses that lakes can be put to, including aquaculture. Lakes are classified according to their trophic state, as oligotrophic, mesotrophic, eutrophic or hypereutrophic, depending on the level of phosphorus or chlorophyll present.

TABLE A4.5. Models and indices used for zoning, site selection and area management.

Model/Index	Developer	Description	Cost	Complexity Rating	Scale
Model					
Dillon-Rigler[1]	n/a	Changes in water quality conditions, particularly phosphorus, based on water residence time and pre-existing conditions, to assess change brought about by adding aquaculture to the system.	$	■	Lake site selection and capacity.
SWAT Model http://swat.tamu.edu	USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research.	Simulates the quality and quantity of surface water and groundwater, and predicts the environmental impact of land use, land management practices, and climate change on that water quality and availability. It is sometimes used in aquaculture to determine freshwater loads to marine systems.	$	■■■	Watershed, river-basin area management, including aquaculture.
FARM[1]	Longline Environment Ltd, London, UK.	Determines sustainable level of production for aquaculture farms culturing a range of species in marine and freshwater environments and pond systems. Predicts species growth and environmental loads to determine site capacity and management decision making.	$	■■	Marine site selection and capacity management.
Ecowin www.longline .co.uk/site/products/ aquaculture	Longline Environment Ltd, London, UK.	An ecological model for large-scale aquatic systems used to model effects of multi-site aquaculture production on environmental conditions over decadal time scales.	$	■■	Marine zoning, area management.
MOM and FjordEnv www.ancylus.net	Gotenborg University, Sweden.	Determines likely impacts from fish cage culture on water quality and benthic conditions, evaluated against standards to limit production. Can be combined with a fjordic circulation model (FjordEnv) to assess wider changes.	$$	■■	Marine site selection and capacity, zoning, respectively.
DEPOMOD, MERAMOD and Derivatives www.sams.ac.uk/ kenny-black/ newdepomod	Scottish Association of Marine Science, UK.	Site selection and capacity model, defining impacts from aquaculture tested against environmental standards to limit production. MERAMOD and other derivatives relate to specific species and/or locations.	$$	■■	Marine site selection and capacity.
ACExR-LESV www.sams .ac.uk/mark-inall/ assimilative-capacity	Scottish Association of Marine Science, UK.	Simulates effects of finfish and shellfish aquaculture at the water body (zonal) scale, and is applicable to regions of restricted water exchange. Contains submodels for particular characteristics.	$$	■■	Marine zoning.

Model/Index	Developer	Description	Cost	Complexity Rating	Scale
Ecopath with ecosim http://ecopath international.org/	Ecopath International Initiative, Spain.	Ecological modelling software suite not developed for aquaculture, but applied notably to shellfish carrying capacity modelling.	$	■■■	Marine zoning.
Qualitative Network Model[1]	n/a	Probability model applying various ecological and social parameters for evaluation of impacts of aquaculture activity within zones.	$	■■	Marine zoning.
SYSMAR	Research and Technology Centre, Kiel University.	Decision support system comprising of modules for farm emissions, site selection, and carrying capacity.	$	■■	Marine site selection and carrying capacity.
Index					
TRIX Eutrophication Index[1]	n/a	Evaluation of multiple water-quality parameters into a single index score. Used primarily in the Mediterranean.	$	■	Marine site selection, zoning.
Nutrient Enhancement and Benthic Index[1]	Marine, Scotland.	Combines models of water quality and benthic change from waste deposition, combined into a single index to define whether further aquaculture development is permitted in Scottish sea lochs.	$	■	Marine zoning, area management.
Sustainability Index[2]	Brazil.	Scoring from 1 (poor) to 5 (high) applied to a number of social, environmental, institutional and economic criteria, combined to create a final sustainability index score.	$	■	Lake zoning, area management.

1 See reading list at the end of this annex.
2 See Brazil case study in Annex 5.
Notes: Cost rating: $$$ > US$5 000; $$ ≤ US$5 000; $ = free. Generally, refers to licence cost and does not include the cost of specific application, calibration and validation to local conditions and species. Complexity rating: ■ = easily applied; ■■ = expertise supplied by developer or a consultant; ■■■ = specialist user requiring knowledge of particular software, often research related.

Hypereutrophic lakes are unsuitable for aquaculture, as phytoplankton growth and the potential for eutrophication is already high and fish production would simply increase the problems. For other conditions, the question of how much aquaculture is feasible depends to a large extent on what maximum phosphorus level is acceptable for the water body, whether a change in trophic status is acceptable for that production, which is in part a social decision, and whether secondary effects of production such as lowering oxygen concentration have a self-harming effect. Freshwaters therefore need an evaluation to assess the likely impacts.

The Dillon-Rigler model was not developed with aquaculture in mind, but is nonetheless applied globally to evaluate the changes resulting from the proposed aquaculture production. Application of the Dillon-Rigler model (see Brazil case study, Annex 5) requires prior knowledge on the existing status of the water body, so data collection of primary data is an important prerequisite. Data are needed on surface area and depth, which allow an estimate of water volume, along with flow rate into and out of the lake so that residence time can be calculated. There also needs to be some estimate of the likely input to the lake system from a certain level of fish culture, and whether this is in particulate form and buries in the sediment, or in dissolved form and is available to phytoplankton in the water column.

Estimates of capacity for aquaculture will also depend on the addition of phosphorus from other sources, natural and human-induced, which then allows apportionment of loading to different activities while remaining within the maximum environmental limit imposed. See further reading on the application of this model.

Further Reading

Beveridge, M. C. M. 1984. *Cage and pen fish farming. Carrying capacity models and environmental impact*. FAO Fisheries Technical Paper No. 255. 131 pp. (also available at www.fao.org/docrep/005/ad021e/ad021e00.htm).

Johansson, T. & Nordvarg, N. L. 2002. Empirical mass balance model calibrated for freshwater fish farm emissions. *Aquaculture*, 212(1–4): 191–211.

Mhlanga, L., Mhlanga, W. & Mwera, P. 2013. The application of a phosphorus mass balance model for estimating the carrying capacity of Lake Kariba. *Turkish Journal of Veterinary and Animal Sciences*. (also available at http://journals.tubitak.gov.tr/veterinary/issues/vet-13-37-3/vet-37-3-12-1110-37.pdf).

Punuska, J. C. & Kreider, J. C. Undated. *Wisconsin lake modelling suite: program documentation and user manual*. Version 3.3 for Windows. (also available at http://dnr.wi.gov/lakes/Model/WiLMSDocumentation.pdf).

Riasco, J., Diaz, D., Beltran, L. & Gutierrez, F. 2012. Dynamical model to estimate carrying capacity in reservoirs with fish farming/Modelo dinamico para estimar la capacidad de carga de cuerpos de agua con piscicultura. *Revista U.D.C.A Actualidad & Divulgación Científica*, 15 (1): 135–145. (In Spanish) (also available at www.scielo.org.co/pdf/rudca/v15n1/v15n1a15.pdf).

Zhang, Y-F., Wang, D.-P., Wei, G.-Y. & Wei, H.-Y. 2012. Cage culture capacity analysis of Dahua Yantan reservoir in Guangxi. *Journal of Southern Agriculture*, 43(11). (In Chinese).

Soil and Water Assessment Tool (SWAT)

The Soil and Water Assessment Tool (SWAT) is a public domain hydrological model jointly developed by the USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research (http://swat.tamu.edu). SWAT simulates the quality and quantity of surface and groundwater and predicts the environmental impact of land use, land management practices, and climate change on that water quality and availability. The model is widely used at the scale of a small watershed to river basin to assess soil erosion prevention and control, non-point source pollution control, and regional management in watersheds.

Its inclusion here results from its use to evaluate the contribution of freshwater flows on aquaculture site selection and production taking place in estuarine and marine systems as a bridge between both ecosystems. Under these circumstances, the SWAT model is used to evaluate freshwater water flows and volumes and concentration of nutrients and sediments as they impact the marine environment, which then support the further evaluation of the marine system at the zonal scale.

Further Reading

Ferreira, J. G., Saurel, C., Lencart e Silva, J. D., Nunes, J. P. & Vasquez, F. 2014. Modelling of interactions between inshore and offshore aquaculture. *Aquaculture*, 426–427: 154–164.

Ferreira, J. G., Saurel, C., Nunes, J. P., Ramos, L., Lencart e Silva, J. D., Vazquez, F., Bergh, Øivind, Dewey, W., Pacheco, A., Pinchot, M., Ventura Soares, C., Taylor, N., Taylor, W., Verner-Jeffreys, D., Baas, J., Petersen, Jens Kjerulf, Wright, J., Calixto, V. & Rocha, M. 2013. *FORWARD—Framework for Ria Formosa water quality, aquaculture and resource development*. 111 pp. (also available at http://orbit.dtu.dk/ws/files/102164373/Publishers_version.pdf).

Marinov, D., Galbiati, L., Giordani, G., Viaroli, P., Norro, A., Bencivelli, S. & Zaldívar, J-M. 2007. An integrated modelling approach for the management of clam farming in coastal lagoons. *Aquaculture*, 269 (1–4): 306–320.

Nobre, A. M., Ferreira, J. G., Nunes, J. P., Yan, X., Bricker, S., Corner, R. A., Groom, S., Gu, H., Hawkins, A. J. S., Hutson, R., Lan, D., Lencart e Silva, J. D., Pascoe, P., Telfer, T. C., Zhang, X. & Zhu, M. 2010. Assessment of coastal management options by means of multilayered ecosystem models. *Estuarine, Coastal and Shelf Science*, 87(1): 43–62.

Application of Dynamic Farm and Ecosystem-Scale Ecological Models for Zoning and Site Selection in Marine Systems

Dynamic ecological models are used in aquaculture to assess the capacity of an area to support cultured species, most typically by providing information and predictions on the growth of species on culture, estimations of waste generated, and how the environment will respond to that waste—essentially, an assessment of the siting of a certain level of production in a certain area. This can be done at both the farm scale (site selection) and more widely at the ecosystem scale, incorporating multiple farms (zoning).

For the models developed, these have been applied almost universally to the marine environment. Models combine submodels on hydrodynamics (water flows), species growth (primarily based on local water temperature in fed species like fish, and temperature and food availability in unfed species like bivalves), and mass balance (the balancing of energy or nutrients in and out of the system) together with baseline environmental information (such as measures of specific parameters, including temperature, existing nutrient loading and so on).

In freshwaters, model use is more limited, but given that most freshwater sites are more fragile ecosystems than corresponding marine environments, further work needs to be undertaken to evaluate the longer-term effects of aquaculture development, particularly in cages in lakes.

The following are some examples of dynamic models currently applied to aquaculture zoning, site selection and carrying capacity assessment. Byron and Costa-Pierce (2013) provide a short review on the application of such models (including others not listed here) in carrying capacity assessment. One important point of note is that all models require calibration and validation when applied within a new situation, or require a certain level of enhancement when applied to new aquaculture species. As such, application to "new" circumstances often need a period of development, including primary and secondary data collection where necessary.

Further Reading

Byron, C. J. & Costa-Pierce, B. A. 2013. Carrying capacity tools for use in the implementation of an ecosystems approach to aquaculture. In L. G. Ross, T. C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez, eds. *Site selection and carrying capacities for inland and coastal aquaculture.* FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, United Kingdom of Great Britain and Northern Ireland. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 46 pp. Includes a CD–ROM containing the full document. 282 pp. (also available at www.fao.org/docrep/018/i3322e/i3322e.pdf).

Hydrodynamic Measurement and Modelling

Fundamentally, hydrodynamic measurement and modelling is an assessment of water movement and water flows, tides and waves. Currents are water density, tidally driven or caused by wind, and waves are caused predominantly by wind. The National Oceanic and Atmospheric Administration (NOAA) maintains a number of fixed buoys at different locations around the world (www.ndbc.noaa.gov). These buoys are loaded with instruments to measure water quality and other parameters, such as wave height, period and spectra. At a broad scale, for assessment of zones, the use of remote sensing data, as outlined above, is useful in determining waves and wind effects on ocean currents.

At its simplest level, current speeds and direction can be measured using a small float, timer and hand-held GPS. At a larger scale, discrete current meters can be deployed (examples are electromagnetic current meters, impeller-type meters and the Acoustic Doppler Current Profiler or ADCP), fixed in one location for a defined period, which measure current speed and direction at different water depths at fixed time intervals throughout the deployment.

Most large-scale hydrodynamic models incorporate tidal harmonics (for a description, see Tidal Analysis Software Kit, TASK, at http://noc.ac.uk/using-science/products/tidal-harmonic-analysis), which are mathematical formulations of water flows based principally on Navier-Stokes equations. (See www.nauticalcharts.noaa.gov/csdl/learn_models.html for a description of what hydrodynamic models are used for).

Examples of flow models include FLOW-3D (www.flow3d.com/commercial-aquaculture-systems), Delft3D-FLOW (http://oss.deltares.nl/web/delft3d), Finite-Volume Coastal Ocean Model (FVCOM) (www.int-res.com/articles/aei2014/5/q005p235.pdf), and ECOM-si (http://woodshole.er.usgs.gov/operations/modeling/ecomsi.html).

Current speed and direction and wind and wave activity are critical for site selection. Wind, waves and water movement (tidal flow effects) affect the cage and mooring design, the spread of farm wastes from aquaculture activity, which impacts the seabed and surrounding water column. Good water movement through the site is needed to ensure sufficient oxygenated water flows through the cages and on-site infrastructure.

Hydrodynamic models also often underpin ecological models that assess the impacts of aquaculture on the local and regional environment. Such models generally refer to the coupling of hydrodynamic and ecosystem models.

Further Reading

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The Farm Aquaculture Resource Management (FARM) Model

The FARM model is designed to determine the sustainable level of production for aquaculture farms culturing a range of species (fish, shellfish and algae) in marine and freshwater environments and pond systems, and to improve sustainability, profitability and environmental stewardship. The model can be applied to a variety of species and environmental conditions.

The underlying models use equations to describe feeding in fed species or food/nutrient availability in non-fed species (such as shellfish and algae); regulation of feeding (such as feeding rate and feed conversion ratio (FCR); species growth; energy input and loss through harvestable products, wastes and biological processes; oxygen consumption through anabolic and catabolic processes; and mass balance equations to reflect and account for inputs and outputs to the production system.

The FARM model thus predicts growth, nutrient uptake and release to the environment, calculates a mass balance to partition where the waste ends up, and is able to assess the changes in water quality over a growth cycle. The approach and the equations used reflect the species concerned and whether they are fed, such as with fish production, or rely on localized primary productivity and nutrient availability, such as with shellfish and algae. Modelling can be undertaken on individual species produced in monoculture and multiple species in integrated multi-trophic aquaculture (IMTA) systems.

The general model framework includes individual growth integrated with environmental drivers and other data on farm practices to produce the outputs. When growing more than one species in an IMTA system, for example, the species, their activity (e.g., growth) and outputs (e.g., wastes) interact over time (e.g., shellfish using some of the particulate waste generated by the fish farm) to provide an overall impact on growth of each species and the impacts for the local environment.

The FARM model is not particularly data intensive in terms of what data are needed to produce tangible results. It is a screening model used to evaluate: (i) optimal carrying capacity (i.e., the greatest sustainable yield of market-sized animals within a given time period); (ii) ecological and economic optimization of culture practice for shellfish and finfish and algae; (iii) information on the effects of changing the timing of seeding and harvest; and (iv) is used for assessment of farm-related eutrophication effects on local water, among other outputs. A limited online version of the FARM model is available for use at www.farmscale.org.

The FARM model has been applied in a number of locations globally, including China, Europe, Thailand and the United States of America (www.longline.co.uk/site/products/aquaculture/farm).

Further Reading

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Saurel, C., Ferreira, J. G., Cheney, D., Suhrbier, A., Dewey, B., Davis, J. and Cordell, J. 2014. *Ecosystem goods and services from Manila clam culture in Puget Sound: a modelling analysis*. Aquaculture Environment Interactions, 5: 255–270.

ECOWIN Model

ECOWIN is an ecological model for large-scale aquatic systems. The basic structure is that of a spatial (2D and 3D) framework of boxes, within which relevant biogeochemistry (e.g., nutrient concentrations) and population dynamics are resolved. There is an underlying hydrodynamic model (such as Deflt3D-FLOW) that imparts water movement characteristics in the model, which allows each of the model boxes to interact and change as a consequence of that interaction so that, for example, changes in nutrients can be assessed over large spatial and temporal scales.

Aquaculture is added into the appropriate model boxes where it exists in physical space through objects corresponding to hierarchies for simulating, for example hydrodynamics, air temperature, shellfish growth, seeding and harvesting processes, and so on. The location of aquaculture production has effects (such as a changed nutrient condition) on surrounding boxes through the application of the hydrodynamic model. The net effect is to assess the impacts of aquaculture development being conducted in relatively limited spatial locations, over a whole area or zone under assessment, thus providing an indication of the overall carrying capacity for individual areas within the zone.

This ecological model is applicable to the ecosystem scale, covering waterbodies or coastal areas, and can be run over time scales of several years to decades to assess the changing situation over the model period. The outputs from the ECOWIN model can also support site specific assessment because the outputs from ECOWIN can be applied within the FARM model (described above) and other models (Figure A4.1).

The ECOWIN model has been applied in a number of locations globally, including China, Ireland, Portugal and the United States of America (www.longline.co.uk/site/products/aquaculture/ecowin).

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Modelling-Ongrowing Fish Farms-Monitoring (MOM) Model and FjordEnv Model

The MOM model was developed initially in 1997 as a means to assess the environmental impacts of single salmon farming sites in Norway.

One of the key components of the MOM model is consideration of the quantity of particulate material released from a fish farm site and the spread of that waste on the seabed for estimation of the likely changes in sediment oxygen concentration from the deposition of that particulate matter, which varies with the level of production and amount of feed used. Likely changes in sediment conditions are predicted and compared to a minimum environmental quality standard (EQS) defined in legislation. The model is run iteratively, increasing or decreasing salmon production until the EQS is not crossed, which then sets the maximum allowable production of fish (www.ancylus.net) for the site. The model contains a range of species that can be modelled in different environments.

At a larger scale, the FjordEnv model gives an estimate of environmental conditions of a marine water body, including physical circulation in fjords and other inshore areas. The model computes rates of mixing intensity, water exchange and residence times in different depth strata. It also computes the expected rate of oxygen consumption and oxygen minimum in the basin water. Furthermore, the model computes changes of water quality due to changes in the supply of nutrients and organic matter from fish farms and other sources through combining estimates defined by the MOM model.

Before the model is applied to a specific area, information on topography and forcing functions must be gathered. Some of the forcing is derived from offshore conditions, such as tidal amplitude, density variations in the water column and the natural vertical flux of organic matter. As these vary on regional and larger scales, means data can only be stored in a database and used by referencing or calling this information through the model. As tidal amplitude is used, hydrographic measurements collected directly using current meters are not specifically needed to complete the model computations, but can be used to improve the quality of the computations carried out.

Further Reading

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DEPOMOD/MERAMOD/TROPOMOD/CODMOD and Shellfish DEPOMOD

DEPOMOD (see Scottish case study, Annex 5) was developed in Scotland, the United Kingdom of Great Britain and Northern Ireland, as a means to regulate marine fish farming activity. Particulate wastes from fish farms are a controlled substance and require permission for discharge—most recently through the Water Environment (Controlled Activities) (Scotland) Regulations 2011 (called CAR licence) administered by the regulatory body, the Scottish Environment Protection Agency.

The DEPOMOD model is a site selection model, originally developed in 2002 as a means to regulate the maximum production permissible on salmon sites. DEPOMOD (Cromey *et al.*, 2002) is a particle tracking model for predicting the flux and resuspension of particulate waste material (food and faeces). The model evaluation is based on an assessment of the associated benthic community impacts resulting from the deposition of solid wastes onto the seabed, resulting changes in sediment condition, and impact on number and type of species present on the seabed.

The model algorithms define the spread of particulate waste on the seabed based on the production of the site, quantities of particulate material released and its dispersion based on particle settling velocity, current speed and direction information (gained through a current meter deployment) and water depth (through a bathymetric survey) to determine where the waste will deposit on the seabed. Applying limits on the impacts in terms of quantity of solids depositing and the application of a benthic index, the model is run iteratively from a starting biomass of fish on site, and that quantity is reduced and/or the cage configuration altered until the site is "passed." The permitted peak biomass is set at this limit. The model defines an Allowable Zone of Effect (AZE) based on the settlement of waste feed and faeces. Within the AZE, a limited amount of impacts is permitted, with government-imposed Environmental Quality Standards (EQSs) defining minimum quality standards expected (examples are minimum number of species present in the sediment and maximum deposition per m^2). The production carrying capacity of the site is therefore limited by comparing model runs against EQSs for benthic species count, medicine concentration and sediment nutrient concentration. Deposition of in-feed medicines, used against sea-lice infestation, is included as a controlled waste and is modelled through a DEPOMOD derivative called AutoDEPOMOD.

More recently, NewDEPOMOD has been developed as a replacement for the original version, which has undergone recoding using new software, new calibration, and validation and implementation of improvement based on a better understanding of deposition and resuspension for high water flow dispersive sites.

The MERAMOD and TROPOMOD models are derived from the original DEPOMOD model for application in Mediterranean and tropical environments, respectively, adapted and calibrated for the fish species and environmental conditions exhibited in those areas (see Philippines case study, Annex 5). CODMOD is a model that completes the same activity for cod species, and Shellfish-DEPOMOD for assessing the impacts of mussel (*Mytilus* sp.) longlines.

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ACExR-LESV Model

The ACExR-LESV(SF) model simulates the effects of finfish and shellfish aquaculture at the water body (zonal) scale, and is applicable to regions of restricted water exchange, such as the fjordic sea lochs found in Scotland, the United Kingdom of Great Britain and Northern Ireland. The model contains a number of submodels to simulate changes in biology and chemistry, an aquaculture fish waste submodel to estimate dissolved and particulate nutrient additions, and a pelagic ecosystem submodel to define water quality characteristics, including dissolved oxygen, chlorophyll, nitrogen and phosphorus. The model averages the results per 24 hours, but simulates the changes that occur over the period of a year. The net effect is a model that defines modelled changes to water conditions that result from fish farm activity.

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Ecopath with Ecosim

Ecopath with Ecosim is a free ecological modelling software suite (available at http://ecopath.org). The suite has three main components: Ecopath, which is a static, mass-balanced snapshot of the system being modelled; Ecosim, which is a time dynamic simulation module; and Ecospace, a spatial and temporal dynamic module primarily designed for exploring impact and placement of protected areas. This modelling suite was not developed for aquaculture, but has been applied to aquaculture, most notably for shellfish production and considerations of carrying capacity as part of zoning and site selection activity.

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Qualitative Network Model Applied to Shellfish

Reun *et al.* (2015) have applied a Qualitative Network Model (QNM) to the consequences of bivalve culture and application of management decisions on species community structure within Puget Sound. This is not a site selection or zoning methodology *per se,* but decisions on these rely also on assessment of consequences of aquaculture development as part of the ecosystem approach, which is why it has been included here.

The process is a probability model using a graphical method that defines a simplified matrix of complex ecological interactions between species responses along with abiotic and other (e.g., social, economic) linkages. The model assesses specific scenarios by evaluating the impacts of changes to the system. In an aquaculture context, this has been applied to additional bivalve aquaculture production, removing predators of bivalves from an area, or assessing changes in nutrient concentrations to then evaluate the consequences on the overall ecosystem structure.

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Example of a Decision Support System

SYSMAR (see Indonesia case study) is a decision support system (DSS) developed for decision makers in the management of finfish marine aquaculture facilities for sites with scarce data availability. The DSS was designed to regulate the development of facilities where the activity is already well established for assessment of suitable locations and estimation of potential environmental impacts of existing cage clusters. In addition, it provides guidance on planning and identification of potential areas for expansion of the activity.

SYSMAR is comprised of modules for estimation of finfish farm emissions, site selection and carrying capacities. Data from various sources and numerical simulation models for flow, waves and water quality are embedded within a graphical user interface using ArcGIS, with the addition of open source modelling systems used to facilitate further developments.

Site selection and carrying capacity limits are defined by adoption of cost-effective methods based on the results of simulation models for water flows, waves and water quality. Freely available bathymetric data are combined with data from remote sensing and ocean forecast systems, enabling cost-effective model developments in places with scarce data. Specific site selection is based on best flushing, protection to hazards and farm operation. Thematic maps based on *in situ* measurements, simulation models and zoning schemes are prepared and imported to the DSS. Templates built using ArcGIS are overlaid for generating suitability maps for marine finfish facilities. Recommendations concerning the relocation and/or best location of farms are provided.

Farm carrying capacity is based on hydrodynamics from measurements or model simulations. The method estimates the maximum fish production for the given flushing at the fish farm location, falling velocities of waste, and a user-defined threshold for carbon deposition on the seabed; and cumulative carrying capacity is dictated by the rate at which nutrients can be added without triggering eutrophication. The emitted load of dissolved inorganic nitrogen (DIN) from all the farms should not exceed a user-defined percentage of the DIN load entering the water body. Recommendations regarding farm and overall carrying capacity of marine finfish aquaculture sites are delivered.

SYSMAR has been successfully applied to several sites in Indonesia. The modules for site selection and carrying capacity have been validated using *in situ* observations in South-East Asia.

Further Reading

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Application of Index Tools

Indices are a method of aggregating univariate or multivariate parameters to define an overall index score within a range of possible scores, with the score defining an overall impact, status or condition. Indices have been used in ecology for many years; examples include diversity measures such as the Shannon-Weiner Index and AMBI (http://ambi.azti.es). Below are some examples of indices that have been used within the aquaculture case studies (Annex 5) summarized in Table A4.1.

TRIX Index

Within the Turkey case study and in regions across the Mediterranean, the TRIX index has been applied to aquaculture site selection and zoning activity. TRIX was originally developed by Vollenweider *et al.* (1998) as an index that defines trophic conditions in marine systems based on generalized water quality parameters, notably the linear addition of the logs of chlorophyll-a concentration, oxygen saturation, total nitrogen concentration and total phosphorus concentration.

The index is not widely used, but is applied to aquaculture in various countries growing fish in the Mediterranean to evaluate changes in water conditions as a result of cage aquaculture deployment. In Turkey (Turkey case study, Annex 5), for example, it has been applied to define areas where aquaculture is permitted and not permitted, based on the existing water quality to parameterize the TRIX model, combined with minimum distance to shore, water depth and current speed criteria. TRIX is used to assess the likely consequences of cage aquaculture through changes to the index score resulting from additional culture. Applied through GIS, with interpolation between data points, the result is a map showing locations where aquaculture is permitted and demarcation of zones that are strictly applied.

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Nutrient Enhancement and Benthic Index

The nutrient enhancement and benthic index has been applied to Scottish sea lochs as a means to categorize whether or not aquaculture is permissible in a particular loch system (body of enclosed marine water, similar to the Norwegian fjordic system). The index uses underlying models of nutrient enhancement, referred to as the equilibrium concentration enhancement (ECE) model, to predict the nitrogenous nutrients arising from fish farming conducted within the loch; and a carbon deposition model to predict the area of seabed liable to be covered by the settlement of particulate waste material (feed and faeces). For interpretation of results, the predicted ECE values and the percentage areas of "degraded" seabed are combined in a manner which identify the relative potential sensitivity of sea lochs to further fish farming development.

The approach adopted is a semi-logarithmic scaling of ECE values from 0–5, such that each sea loch can be assigned an index of nutrient enhancement. In a similar manner, the percentage area of degraded seabed is scaled from 0–5, allowing each sea loch to be assigned an index of benthic impact. These two scaled indices are then added together to give a single combined index for each sea loch. The resultant single index, scaled from 0–10, is used to provide an indication of the relative sensitivity of a sea loch system to further fish farming development by assigning three categories. Category 1 sea lochs are the most sensitive, and precaution is applied for not allowing further aquaculture development (where aquaculture already exists). Precaution is also applied to Category 2 water bodies, but allows for some further development, where a developer has shown (through EIA and modelling work) that no additional harm will be caused. For Category 3 lochs, further development of aquaculture is permitted, although EIA is still necessary, as it is for all aquaculture development in Scotland, the United Kingdom of Great Britain and Northern Ireland. The system has been applied to all Scottish sea lochs on the west coast (aquaculture is not permitted on the east coast of Scotland, the United Kingdom of Great Britain and Northern Ireland), and an atlas also produced to show stakeholders the results as part of the overall strategic plan.

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Brazilian Aquaculture Sustainable Development Index

Brazil has undertaken development of an Aquaculture Sustainable Development Index (ASDI), used to rank the overall sustainability of aquaculture development in freshwater lakes. Four sub-indices are incorporated, covering social sustainability, environmental sustainability, institutional sustainability and economic sustainability, each graded between 1 (poor) and 5 (high), with 3 being average. Each sub-index has up to five criteria that are evaluated and scored using an average weighting to calculate the overall sub-index score. Each of the four sub-indices are then weighted (social = 5, environmental = 4, institutional = 3 and economic = 2) to calculate the final score for the ASDI. A score of 3 to 4 suggests the lake is considered medium sustainability.

Further reading: No references are available. See case study in Annex 5.

Additional Reading

The following provide some additional references not specifically identified in Part 3, which offer additional routes to find required information on models and tools available.

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Byron, C., Link, J., Costa-Pierce, B. & Bengston, D. 2011. Modelling ecological carrying capacity of shellfish aquaculture in highly flushed temperate lagoons. *Aquaculture*, 314(1–4): 87–99.

Filueira, R., Guyondet, T., Comeau, L. A. & Grant, J. 2014. A fully-spatial ecosystem-DEB model of oyster (*Crassostrea gigas*) carrying capacity in the Richibucto Estuary, Eastern Canada. *Journal of Marine Systems*, 136: 42–54.

Lauer, P., López, L., Sloan, S. & Doroudi, M. 2015. Learning from the systematic approach to aquaculture zoning in South Australia: A case study of aquaculture (zones-lower Eyre Peninsula) policy 2013. *Marine Policy*, 59: 77–84.

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Salama, N. K. G., Murray, A. G. & Rabe, B. 2015. Simulated environmental transport distances of *Lepeophtheirus salmonis* in Loch Linnhe, Scotland, for informing aquaculture area management structures. *Journal of Fish Diseases*, 39(4): 419–428.

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Tironi, A., Marin, V. H. & Campuzano, F. J. 2010. A management tool for assessing aquaculture environmental impacts in Chilean Pataginian fjords: Integrating hydrodynamic and pellets dispersion models. *Environmental Management*, 45(5): 953–962.

Yusoff, A. 2015. Status of resource management and aquaculture in Malaysia. In: Romana-Eguia, Parado-Estepa, Salayo, & Lebata-Ramos, eds. *Resource enhancement and sustainable aquaculture practices in Southeast Asia: challenges in responsible production of aquatic species,* pp. 53–65. Proceedings of the International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia 2014 (RESA). Tigbauan, Iloilo, Philippines, Aquaculture Dept., Southeast Asian Fisheries Development Center.

Annex 5. Case Studies

To assist in the preparation of this publication, case studies from ten countries—Brazil, Chile, China, Indonesia, Mexico, Oman, the Philippines, Turkey, Uganda and the United Kingdom of Great Britain and Northern Ireland—were selected that represent partial or full implementation of aquaculture zoning, site selection and area management, covering different environments, species and farming systems.

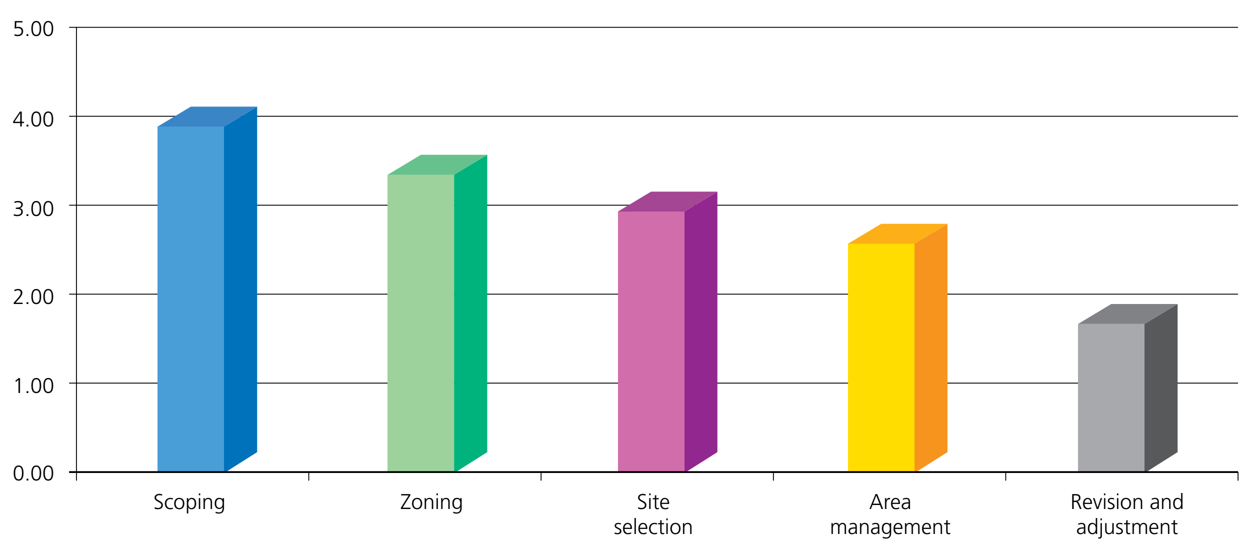
The case studies from Oman and Uganda are good examples of scoping as an initial first step in spatial planning for aquaculture. Case studies on aquaculture zoning cover marine fish cages (Indonesia, Turkey), fish farming in cages in freshwater reservoirs and lakes (Brazil), and shrimp ponds in Mexico. Case studies on aquaculture management areas include: Chile, Hainan Island in China, the Philippines and the United Kingdom of Great Britain and Northern Ireland.

Each of the ten case studies presented in this paper describe, according to their national context, the main spatial planning and/or management processes as defined in this publication and expand on their ideal steps and processes.

To generate general recommendations, the workshop participants identified strengths and weaknesses of the spatial planning and area management processes by assessing the case studies performance against a set of main criteria (as appropriate under each step), such as: (i) promoting stakeholders participation; (ii) establishing agreed national/subnational priorities for aquaculture; (iii) enabling policy, legal and institutional frameworks; (iv) identifying main issues and opportunities; (v) conducting assessments of suitability for aquaculture; (vi) assessing risks to establish priority actions, location, maximum production, management measures, etc., including aspects of carrying capacity and biosecurity. Also included were (vii) the development of management plans; and (viii) some form of monitoring and evaluation of the management plans.

A matrix is presented at the end of each case study to summarize according to each phase/step, if the phase/

FIGURE A5.1. Overall summary analysis of ten case studies.



Note: The average scores (0–5) according to the main spatial planning processes/steps are presented (i.e., 0 not achieved to 5 fully achieved).

step was either well done/achieved (briefly describing the main activities) or not done/not achieved (still pending). In addition, the matrix lists the associated/main activities and tools; a rating (0 not achieved to 5 fully achieved); and an approximate "incremental" investment needed for each step (United States dollars).

As a result of this exercise, it was concluded that scoping, as described in this paper, and aquaculture zoning and site selection are common processes in all the case studies, and in most cases steps (i) to (v) are followed. However, the establishment of aquaculture management areas (AMAs) with specific management plans is somewhat less common, and the criteria (vi) to (viii) are rarely considered (Figure A5.1).

According to the findings, the carrying capacity of an aquaculture site is rarely assessed. Some models and proxies are used, but in general there are no ecosystem response or long-term assessments. Management plans are often present for each site (in the case of large farms), but they are rare or less explicit for clusters of farms, aquaculture zones and AMAs. Monitoring and evaluation of management plans for AMAs are therefore rare or less implemented. However, in some areas, proposals for zoning and AMAs have already been initiated, such as in the aquaculture parks in Brazil and Uganda. Other countries like Indonesia, Mexico and Oman will need more time to report on their implementation.

The information described in the case studies and the feedback received from the authors of the case studies during a workshop in Turkey was used to improve and complete the spatial planning and management processes described in the main part of this publication.

Brazilian Aquaculture Parks—Fish Farming and Mariculture

João Felipe Nogueira Matias[1]

ABSTRACT

In Brazil, the waters are owned by the federal government (Union) or by the states. In Union waters domain it is the great differential of the Brazilian aquaculture. More than 200 reservoirs (used to generate electricity) are available for aquaculture, with a carrying capacity of almost 2.5 million tonnes of fish per year. For over 20 years we attempted to achieve the use of these reservoirs for fish production, but the existing legal framework at that time, does not let us make it possible. Only in 2003, Decree 4895/2003 enabled the legal certainty necessary for the implementation of aquícola areas and aquícola parks and the first concessions were made in 2009. Currently, there are fish farms in more than 10 reservoirs.

Expensive and time-consuming studies, which take into technical, geographical, social, economic and environmental parameters, are needed for the demarcation of these parks. After these studies, the parks are demarcated and public hearings are held to discuss the implementation and occupation. Actually, there are two crucial issues surrounding this program in Brazil: i) environmental monitoring which allows a simple and faster environmental licensing process; ii) the management of parks that allow an orderly settlement.

Thus, the exchange of experiences with other countries working with aquaculture parks and the support of institutions such as FAO and World Bank will be very useful for Brazil to move forward with this public policy that will put our country as one of the largest aquaculture producers in the world with sustainability.

1. INTRODUCTION

1.1 Brazilian Aquaculture

In 2014, the national aquaculture production was 562,500 tonnes (FAO, 2016). Following the pattern observed in previous years, the bulk of aquaculture production comes mainly from the fresh water fish culture (especially Tilapia—*Oreochromis niloticus* and Tambaqui—*Colosoma macropomum* and its hybrids) with 474,300 tonnes. The marine culture was

TABLE 1. Aquiculture production in Brazil in 2011.

Aquaculture	2014 Production (tonne)	%
Total	562,500	100
Fish Culture (freshwater)	474,300	84,32
Crustaceans (shrimp)	65,100	11,57
Molluscs	22,100	3,93
Aquatic Plants	700	0,13
Other Animals	300	0,05

Source: FAO (2016).

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

Matias, J. F. N. 2017. Brazilian aquaculture parks—fish farming and mariculture. In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document*, pp. 148–169. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

represented by shrimp culture (*Litopenaeus vanammei*), with 65,100 tonnes; molluscs (mainly *Perna perna* and *Crassostrea gigas*), with 22,100 tonnes. And Brazil also has aquatic plants (700 tonnes) and other animals (300 tonnes) in its aquaculture production.

1.2 Aquaculture in Waters Owned by the Federal Union

According to the ANA (2007), Brazil's geographic position is a privileged one when it comes to water resources, considering that the average discharge of the rivers in the Brazilian territory add up to 180 thousand m^3/s. Over the course of a year, this figure corresponds roughly to 12 percent of the world's available water resources. In addition to that, Brazil has an 8,500 km long coastline, a 200 nmi[2] Exclusive Economic Zone and, according to Ostrensky, Boeger e Chammas (2008), over 5.5 million hectares of waters impounded in lakes and reservoirs. According to these authors, Brazil's climate is predominantly tropical, it is self-sufficient in grain production, and it benefits from the fact that qualified structures for staff training and Research and Development are abundant, as well as existing industries that provide services, equipment and all sorts of other input to aquiculture.

Thus, Brazilian aquaculture's growth potential is one of the largest in the world. Nevertheless, such increase of the output of aquaculture must be accompanied by a corresponding shift of the public sector's role in the area. Ostrensky, Boeger e Chammas (2008) conclude by recommending the implementation of the following policies: focusing funds on aquacultural extension services, building efficient mechanisms to guarantee health and sanitary compliance, promoting the creation of new markets, and adjusting credit lines and instruments that ensure simple legalization procedures for businesses.

The expansion of aquaculture in water bodies under federal control must be subject to regulatory mechanisms—not only due to the fact that these waters are a common good, but also because it would affect other users of these water resources—and an instrument created to order and regulate the assignment policy of the Union domain waters for aquaculture purposes was established by a new agrarian structure, the Aquaculture Parks. These parks must transform aquaculture in a great alternative development for communities located in the vicinity of dammed water reservoirs and in coastal areas of Brazil; with the possibility of promoting development based on the dimensions of technical, economic, social and environmental sustainability.

Types of Concession

Free Concession

The NI[3] 01/2007 rules that "concession of usage rights over physical spaces in water bodies under Federal control for aquaculture purposes may be free, when intended for members of traditional communities contemplated by social programs, as long as their selection processes have been carried out by the Ministry of Fishing and Aquaculture. MFA can only concede usage rights freely through the publication of Notices of Selection that clearly describe the participation criteria. There are two types of criteria:

- The elimination criteria (individuals whose family income is below five minimum salaries and that have proof of residence in municipalities surrounding the reservoir in which parks and/or aquaculture sites are being tendered);
- And the classification criteria, that take into account social and economic aspects of the submitted proposals through the evaluation of objective parameters that measure the capability to effectively fulfil the aquaculture project and its level of compliance with the MFA's Development Programme's social goals.

Paid Concession

The concession of usage rights will be paid for in the case in which more than one interested party compete for a particular space and its cost must be determined through a public selection process. The public selection process criteria should consider objective parameters that lead to the achievement of intended goals described in sections I to IV of Article 1 of the Decree in 4895, of 2003. The Winner of the public selection will be the application that offers the best indicators in the following social criteria: the proposal's enduring viability and sustainability over the years; its

2 Nautical Miles.

3 Normative Instruction.

contribution to the increase in the production of fish; the creation of new jobs; and social actions aimed at expanding the supply of food.

The appreciation of the "Financial Proposals" will take into consideration the type of bidding set out in paragraph 1 of section IV of Article 45 of Law No. 8.666/93, that is, the "Greater bid or offer." The Winner will be the bidder whose bid complies with tender specifications and who offers the highest bid. In the case of absolute equality of conditions between two (02) or more Financial Proposals as tie-breaker will be held the drawing for the winner's choice, subject to prior notice, as provided by paragraph 2 of Article 45 of Law No. 8.666/93.

Legal Framework

Some instruments that are part of the legal framework that solved the procedure for concession of waters under Federal control for aquaculture purposes are the Presidential Decree No. 4895 of 2003 and the Interministerial Normative Instructions (INI's) No. 06 of 2004, No. 07 of 2005 and No. 01 of 2007.

Presidential Decree No. 4895 2003 (BRAZIL, 2003), in its Article 1 states that "the physical spaces in water bodies under Federal control may have their usage authorized for purposes of aquaculture development, given their compliance with order, location and preference criteria, that take into consideration: sustainable development; the increase in the Brazilian production of fish; social inclusion; and food security." The Decree further states that "such authorization will be granted to individuals or companies that fall into the category of fish farmer, as specified in the legislation."

The INI No. 06 of 2004 (BRAZIL, 2004) established additional rules for the concession of usage rights of physical spaces in water bodies federally owned for aquaculture purposes. The INI No. 07 of 2005 (BRAZIL, 2005b) establishes the guidelines for the implementation of parks and aquaculture sites. INI No. 01 of 2007 (BRAZIL, 2007) establishes operating procedures for effective usage authorization of physical spaces in water bodies under Federal Control for aquaculture purposes.

With the creation of the Ministry of Fishing and Aquaculture (MFA) by the Law No. 11,958/2009 (BRAZIL, 2009b), the attributions of the former SEAP/PR[4] were transferred to the Ministry. According to the existing protocol, the Ministry of Fishing and Aquaculture (MFA) receives requests from aquaculture sites (spontaneous demands) or performs the demarcation of aquaculture parks (induced demand). In either case, a technical and GIS assessment is conducted by the Aquaculture Planning Secretariat (SEPOA) of the MFA. If the analysis is negative in either of the two cases (technical or GIS), the candidates proposal will have to be reformulated. In case of a positive opinion, it will then be analysed by the Brazilian Navy, the National Water Agency (NWA)—if in continental waters (in coastal waters the ANA assessment is not needed)—and IBAMA.[5]

If there is any negative opinion, the responsible institution returns the case to the MFA, which in its turn will forward it to the interested party for correction purposes. If the three opinions are positive, the proposal proceeds to the Federal Union Patrimony Secretariat (SPU),[6] so that the area in question can be transferred to the MFA (INI No. 01 of 2007). That is done through a public selection process (bidding), according to Law 8,666/93 (BRAZIL, 1993), the concession of physical spaces in waters under Federal control in question, for fish farming. Before the transfer is carried out, it is still necessary that the environmental licenses by the State Agencies for the Environment (OEMA's) are issued. Figure 1 illustrates the flowchart of the process of concession of usage rights of water bodies under Federal control for aquaculture purposes.

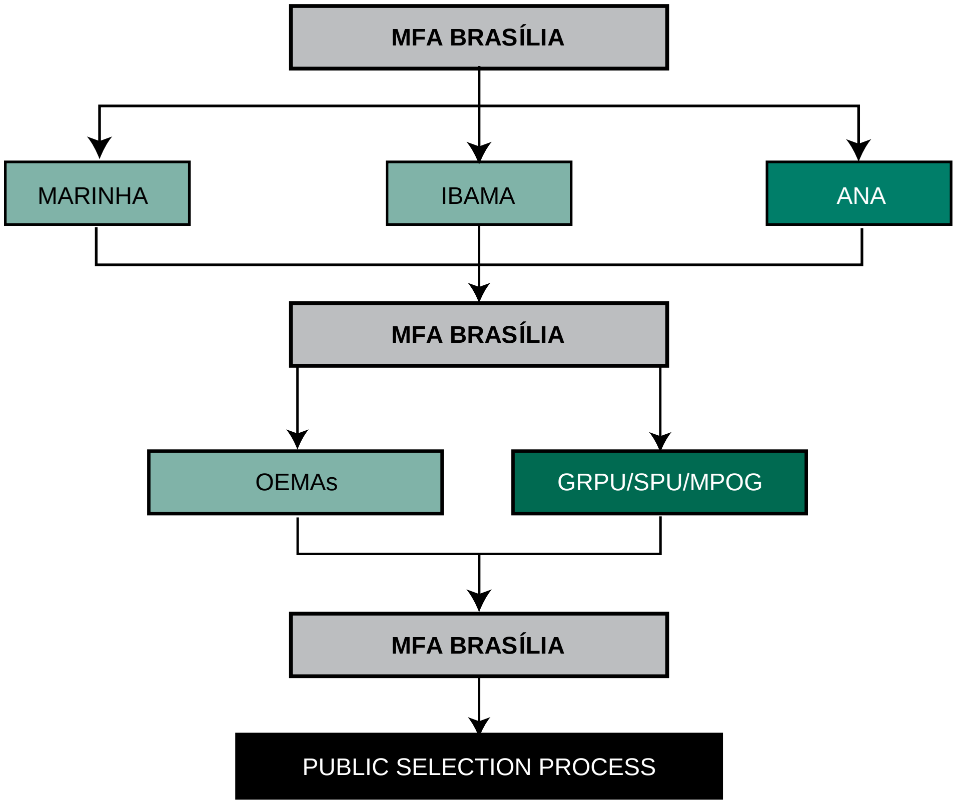
It is the MFA's responsibility, according to Presidential Decree No. 4895 of 2003, to inform all governmental institutions involved in the process of granting

4 Aquiculture and Fishing Special Secretariat for the President of the Republic—*Secretaria Especial de Aquicultura e Pesca* in its Portuguese original denomination.

5 Brazilian Institute of Environment and Renewable Natural Resources—*Instituto Brasileiro de Meio-Ambiente e Recursos Naturais Renováveis* in its original portuguese denomination.

6 *Secretaria de Patrimônio da União* in its original Portuguese denomination.

FIGURE 1. Flowchart of the processing of transfer processes use physical spaces in the Union domain waters for aquaculture purposes.



permission of use of aquacultural areas of either the authorization or the non-authorization, so that each institution (ANA, IBAMA, the Navy) can take the measures within their authority, which are as follows:

National Water Agency[7] (ANA)

It will be up to the ANA, when requested by the MFA, to issue a preventive grant that ensures the availability of water reservoirs in order to allow the investors to elaborate plans. The preventive grant will be automatically converted by the ANA into the grant of usage rights on water resources after the project's approval by the MFA.

IBAMA

IBAMA—or any other body delegated by it—shall analyse the project within its competence and forward its recommendation to the environmental agency of the State to which the area belongs to, either to issue the necessary environmental permits or not.

7 *Agência Nacional de Águas* in the original Portuguese form.

NAVY

The Port Authority shall send the MFA its conclusive opinion on safety in maritime traffic, as ruled by the Maritime Authority Norm that sets the procedure for the execution of building works under, on, and on the banks of waters under Brazilian jurisdiction.

SPU

The Federal Union Patrimony Secretariat (SPU), being responsible for the management of Federal Union assets, shall issue an official record on having transferred Federal Union Ownership Waters to the MFA, so that the latter can carry out the Concession of Usage Rights to the interested parties, according to Law 8666/1993.

SEAs[8]

According to the CONAMA[9] Resolution No. 413, 2009 (BRAZIL, 2009b), it is the State Environmental Agency's responsibility to issue the necessary environmental permits that will allow the implementation and the operation of activities related to aquaculture in the conceded area. CONAMA Resolution No. 357, 2005 (BRAZIL, 2005a), rules on the classification of water bodies and more precisely on environmental guidelines to classification. It also establishes conditions and standards for effluent discharges and other measures. The two referred CONAMA resolutions are those that influence environmental permitting of aquaculture.

2. ZONING PROCESS

The Ministry of Fishing and Aquaculture (MFA) sees the planification of aquaculture in Federal Union waters as one of its top priority actions, which includes several mechanisms intended to promote a sustainable increase in fish production in the country, and also to promote the planification and management of mariculture via the implantation of Aquaculture Harvesting Parks. For the implantation of aquaculture ventures in Federal Union, specific rules shall have to be followed in order to have a permit to use Federal Union waters granted, according to Decree No. 4,895/2003 and the Interministerial Instruction No. 06 of May 31, 2004.

The process of implanting an Aquaculture Park includes several stages: studies, demarcation, legal regularization and implementation.

Studies for demarcation of aquaculture parks take various factors into account, mapping exclusion areas (such as protected areas—PA—preserved totally, areas of port activity, other impediments planned by management plans, etc.); classifying the areas according to their degree of suitableness for the practice of aquaculture; analysing physicochemical aspects, species that will be farmed and the current legislation; conducting a study of potential environmental conflict areas as well as mapping of infrastructure, logistics and community organization. These studies are intended to help choose growing areas that integrate aquaculture with other activities developed in the area as a way of mitigating conflicts related to the area's use and also to standardize the system of cultivation so to decrease the various impacts, as well as providing social and economic benefits to the community, ensuring the rational use of natural resources, as well as protecting and preserving the functioning of the ecosystems, and reducing the production and dispersion of pollutants, among other factors.

After these studies, the next step is the demarcation of aquaculture parks. The demarcation is a planning tool for the delimitation of areas for aquaculture, promoting the planning of local production and generating subsidies for aquaculture management in the region.

After the establishment of the Aquaculture Parks by this Ministry, each park's proposed project is submitted to the other Departments involved in the Usage Rights Concession process (Brazilian Navy, National Water Agency, SPU and Environmental State Agency) for regularization.

Once they are regularized, Public Hearings are held in order to disclose the implantation of the parks in their respective municipalities. Then the public selection process for transfer of the defined aquaculture parks areas is open, paid or non-paid. The selection of non-paid areas has a highly social aspect and these areas are therefore offered freely, via public tender. The selection of entrepreneurs for paid areas is done through bidding, of which the winner is the one whose bid for the area's usage rights is the highest. The Aquaculture Parks are implanted by the Aquaculture Planning Department (SEPOA) of the MFA, with the support of federal superintendence in every State.

3. CARRYING CAPACITY ANALYSIS

In Brazil, the classification of water bodies and environmental guidelines for such classification, as well as the conditions and standards for effluent discharge into water bodies are recommended and established by the National Environment Council (CONAMA) through Resolution 357 of 17 March 2005. The standards of water quality established in this resolution

8 State Environmental Agency: Órgão Estadual de Meio-Ambiente (OEMA) in the original Portuguese form.

9 National Environment Council—*Conselho Nacional de Meio-Ambiente* in its original Portuguese denomination.

set individual limits for each substance in each class of water that must be achieved or maintained in the long run.

The National Water Agency—ANA, an agency of the Ministry of Environment responsible for regulating the use of water among other attributions, based on CONAMA's resolution, is responsible for determining the amount of phosphorus that can be released to the environment through the feed in order to ensure the sustainability of the activity. All aquaculture projects in Federal Union waters, whether private or governmental, must be approved by that agency.

To calculate the maximum increment of nutrients from aquaculture, ANA uses the conservative model of Dillon and Rigler (1974) adapted to reservoirs. In aquaculture, ANA estimates a maximum increase of 1/6 of the concentration permitted by CONAMA Resolution 357/2005 for water bodies of Class II, in which the use for aquaculture farming is included. This corresponds to 5 mg/m^3. The other 5/6 would be reserved to other uses that add phosphorus to water, such as the dilution of domestic and industrial sewage, agricultural activity and, of course, natural phosphorus increment.

Thus, each grant issued today includes a maximum annual production of fish, the maximum daily amount of feed given and the maximum daily load of phosphorus added to the water—as well as other items such as the grant's validity period and the geographical coordinates of the project.

The Ministry of Fishing and Aquaculture is responsible for planning, regulating and monitoring aquaculture activities and for promoting research to improve the carrying capacity calculation method.

4. SITING AND LICENSING

The Environmental Licensing is a form of pre-controlling activities involving the incidence of direct or indirect impacts on natural resources and for this reason is the environmental management tool in the pursuit of reconciliation of interests between economic development and preservation of the environmental balance. The conduction of this procedure is under responsibility of environmental agencies within the Executive, in regular exercise of its police powers, defined by law, in which the competent body aims to grant or not grant the environmental license. The environmental permit seeks to guarantee that these preventive measures in favour of the environment are compatible with sustainable development.

However, one of the difficulties encountered by Brazilian farmers is related to the regularization of their businesses, particularly in obtaining environmental licenses. The current procedure for obtaining environmental permits for aquaculture enterprises is complex and extremely difficult to be done by small farmers acting alone. The main aspect of this limitation is related to the time and costs associated with legalization. The need to spend, in advance, time and money, also discourages the development of the sector. The higher the cost of the regularization process is, the greater the chance that only large, diversified companies will have time and capital to go through the whole process.

It is also responsible for informing about legal doubts related to environmental permitting of aquaculture in the Federal Union seawaters, considering that the Complementary Law 140/2011 assigns to the Federal Union, according to clause b, section XIV of Art. 7:

"Art. 7: The following administrative actions are under the Federal Union's responsibility: XIV—promote environmental permitting of projects and activities: b) located or developed either in the territorial sea, the continental shelf or the exclusive economic zone."

In order to implant Marine Aquaculture Parks in a regularized manner the consent of some relevant agencies will be needed, including environmental agencies, by issuing the environmental permit. In most cases, this permit can be issued by the State Environmental Agency—OEMA. Environmental permitting's goal is to protect environmental quality, seeking to significantly reduce the impacts of that activity. One of the main ways to control the possible impact on the environment is through the environmental conditions, which are demands made by the competent agent for maintenance of licenses, having in mind its impact mitigating role.

The conditions are what the interested parties have to commit to, considering their project and the mitigation programs and measures established in environmental studies, both by law and in accordance with the objectives and goals sought to mitigate the predicted environmental impacts. In this sense, the environmental conditions are demands made throughout the licensing process by the relevant agent and they also have the role of mitigating impacts. In many cases the conditions become the main base of verification of environmental compliance of the project, either in terms of state supervision or in reviewing the environmental permits, via the verification compliance with the proposed plans and programs or even the various recommendations in the mitigation measures proposed the environmental study. In addition, they are taken as a basis for the formulation of environmental monitoring programs within the aquaculture parks.

The candidate's noncompliance with these conditions can lead to various penalties, including the termination of the license, and the consequent disruption of the licensed activity, the nonextension to following phases, or nonrenewal of the agreement.

5. OPERATION AND MANAGEMENT

Aquaculture Park Demarcation Studies

Studies indicate which areas are technically best suited for the demarcation of aquaculture parks. Furthermore, each study provides details of socioeconomic regions, allowing an analysis of how the town is organized. With the completion of studies and the identification of areas of higher suitableness already demarcated, begins the process of defining areas to be granted.

The Definition of Areas to Be Conceded

The data collected and the parks already demarcated by studies should set the guiding light of the process of defining priority areas for bidding, which still goes through an extensive process of meetings with agencies and local entities in order to collect the demands of communities and disseminate the results of the studies.

Disclosure and Publicizing

As in most cases local communities are the main beneficiaries of aquaculture parks, it is fundamental to develop an efficient publicizing plan in order to foment an efficient occupation. Usually the period between studies for demarcation of parks and their actual tender is long (over 3 years) making local communities reticent about the possibility of occupying the parks, and without such publicizing, communities may even not occupy the parks. In this scenario, contact must be made with the community shortly before the public tender dates. Visiting these places is intentional to clarify where the parks will be installed, how the tendering process takes place and what are the prerequisites to participate. The publicizing must be conducted by local bodies that already have familiarity with these communities, in order to facilitate contact and accelerate the process, while also considering the credibility that these institutions already have in the region.

Public Tender

After the completion of the disclosure and publicizing stage, the bidding process begins and may be made in the paid and/or the unpaid forms, depending on the target audience.

Mobilizing for the Occupation

The occupation has been one of the hot spots around the park management process. This is because many people who win an area are not producers or develop the activity in the informal sector and need to transfer their cultivation to the new demarcated area. Thus, a suitable occupation can facilitate management of the park and all following steps.

Once the winners of each area are known, the mobilization for occupation of these areas begins. To make this process quick, local extension entities, municipalities and associations must participate, taking the results of the bidding process to the communities, and initiating contact with the winners so that they can occupy their respective areas. This methodology seeks an occupation with fewer conflicts, more quickly and with standard equipment. While this step is conducted in the area of aquaculture park by local authorities, the

MFA should start the nautical signaling process. Thus, it is expected that by the end of the occupation phase, the signalling process will have started and will finish as soon as possible.

The Occupation of Aquícola Parks

The occupation phase can take place between the definition of which parks will be tendered and the effective occupation of aquaculture parks (beginning with the installation of the equipment for cultivation). Thus, this step has three phases: disclosure, tendering and mobilization. However, for the beginning of the occupation it is essential that the region presents an installed support infrastructure. The construction of a scenario that offers minimum conditions so that the producer can develop his work should be a priority for the occupation of the park. Investments in infrastructure and specific projects can be a way to begin the installation and operation of parks; however, the creation of a long-term investment program is crucial for the sustainability of these projects.

Aquaculture Parks Management

The first step of this process is the creation of a managing committee (MC) in the region. In this case, the Committee aims to:

"Act as an advisor and propositional body and advisory decisions in the administration of the Aquaculture Parks, acting as a participatory management tool to assist in the development of rules, criteria and standards for the management and planning of sustainable use of Aquaculture Parks."

Once the MC is established it is responsible for systematizing the process, describing what each institution can and should do, and establishing a description of the production process performed in the parks that are part of that Committee. Thus, all processes related to parks should be described and recorded in the MC, from bureaucratic aspects to the actual concession, even those related to health monitoring and the market of suspension. To define the occupants members of the parks, the participation of the producers is essential. Thus, each park should have a representative to the Committee, being chosen among the occupants of aquaculture areas in the park. In case the assignees of the park already have an organization constituted as an association, cooperative, etc., the President of that institution must indicate the MC member.

Supervision

Supervision and monitoring are under the responsibility of the MFA or a delegated authority for it. Thus, aspects related to the implantation of structures, effectively occupied areas of origin of the young form, destination and volume production will be monitored in an indirect and direct way by the MFA.

Indirect supervision will occur through annual completion of an Aquaculture Production Report in Union waters—Aquaculture Model Navy, which will have its system linked to the Registrar General of Fishing Activity—RGP. With this you obtain information, and so direct the direct enforcement actions.

Already the direct supervision should be delegated to local authorities since the MFA does not have enough staff to supervise all Aquaculture Parks. However, these actions can be directed according to recommendations of CGs and the results of the indirect supervision.

Another relevant point is the monitoring of the environmental licensing conditions. This point should also follow the methodology cited above; however the Steering Committee plays an important role in collecting the occupants of the parks following these recommendations, since everyone will be harmed if the rules are not followed. Already the supervision regarding the installation of nautical sign is the responsibility of the Navy of Brazil.

The supervision of aquatic animal health aspects involves several institutions (state and municipal health surveillance and ministry of agriculture, livestock and supply—MAPA) and it must follow the recommendations of federal, state and local legislation.

Monitoring

Monitoring is the stage of the management model designed to ensure the efficiency of all stages of process management of aquaculture parks. This model proposes that monitoring is carried out through indicators, and these should be designed for each specific stage. Thus, according to the results obtained, the process management may be revised to solve the identified problems.

6. ENVIRONMENTAL MONITORING

The environmental monitoring can be understood as a data collection process and continuous and systematic monitoring of environmental variables, in order to identify and evaluate qualitatively and quantitatively the conditions of natural resources and environmental trends in a predefined time scale. In addition to identifying trends, the results must as far as possible, provide a database for projections of future developments.

The UNEP (United Nations Environment Programme World Conservation Monitoring Centre, 2006) explains that monitoring is an activity that involves repeated observation, according to a predetermined schedule of one or more elements of the environment so that you can detect its characteristics and trends. The tracking therefore provides tangible information on past and present environmental conditions within a regular database. In addition to the environmental information, monitoring systems can also collect social and economic information that is relevant to the systemic understanding of environmental issues.

Before deploying a monitoring system it is critical to have a coordinated and strategic vision (Department of Climate and Industry, 2011):

- What needs to be monitored;
- How the different monitoring systems work together;
- How the information will be communicated; and
- How will the monitoring results be used.

With this plan in mind, environmental monitoring becomes a source of critical information essential to evaluate the current state of the environment, to predict potential impacts and prevent them, and to develop sound strategies for environmental management, and to assist in decision making.

According to Woerden *et al.* (2014), these systems can be developed for various purposes, such as:

- to evaluate the quality of the local environment, and to promote local awareness of the environment;
- to determine compliance of a certain activity with national and international standards;
- to assess population exposure to pollution, and the impact on human health that such exposure may cause;
- to identify potential threats to the natural environment and to develop contingency systems and risk/disaster prevention;
- to identify sources of pollution that may harm the multiple uses of aquatic environments by offering the same control measures;
- to provide information for planning and executing environmental management and planification; and
- to support the development of public policy, management tools and the determination of environmental priorities.

So that aquaculture can grow without environmental impacts becoming significant enough to impair production and the environment, it is necessary to elaborate measures of planification, control, recovery, environmental preservation and conservation, through instruments that allow the maintenance of natural resources in their ideal conditions.

The main bottleneck in the set water monitoring initiatives in Brazil, and also in the world, is the lack of integration between existing databases, as well as the methodologies used between continental and oceanic systems. It is of utmost importance that the environmental monitoring of these areas aligned, and that water systems are seen in a systematic and integrated way. Environmental management for aquaculture parks can consist of the following programs:

- Water quality monitoring.
  The monitoring of water quality should take into account the CONAMA Resolution No. 413/2009. The parameters set for this resolution represent the very least that should be monitored for compliance with environmental permitting conditions of an aquaculture park.

- Solid Waste Residue Management Plan.
  The Solid Waste Management Plan should be developed through actions that prioritize the sustainable management of waste from the parks. It is important to follow recommendations to reduce the generation of waste and to determine their management and arrangement, in order to minimize environmental impacts. In the case of clam harvesting, for example, the generation of shells is substantial. These may have an alternative and sustainable destination, such as the building materials industry, and even handicrafts, generating income for the communities.

- Environmental Education Programme.
  To raise awareness of aquaculture producers, it is necessary to develop an Environmental Education Programme that aims to foment individual and collective participation in the preservation of the environment using aquaculture as a tool, clarifying and making them aware of the interdependence between good management practices, the maintenance of environmental quality and sustainability of this type of cultivation.

- Monitoring the Surroundings (Fauna/Flora).
  Monitoring the surroundings, including the fauna and flora, has the task of monitoring and mitigating the impacts that aquaculture farms can generate on the animals and vegetation during installation and operation of the project. Thus, the areas of influence of the projects should be evaluated in order to collect and record the animals and vegetation found before and during the operation of the park.

- Recovery of Degraded Areas.
  In the case of suppression of native vegetation in estuaries, mangroves and around reservoirs, a Recovery of Degraded Areas Plan should be carried out. The suppression can occur due to the moving of equipment and people in their access to the cultivation site as well as due to the installation of supporting structures. The species that were directly affected must be closely observed, prioritizing their restoration.

- Good cultivation practices.
  Good Cultivation Practices are a set of actions to be undertaken by the entrepreneur himself in the day-to-day of his work, that is well planned, can greatly optimize his business and at the same time can make it more sustainable. Actions must prioritize production safety, the proper choice of species and cultivation system, the feeding of farmed organisms; the improvement of production, among others topics.

The Tilapia Cage Farming in the Castanhão Dam, State of Ceará, Brazil

The Castanhão dam was built on the bed of the Rio Jaguaribe in Ceará, Brazil (Figure 2) and inaugurated in 2003. The reservoir consists of a 60 meter high earth barrage, and an artificial lake with a 32 500 hectares when at its lowest level and 60 hectares at highest capacity, estimated at roughly 6.7 billion cubic meters (DNOCS, 2009).

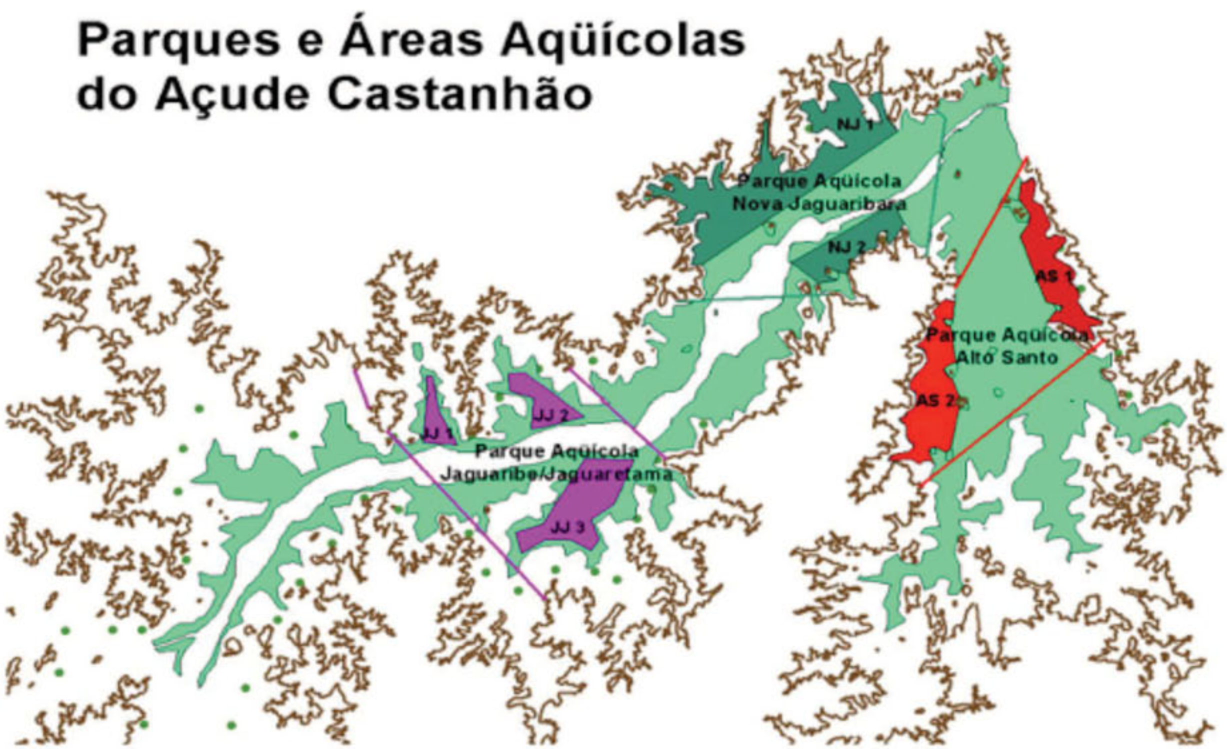
The Aquaculture Parks in Castanhão Dam

In 2008, the Aquaculture and Fishing Special Secretariat (SEAP/PR)—nowadays Ministry of Fishing and Aquaculture (MFA)—in partnership with the National Water Agency (ANA), the Environment Superintendency of the State of Ceará (SEMACE) and the Drought Prevention National Department (DNOCS), carried out the demarcation of the aquaculture parks in Castanhão Dam, in Ceará (Figure 3). This coordinated action allowed the demarcation of three aquaculture parks in Castanhão (Jaguaribe/Jaguaretama, Jaguaribara and Alto Santo), with more

FIGURE 2. Castanhão Dam.

Source: DNOCS, 2009.

FIGURE 3. Aquaculture Parks in the Castanhão Dam—Ceará.



Source: MFA, 2012.

FIGURE 4. Tilapia cultivation centers in the Aquaculture Parks in the Castanhão Dam.

Source: Osvaldo Segundo, 2011.

than 680 cultivation areas and capacity to produce 32 000 tonnes of fish per year.

In 2008, the MFA granted the usage rights of physical spaces in the Federal Union waters for fish farming purposes in these parks. Figure 4 depicts the cultivation of tilapia fish in one of the dam's aquaculture parks.

The Elaboration of Sustainability Indexes

Social Sustainability Sub-Index (SSS)

Among the five variables that compose this sub-index: the illiteracy rate (among people aged 15 years or more) was above average and the percentage of adults (15 years and older) having finished their primary education was below the average; which made these two variables yield the lowest "score."

The other three variables: percentage of households with adequate water supply, percentage of households with access to the sewage collection network and average family income per capita in reais, were above the average; which made these three variables yield the highest "score."

The social sustainability of fish farming in aquaculture parks in Castanhão-Ceará sub-index was 3.4, which qualifies as a medium social sustainability score and had five weighting for purposes of calculating the aquaculture sustainability index. This sub-index shows medium sustainability and suggests, with regard to training and identifying the social profile, that aquaculture was of crucial importance, with all variables yielding better results among the beneficiary group (already produces fish) than in the control group (still doesn't produce fish).

But when it comes to variables that are inherent to the public service, it is possible to conclude that greater investments in social related aspects are greatly needed, especially in education.

Environmental Sustainability Sub-Index (SSA)

The sub-index of environmental sustainability of fish farming in cages in aquaculture parks in Castanhão-Ceará was 3.4, which qualifies as medium environmental sustainability, and weighting had four in the calculation of the final aquaculture sustainability index.

Among the five variables that compose this sub-index, the rational use of natural resources and the risk of eutrophication were below average, which made these two variables yield the minimum "score." The other three variables: the existence of an environmental permit, the destruction of vegetation and the viability without electricity or fossil fuels were above the average, which meant that they stayed within the highest level of "score."

This sub-index yielded a medium sustainability level, which proves that aquaculture is not of high environmental impact, but is influenced and influences the environment, as well as all other activities around the aquaculture system; whereas in most cases, other activities have greater environmental impact.

Economic Sustainability Sub-Index (SSE)

Among the five variables that compose this sub-index, all five variables (average price/cost of production, break-even point, net present value, "payback" and attractiveness rate) were above the average, which made these yield the highest level of "score."

Thus, this sub-index of economic sustainability was rated 5.0. It is considered highly sustainable and had weight 2 in the calculation of the fin Aquaculture Sustainability Index. The economic sustainability sub-index yielded high sustainability results, which proves that an activity that generates alternative employment and income in poor and disadvantaged communities tends to have huge returns in quality of life for populations that are socially vulnerable.

Institutional Sustainability Sub-Index (SSI)

Among the five variables that compose this sub-index, the approval of investments was below average, which made this variable to yield the lowest "score" level.

The variable "execution of decisions made at the meetings" was on average, which made it yield an intermediate "score."

The other three variables: active participation in the meetings, assessing the presented suggestions and participation in the choice of leaders were above average, which meant they yielded the highest "score" level (Annex 1).

Thus, the institutional sustainability sub-index was rated 3.8. It is considered of average sustainability level and had weight 3 in the final calculation of the Aquaculture Sustainability Index.

In this thesis, the institutional dimension was widely explored and the existence of two associative groups that have the power to build their own destinies and that see in aquaculture a way to improve their lives and that of their families was vehemently verified by the conducted case studies. However, this participation still lacks investments intended to strengthen and democratize the current management structures, having in mind the development of the territory in question.

Aquaculture Development Sustainability Index (IDSA)

Among the four sub-indexes that compose the Aquaculture Sustainable Development Index, the Social Sustainability Sub-Index (SSS) was rated 3.4; the Environmental Sustainability Sub-Index was 3.4; the Institutional Sustainability Sub-Index was rated 3.8 and the Economic Sustainability Sub-Index was 5.0. When we take into account the considerations made by local representatives, we had that the ADSI was equal to 3.71. It is therefore considered to be of medium sustainability. (Table 2).

- Unfortunately, after 5 years of the most strongest drought in 100 years and in a scenary of no management, no monitoring and no controlling by government agencies and local producers, the fish culture production in these aquaculture parks had two huge losses in 2015 and in 2016. We believe that it will need two or three years to be back, if it would be done in a sustainable way.

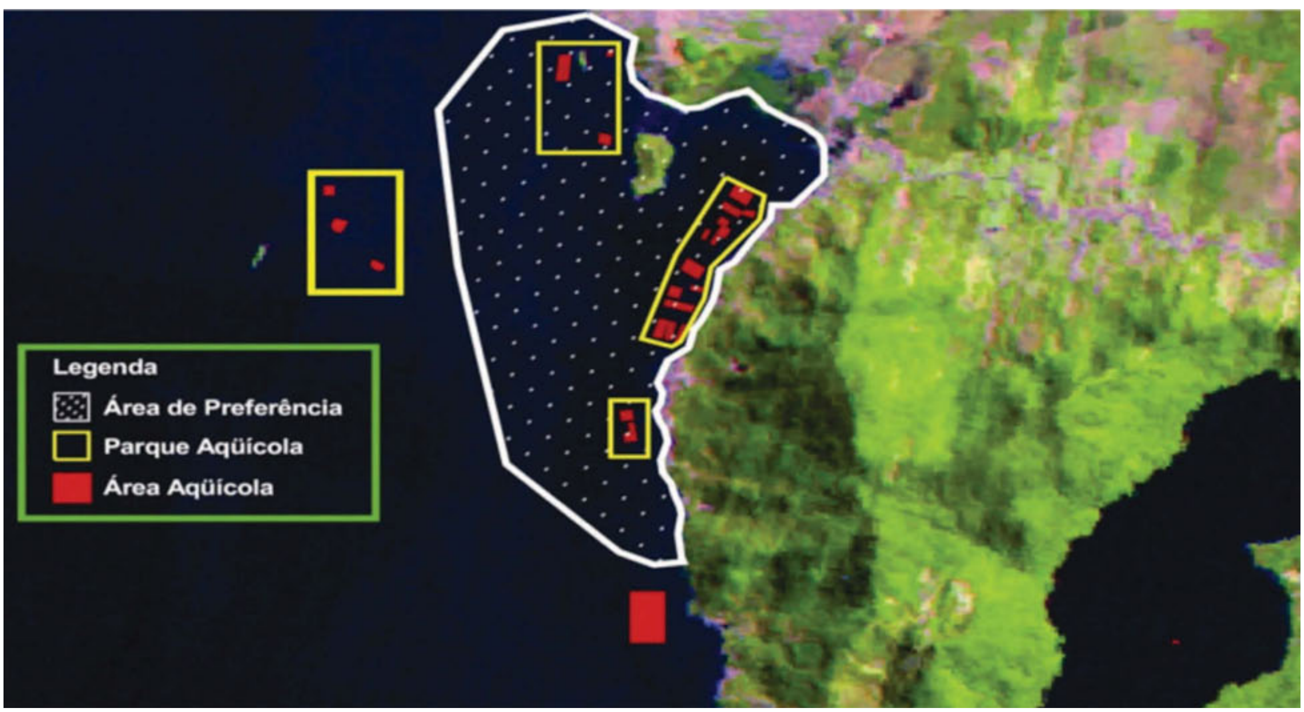
TABLE 2. Weighted elaboration of the ADSI. Thesis' results.

Sub-Index	Absolute Value	Weight	Weighted Value
Social	3.4	* 5	5 × 3.4 = 17
Environmental	3.4	* 4	4 × 3.4 = 13.6
Institutional	3.8	* 3	3 × 3.8 = 11.4
Economic	5	* 2	2 × 5 = 10
Subtotal	—	—	Σ (17 + 13.6 + 11.4 + 10) = 52.0
ADSI = Subtotal/14	—	14	Σ (52.0)/14 = 3.71

The Cultivation of Oysters and Mussels in Marine Aquaculture Parks in the State of Santa Catarina, Brazil

Santa Catarina is the only Brazilian State where Marine Aquaculture Parks where implanted with a formal Monitoring Plan through the Agreement No. 17/2012 between the MFA and the State Agriculture and Fishing Secretary of Santa Catarina—SAR (SICONV 775438/2012) having been technically implemented by EPAGRI—Agricultural Research and Rural Extension Company of Santa Catarina. According to EPAGRI (2014), the first public tenders were held in 2011, and currently most of the aquaculture sites have already been granted to producers. Furthermore, most of the seawater fish farms established in Santa Catarina (Picture 1) were granted permits by the competent environmental agencies for the cultivation of mussels and oysters (Picture 2).

PICTURE 1. Marine Aquiculture Parks in the state of Santa Catarina, Brazil.



PICTURE 2. Oyster and mussels cultivation centre in Marine Aquiculture Parks in the state of Santa Catarina, Brazil.

7. DISCUSSION AND CONCLUSIONS

Brazil has witnessed a period of huge development of its aquaculture, especially in the last ten years. The resolution of federal concessions to aquaculture has opened new possibilities of fishing production in our country. There are more than 5.5 million of hectares of water, only in reservoirs under federal domain. Thus, it was imperative to work in elaborating public politics which could give us the planning of this development process.

Actually, our country has a legal framework that still is bureaucratic, but that will allow the concession of usage rights to Federal Union waters to aquaculture. In this framework, we can highlight the Presidential Decree 4895/2003, the Interministry Instruction no 06/2004 and the CONAMA Resolution no 413/2009. This framework also allowed the first Federal concessions to aquaculture in Brazil and have democratized the access to Federal Union Waters, because there is a possibility to give nonpaid concessions to that population in social vulnerability who lives near the reservoirs, rivers and in the coastal areas and at the same time give the concessions to big companies, but through a paid process. We also have two different ways to give the federal concessions:

1. Aquiculture Areas: Through an individual or a company who have the interest in some areas and ask Brazilian Ministry of Fisheries and Aquaculture to give them the concessions;
2. Aquiculture Parks (both marine and freshwater): The Brazilian Ministry of Fishing and Aquaculture itself offers areas inside these parks to the producers.

In order to carry out the demarcation of Aquaculture Parks, complex studies are necessaries which include not only technical and environmental factors, but also social and economic ones. After the studies, aquaculture parks are demarked and the concessions process is realized, with a big and important participation of local stakeholders.

Brazil already has freshwater aquaculture parks in more than 25 (twenty five) reservoirs, and marine aquaculture parks in 4 (four) different states, with a capacity of almost 1.5 million tonnes/year with freshwater fish; 87,000 tonnes/year of moluscs; 197,000 tonnes/year of marine fish and 85,000 tonnes/year of algae in marine water.

Otherwise, the public policies for aquaculture parks are too recent. It wasn't until 2009 that first aquaculture parks got built and are in different stages of development:

- Aquaculture Parks with studies in development or to be started;
- Aquaculture Parks in demarcation;
- Aquaculture Parks in process of concession;
- Aquaculture Parks in production.

So, Brazil already has some conclusions to be discussed about these different experiences:

1. The necessary studies to demarcate the parks are too complex, expensive and slow;
2. The demarcation of parks remains a huge and difficult work for zoning, because we have different uses and users to water;
3. The process of concessions, although resolved and which give the legal security to the producers, are still slow and bureaucratic;
4. The aquaculture parks in production, remind a management, monitoring, controlling and supervision; that hasn't been possible to carry out (for different reasons).

- Since october 2015, the Ministry of Fisheries and Aquaculture was joined to the Ministry of Agriculture, Livestock and Food Supply (MAPA); and so, where we see MFA, we must understand MAPA.

Finally, the exchange of international experiences among countries can be crucially important in this process of development to planning aquaculture parks in Brazil and in many other countries. And actions like this, with the support of FAO and World Bank, must be incentivized.

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ANNEX 1. TILAPIA CAGES CULTURE IN CASTANHÃO RESERVOIR, CEARÁ STATE, BRAZIL—CASE STUDY EFFECTIVENESS MATRIX

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	The boundaries were defined after studies realized by some institutions (DNOCS, ANA, MPA, SEMACE) and after consultation with stakeholders considering the main geographical and hydrographical administrative, and social boundaries.		• Background documents; • EAA baseline reports; • Participatory meetings; • Consultations with relevant institutions.	4	350,000
1.2 Identify over-riding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	All relevant legislations, regulations, directives, decisions and administrative procedures related to aquaculture development were consulted.		• Review of relevant policy and legal framework; • Institutional analysis; • Stakeholder analysis; • Consultations with relevant institutions.	5	NA
1.3 Setting the broad development objectives and identifying the main issues	Understanding the development context considering natural and human resources and economy. Understanding the development options.		• Communication, consultation, participation; • Assessment of available resources, needs and values.	5	NA

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)				Identifying and prioritizing the main issues	Tree issues identification and priorization
1.4 Zone boundary definition based on relevant criteria	Essential environmental socioeconomic and governance criteria were identified for the zone as well as risks (e.g., eutrophization).		• See bullet points for activities and tools in Step 1 above; • Participatory meetings; • Literature review and Internet searches;	4	NA
1.5 Gross estimation of potential production/ area	The maximum production per aquaculture zone was estimated based on Dillon & Riggler Methodology.		• Simple mass balance models; • Sophisticated nutrient models.	3	NA
1.6 Formal allocation of the zone for aquaculture purposes	Zones were allocated through a national/ provintial norm/rule sharing aquaculture with other uses of water.		• Participatory allocation process; • Communication and dissemination of allocated zones.	5	NA
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	Essential environmental socioeconomic and governance criteria were identified for the site as well as risks (e.g., eutrophization).		• Participatory meetings; • Literature review and Internet searches; • Field data collection and field measurements.	4	NA

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.2 Carrying capacity estimation	For cages, site selection and maximum allowable production was set through a rough conservative estimate of carrying capacity; using Dillon & Riggler Methodology.		• Environmental Impact Assessment (EIA); • Risk assessment tools.	3	NA
2.3 Set license production limits within zone or water body carrying capacity	Maximum production per zone was estimated as indicated above and maximum production per site.		• EIA; • Risk assessment.	3	NA
2.4 Allocation of licenses and permits	Allocation of licences was done through a participatory agreed process considering equal user access rights, under adequate regulation and considering aspects of carrying capacity and minimum distance between sites.		• Participatory processes; • Environmental licenses by provincial agency; • Federal concession to aquaculture use by Brazilian Ministry of Fisheries and Aquaculture (MPA).	3	NA

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant waterbody or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries	Hydrodynamic conditions, currents were identified for sets of cage culture farms and risk assessment was done to address environmental and socioeconomic threats and others; e.g., eutrophization.		• Participatory consultations; • Hydrodynamic models; • Depth and current maps; • GIS and remote sensing data and tools.	4	NA
3.2 Estimate total carrying capacity if appropriate based on the different risks	Maximum production per area was set according to the agreed levels of acceptable risk (Dillon & Riggler Methodology).		• Environmental Impact Assessment (EIA); • Risk assessment tools;	3	NA
3.3 Organize a formal association of all farmers in that area	Farmers are well organized with identified leaders and supporting technical groups/services.		There are many problems for the management of the aquícola parks.	3	NA
3.4 Setting the broad development objectives and identifying the main issues. Agree on common management[10], monitoring and control measures	There is not a management plan.	Not Done	NA	NA	NA

10 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant waterbody or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.5 Monitoring of relevant variables and enforce management measures	The monitoring system of the environmental and fish health conditions (not only for individual farms but to assess the overall situation/condition of the area as a system) is only in the beginning.	Not Done	NA	NA	NA
4.1 Regular monitoring and evaluation	NA	Not Done	NA	NA	NA
4.2 Periodic review and adjustment	NA	Not Done	NA	NA	NA
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**	**Approximate production from each aquaculture zone or AMA**			
Number of zones and range of implementation	30 reservoirs with fresh-water aquícola parks; 17 states with marine aquícola parks.	Carrying Capacity: Freshwater Aquícola Parks: Freshwater Fish: 2.4 million tonnes/year Marine Water: Marine Fish: 200,000 tonnes Moluscs: 90,000 tonnes Algae: 85,000 tonnes			NA
Other notes	**Positive issues**	**Negative issues**			
(especially social issues)	High production with a huge social and economic impacts.	The management is being a big problem.			NA

**NA = not applicable*

Chile Case: The Spatial Planning of Marine Cage Farming (Salmon)

Adolfo Alvial[1]

ABSTRACT

Chilean salmon farming has shown an impressive growth. In about 25 years the country became the leader as farmed trout producer and the second as farmed salmon producer. In general, regulations moved back the industry growth generating several gaps that did not help in preventing environmental/sanitary problems. In fact in 2007 the ISA crisis caused an enormous impact on the industry with important socioeconomic consequences. This fact pushes for a rapid and profound change in regulations triggering the spatial management that complement the initial Appropriate Areas for Aquaculture (AAA) and Licenses. Then spatially connected Groups of licenses (AMA's or neighbourhoods) were established as well as Macro zones.

Presently an integrated spatial management system is in place which, in spite of its weaknesses, has contributed to coordinate efforts to control diseases, improve efficacy of measures in front of a sanitary risk and create better conditions for environmental/sanitary recovery of the macro zone. Notwithstanding, improvements have to be done to move closer to an ecosystem approach to aquaculture, principally emphasizing carrying capacity studies and tools, interaction with communities and other sectors and also increasing participation and developing an incentives regime. The highest contributions of the AMA's system have been the increase in social capital in the industry and the development of highest levels of public-private interaction.

1. HISTORICAL ASPECTS

Sea cage farming in Chile is only applied in salmon production. Salmon farming started in the 80s in Chile. In 1988, 16 farms produced 3,400 tonne and there were 178 authorized farming sites, with a production projection of 15,000 tonne as per the technology applied at that time. The geographical location of the farms was determined by the proximity to areas that provide good access and services such as roads, energy, and other vital needs. Those initial sites were easily accessible and very concentrated in Chiloé (Los Lagos Region) which contained 86 percent of the country's allocated farm sites (Mendez & Munita, 1989). That happened under almost no regulations to establish sites, except some nonstandardized evaluations and an approval process by the Undersecretary of Fisheries (SUBPESCA) and the National Direction of Maritime Territory (DIRECTEMAR). At that time it was expected that the recently established official standard for minimum distance of 1,5 miles (2,41 Km) between farms could diminish the number of sites while also minimizing speculators that

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

Alvial, A. 2017. Chile Case: The Spatial Planning of Marine Cage Farming (Salmon). In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document*, pp. 170–197. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

had flooded the Maritime Authority with requests for allocation and use of unoccupied places. The regions of Aysén and Magallanes, with abundant sites, did not attract much interest due to the limited logistic support available for farm operations (Mendez & Munita, 1989). Twenty six years later (2015) the salmon industry has more than 350 sea sites under operation, over 1300 total licenses approved, distributed in Los Lagos, Aysén and Magallanes regions, producing around 800,000 tonne per year. An entire system establishing Appropriated Areas for Aquaculture, Macro zones, Neighbourhoods and Licenses or Concessions, are the spatial base of the industry.

Until 1988 the rapid industry growth exceeded the capacity of the Government to establish an adequate regulation. Just a few nonconnected legal instruments were behind this initial development. Those were the articles 12 to 18 of the D.S. N° 175 (1980) of the Ministry of Economy on Fisheries activities and D.S. 162 (1985) from the same Ministry ruling on the disease control in salmon species. Additionally D.S. 223 (1968) of the Defense Ministry (Navy) ruling on marine licenses was relevant. Just as in 1988 the D.S. 99 of the Ministry of Economy established the minimum distance above referred, initiating territorial regulation of the activity (Mendez & Munita, 1989). With the General Law of Fisheries and Aquaculture (GLFA) in 1991 licenses and authorizations for aquaculture were clearly defined and their authorization subjected to several requirements, including that they should be located in authorized areas for aquaculture. In 2003 through the D.S. 125 (Ministry of Economy) the National Policy of aquaculture expressed an objective "to promote maximum economic growth of Chilean aquaculture along the time, in a framework of environmental sustainability and equity in access to the activity."

In legal terms it is important to highlight that the GLFA was followed in 1994 by Law 19,300 of the General Basis of Environment that introduced the EIA system in Chile also impacting aquaculture. Also the GLFA was followed by the National Policy for the use of the Coastal zone, D.S. 475 (1995) of the Ministry of Defense, that requests coastal zoning establish areas of preferential use including aquaculture. Thus, from the early nineties, licensing and zoning in aquaculture were modulated in several ways.

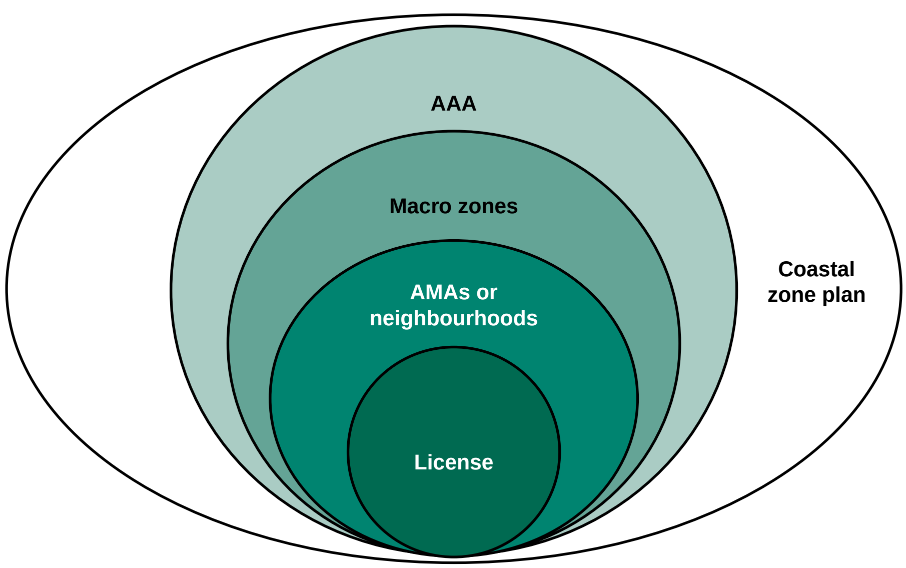
2. AQUACULTURE ZONING

2.1 Scoping

At present there are four spatial territorial categories dealing with aquaculture in Chile, including sea cage farming (Figure 1):

- *Appropriate Areas for Aquaculture (AAA).* The areas where aquaculture (not only salmon farming) can be developed in the jurisdictional sea of Chile according

FIGURE 1. Spatial categories related to sea cage salmon farming in Chile. AMAs are established for the three species farmed and licenses for individualized species.



to the General Law of Fisheries and Aquaculture (Law 18,892 or GLFA, vers. 2013, Law 20,657). An AAA includes Macro zones, Neighbourhoods and farming sites (also mentioned as Licenses or Concessions).

- *Macro zones (MZ).* Zones defined by the Authority (SUBPESCA) to avoid dispersion of a given disease or infection in any farmed species that have created an emergency situation. (GLFA, D.S. 391, 2001). Macro zones include AMAs (Neighbourhoods) and farming sites or licenses.
- *Aquaculture Management Areas (AMAs); Also named Salmonid groups of licenses or Neighbourhoods (NEI).* Group of aquaculture concessions within an AAA situated in a sector that presents safety, epidemiological, oceanographic, operational or geographical features that justify its coordinated sanitary management by species group (for instance salmonid species), as per SUBPESCA declaration (LGPA, vers. 2013). Neighbourhoods include farming sites or licenses.
- *Farming Sites (Licenses or concessions, LI).* The administrative act through which the National Ministry of Defense gives to a person/entity rights of use of a resource (water column, sea bottom, coastal site, etc.), for a period of 25 years renewable, to carry out in them aquaculture activities (GLFA, vers. 2013).

The National Policy of the Coastal zone dictates that Coastal Plans have to be established in coastal regions of the country defining zones of preferential uses (Figure 1).

Sea cage farming in sea water in the country is just practiced for salmon species, i.e:

- Atlantic salmon (*Salmo salar*)
- Rainbow trout (*Oncorhynchus mykiss*)
- Coho salmon (*Oncorhynchus kisutch*)

AAA evolution. AAA were established in the 1991 General Law of Fisheries and Aquaculture (GLFA) as areas situated under public use where aquaculture can be developed prior to consultation with relevant organizations in charge of alternative uses for those spaces. According to the current Law, AAAs are not exclusive, because other activities noninterfering with aquaculture can be developed within them like tourism and benthic resource management areas, among others (FAO, 2012; García, 2013).

Immediately after enactment of the GLFA in 1991, the Chilean Government, through SUBPESCA, initiated the process to establish the AAA in the country giving priority to the regions where aquaculture was initiated.

Process and consultation. Under the Law, it is the responsibility of the SUBPESCA to develop technical studies for identifying appropriate areas for the exercise of aquaculture, consulting with agencies responsible for alternative uses of those areas over water or land, and considering especially the existence of aquatic resources or conditions for their production and protection of their environment. These studies should also consider artisanal fishing activities and related communities, mining and communities, exit and entrance tracks to ports, anchoring areas and areas for practice of the national Navy ships, areas of ports development and touristic attractions. Also AAA cannot be established over fishing grounds established according to the Law. AAA should also be excluded of natural banks of benthic resources and algae beds. On the other hand, intensive or extensive farming of exotic species must keep a minimum distance of 1.5 nautical miles from marine parks and marine reserves. In cases where the land protected areas have their limits with the sea, a protection marine band will preclude the development of intensive or extensive aquaculture based in exotic species. Once studies conclude, SUBPESCA must publish in the official newspaper and in another one of the involved region the proposed AAA. Within 60 days from the publication individuals or institutions can express their opinions (written) on the studies. In such case, the SUBPESCA shall respond to stakeholders within 60 days. Final proposal and studies must be sent to the Ministry of Defense. Final decrees will have to approve the AAA specifying their perimeter. The process is schematized in Figure 2.

Since the beginning (1991) the AAA establishment was a participative process under which the officials of the SUBPESCA visited the regions organizing meetings with local authorities, farmers, scientists, interest

FIGURE 2. Process to establish AAA in Chile.

groups, and the Navy, among the principal ones. The authority presented their initial studies and ideas about the AAA envisaged which served as a base of discussion. The definitions were strongly influenced by the current production technology in all ambits of marine aquaculture and by the purpose of operating farms in areas well protected of adverse environmental conditions, essentially winds and waves. Also the logistic factors were considered based on the current installations as those expected as per the geographic characteristics of the coast.

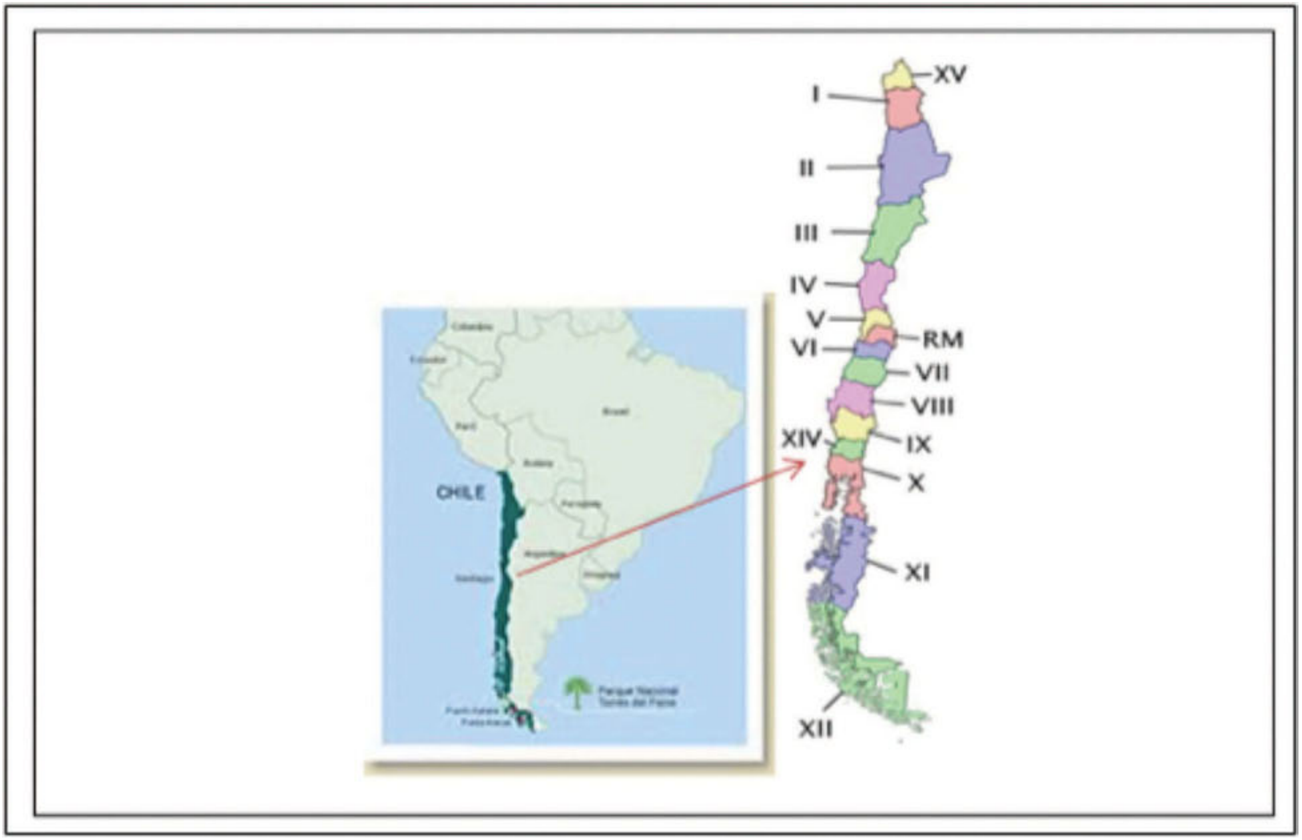
Based in the above presented process the Authority published the AAA and received public observations that were finally considered before the final Decree of the Ministry of Defense. In 1991–1992, essentially the predominant sea aquaculture activities were salmon, trout, red seaweed and mussel farming in the Los Lagos Region and scallop farming in the Atacama and Coquimbo regions. Those were the prioritized regions to establish AAA.

At present 12 of 15 regions of Chile have AAA. Still pending: the regions Arica—Parinacota (XV) and Valparaíso (V). Metropolitan Region (XIII, RM in map) do not have coast. A summary can be seen in Figure 3.

Legal, regulatory and institutional frameworks. The Law 19,800 (2002) of the Agriculture Ministry modified the article 158 of the GLFA (Law 18,892). With this change, lakes, rivers and maritime zones forming part of the National System of Protected Wildlife Areas are excluded from all extractive aquaculture and fisheries activities. However, in the Maritime zones that are part of the National reserves zones these activities can be developed with previous authorization of the competent agencies, to complement maritime activities of aquaculture.

The coastal zoning in Chile is the process of management and planning of the coastal spaces, in order to define the territory and establish its multiple uses, expressed in preferred applications that will not be exclusive, except in cases of use incompatibilities with specific activities determined in defined sectors of the same zoning plan. The zoning plan identifies specific zones, limits, conditions and restrictions for administration in accordance with the provisions of the National Policy on the use of the coastal zone. According to this regulation if in a given region coastal zoning has been established and duly published, the AAA should be amended to be compatible with this zoning. From the date of publication of the decree establishing zoning no new aquaculture concessions will be granted in sectors that have been defined not consistent with that activity (Silva, 2010). In cases where SUBPESCA proposes suitable areas for aquaculture, the Regional Commission of the coastal zone must analyze and respond within six months counted from the time of requirement.

FIGURE 3. All regions of Chile have AAA, except XV, V and Metropolitan (RM). X region is closed for new licenses.



Development context. During the last 2 years the AAA has been questioned principally by the salmon industry that has demanded a review that can facilitate site relocations and reduction of site concentration. On the other hand, different actors have mentioned the convenience to adapt them to the need of moving the sites gradually towards more exposed or oceanic places releasing the coastal zones for other activities like artisanal fisheries, mussel and small-scale farming, and tourism among others. This was pointed out as early as 1996 (Alvial and Reculé, 1996).

In 2005 several studies evidenced the limitations of AAA boundaries established 10 years before without oceanographic and environmental studies for each zone. As a result some areas were declared appropriate when in reality they were not (Aldayuz, 2005).

Authorities and the private sector have included this important topic in the agenda to review the system and introduce in the future complements or modifications. The former President of SalmonChile A.G. (the Chilean salmon industry association), C. Barros, pointed out that territorially AAAs accomplished their original objective to spatially order the activity, "but technologies changed through time making feasible farming in more exposed areas of the sea; however the system did not adapt to the new changes and new aquaculture developments. As a consequence the system moved from a positive tool ordering the activity to a serious constraint that tended to concentrate farms" (García, 2013). For other leaders, like Julio Traub, "the AAA's more than appropriate areas for aquaculture should be considered 'authorized areas' because in its creation the system did not limit other activities in them and just permitted aquaculture respecting distances between farms." These present objections are also shared by mussel producers who estimated through one of their leaders, Eugenio Yokota, that the AAA establishment was a very fast procedure with no adequate consultation process.

AMICHILE, the biggest association of mussel farmers, also considers that any eventual review has to consider water body capacities before approving future changes (García, 2013).

For the author of this paper, cited in the same publication, the review of the AAA should be based on the best available environmental and oceanographic information, and should consider a displacement of salmon farming sites toward more oceanic waters releasing coastal sites for artisanal fisheries, mussel and seaweed farming, minimizing saturation and conflicts close to the coast.

Main socioeconomic, environmental, biosecurity and governance issues and factors. The AAA system was established in order to regulate use of aquaculture of the space in the coastal zone. This need was principally evident in the X Region (essentially Puerto Montt and Chiloé areas) where a gradual concentration of salmon and mussel farming sites became evident as interfering with other users. The scallop farming in the northern regions, IV and III experienced a similar but less intensive situation.

AAA represented the very first zoning effort of an economic activity in the Chilean Sea. Not being in the context of a wider multi-sector system, the risk was from the beginning of potential conflicts of AAA with other users in the future, and it finally has happened. In fact, the national use of the coastal zone policy was enacted years after the AAA was established. Consequently, when the regions having AAA faced the process to define a management plan of coastal zoning, the conflict emerged to conciliate other uses like artisanal fisheries, natural reservations, tourism, etc., with the already established AAA.

In summary it is possible to say that originally the AAA's definition was essentially based on environmental aptitude of coastal zones for sea farming (emphasizing protection of bad weather conditions) and almost not considering oceanographic and environmental knowledge which requires a review of AAAs.

During past years several modifications to the original limits of the AAA have been introduced in the different regions. More recently modifications have been done to adjust them to regional coastal zone plans.

Through the Law 20.434 (2010) was introduced the option to declare AAA for group of species. The same Law closed new license applications in the X Region except for seaweed farming; it closed temporarily, for 2 years licenses for salmon species farming in the XI Region and also temporarily closed applications in the XII Region until the modification of the AAA for group of species in the period of 12 months.

In 2012, due to the high farm concentration in the X Region, particularly of salmon and mussel, the Sub Secretary of fisheries declared the AAA of the X Region not available for new license requests, the only exemption being seaweed farming (R.EX. 825—2012, under Secretary of Fisheries and aquaculture). This fact will strongly reinforce the observed tendency showing an increase of licenses and salmon operations in the XI and XII Regions. In fact, at present the XI Region is leading farmed salmon harvest in Chile.

Risk assessment analysis has not been explicitly included within the elements considered by the authority in the definition of the AAA. This aspect has been part of the discussion in the meetings and workshops when other agencies and users are included in the consultation process.

2.2 Zoning Process

The process. The first Fisheries Law enacted in 1991, established the AAA. The same Law indicated the general procedure to establish them. Then the Under Secretary of Fisheries leaded an initial proposal and developed a consultation process, including committees in regions and headquarters in Valparaiso, to prepare the first AAAs. Priority was given to regions with existing aquaculture operations like: Coquimbo (IV) and Los Lagos (X). The final proposal was presented to the National Fisheries Council, the Under Secretary, The Defense Minister (Navy) and the Minister of Economy.

Choosing the tools for spatial planning. Charts initially used in the 80s were those managed by the

Oceanographic Service of the Chilean Navy (SHOA) that became obsolete. The same procedure was used in defining location of licenses. Positioning was done in active cooperation with the Navy. Late in the 90s a geo referential unit was created in SUBPESCA to manage spatial aspects of licenses and zones. The approving decrees were spatially referred to in the original charts.

Problems associated with new licenses positioning revealed deficiencies of the old system applied causing conflicts between aquaculture users and between them and other users of the coastal zone. That situation determined the need to regularize sites and zones adjusting their location and boundaries introducing a modern and widely applied digital cartography WSG-84 system, scale 1:50,000. This process initiated long ago in the past decade has progressed in the different regions demanding very exhaustive analysis and adjustments. This approach has allowed the use of Geographic Information systems (GIS) and Geographic positioning systems (GPS) facilitating use by the authority, companies and general public. Regularization started with the complex X Region and it was followed by the XI and XII Regions. All of them were related to sea salmon farming. Then regularization continued in the other regions. The new system has expedited procedures connected to zones and license approvals and modifications.

The new charts are published in the SUBPESCA web site, in section: "Áreas apropiadas para el ejercicio de la acuicultura (AAA)," link www.SUBPESCA.cl/institucional/602/w3-propertyvalue-50829.html, and then under Cartografía digital de AAA (Digital cartography of AAA), and Información georeferenciada, where AAAs may be seen for all regions. An example is shown in Figure 4.

The execution of the technical studies has been in charge of specialized consultants selected through public selection processes. They have obtained photogrammetric surveys of the coastal zone situating on them the concessions now positioned with high precision (Aldayuz, 2005).

Zoning application. AAAs have been applied in all regions except the three ones mentioned above. In all cases legal process and procedures have been strictly respected, allowing public participation. New knowledge and demands for the use of the coastal zone by other sectors, as well as the adjustments necessary in light of the coastal zoning plan defined

FIGURE 4. Part of the AAA in the X Region using the digital cartography system of SUBPESCA.

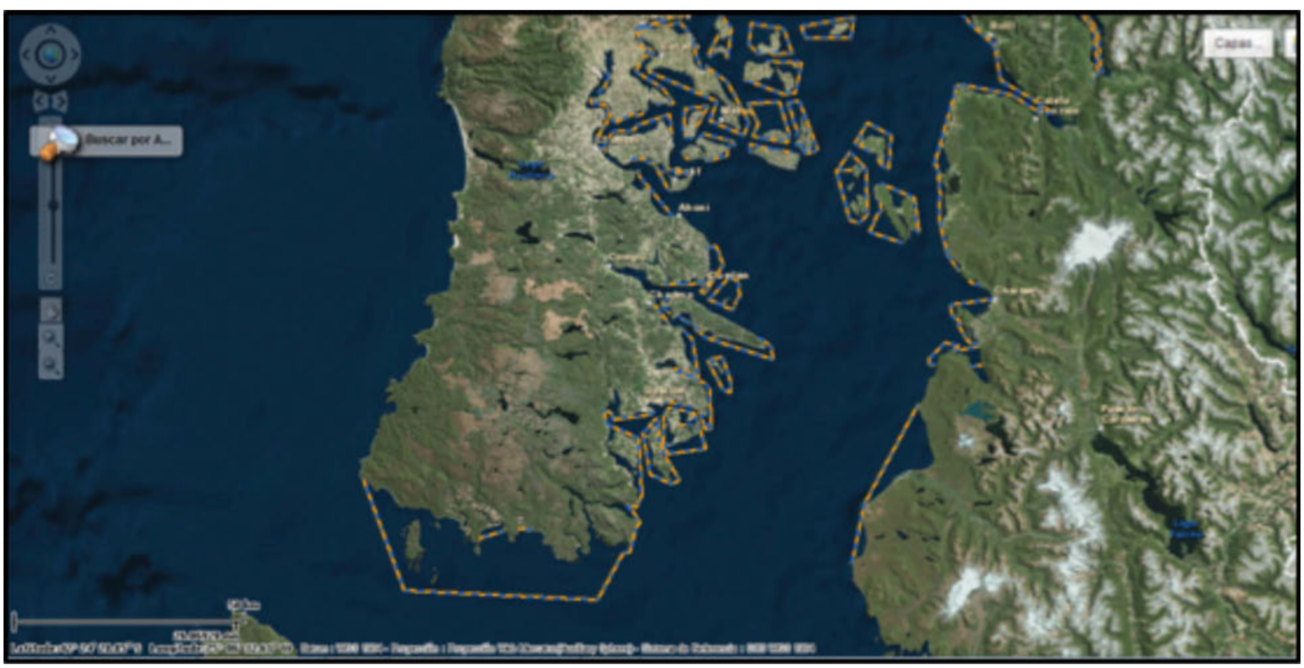


TABLE 1. AAA's surface in hectares per region and total. Only salmon sea farming regions are considered.

Regions	AAAs Hectares
X Region	357 498
XI Region	550 782
XII Region	185 211
Total	1 093 491

by regions, have motivated modification of the AAAs approved through decrees explained in the SUBPESCA web site www.SUBPESCA.cl/institucional/602/w3-propertyvalue-50861.html. Presently 12 of 15 regions of the country have AAA's approved, a summary of the total surface covered by them by region and total is specified in Table 1.

Sectorial planning. AAAs have been integrated in the context of the coastal zone management plan established in different regions. In fact, the regional plans recognized different zones of preferential use (National Commission of the coastal zone use, www.ssffaa.cl/comision-nacional-de-uso-del-borde-costero-cnubc/), like:

- Appropriated Areas for Aquaculture (AAA)
- Management and exploitation areas of benthic resources
- Distribution areas of the main national fisheries
- Protected marine areas
- Vulnerable marine ecosystems
- Coastal spaces of originary people
- Free access areas Ref.: www.SUBPESCA.cl/institucional/602/w3-article-60648.html

An example of the coastal zoning is shown in Figure 5 (Aysen Region). A complete detailed mapping with all coastal zoning plans in the Chilean regions can be found in "Geoportal de Chile: www.geoportal.cl/geoportal/catalog/data/uso-de-borde-costero/zonificacion-de-uso-de-borde-costero.html as part of the web site "IEDE Chile—CatálogoNacional de InformaciónGeoespacial" (IEDE—Chile—National Catalog of geo spatial information).

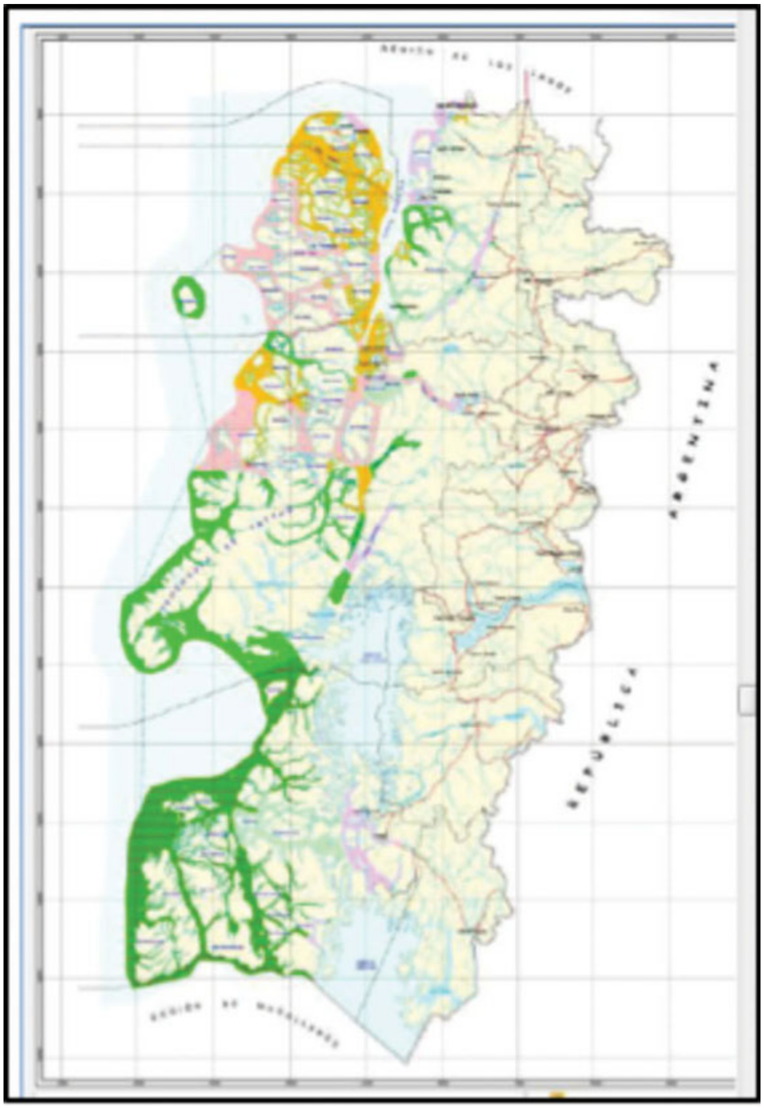
Estimation of aquaculture potential. Based in the use of AAAs in the three regions where sea cage farming is practiced (X, XI and XII), considering present regulation, production technologies, neighbourhoods rotation programs and that the X Region is closed for new licenses, an estimate of total maximum salmon production is around 1,5 to 2 million tonnes.

Selecting the optimal zones for aquaculture. As was mentioned above, originally the AAAs definition was essentially based in environmental aptitude of coastal zones for sea farming (emphasizing protection of bad weather conditions) and almost not considering oceanographic and environmental knowledge which requires a review of AAAs. Then a review of restrictions was applied to make necessary adjustments. These restrictions were essentially in: port influence areas, fishing zones, known breeding and spawning zones of marine species, navigation tracks and ships mooring zones, strategic areas reserved for the navy, natural reservation zones, zones that should be protected and/or reserved according to contributions of the participants in the different committees from regions and Valparaíso involved in the process, like endangered habitats, and areas of potential value for tourism among others.

However the technological evolution of aquaculture, its expansion, the emergence of some conflicts with other users of the coastal zone, and the emergence of coastal zoning in some regions, determined that AAA had to be part of the map of preferential uses zones and adjust to the new specifications for any new license in the future. This fact caused some concern in the salmon sector (Silva, 2010) because in their opinion this opens uncertainty for the future of the activity.

Lessons learned from recent ISA (Infectious Salmon Anemia) crisis and the evidence of high concentration of farms in sensitive areas have determined some changes in regulation that allow modifications of AAA, limit new licenses in determined AAA and accept eventual relocations of licenses within a given AAA.

FIGURE 5. Example of coastal plan zoning (Aysen region). Aquaculture preferential use zones in dark pink (taken from Zúñiga, 2013).



Any eventual AAA considered should be part of the coastal zone management plan of the pertinent region following the evaluation of the regional Commission of the Coastal Zone and then the final approval of the National commission. The commissions are integrated by representatives of different sectors dealing with: the aquaculture industry, other economic sectors, indigenous people (Law 20249, 2008, creates marine space of original people), local communities, regulation and enforcement authorities, research institutions and NGOs related to environmental and social protection. They assure that consideration is given to several potential impacts, like: environmental and biosecurity problems for the industry, regulation and enforcement prohibitions/constraints, conflicts or not desirable effects on other users, indigenous people zones, neighbourhood communities, risk of impacts on ecosystem, endangered species, natural reservations and sensitive zones, among others.

Risk mapping. After an initial long period in which risk analysis was only applied in the aquaculture industry by few companies and R&D institutions, like Marine Harvest—Chile (where the author was Technical Director), after the ISA crisis more private companies and the public sector introduced risk analysis.

In fact, presently authorities, associations, technological institutions and R&D entities are regularly applying in their analysis decision making processes holistic risk analysis methods. In general they proceed through expert consultants principally in the areas of epidemiology, environmental assessment and biosecurity (José M. Burgos, Former National Director of Aquaculture, SERNAPESCA, personal communication).

Examples of these risk analyses are: epidemiologic studies for new regulations and site management in farm companies; and epidemiologic, biosecurity and risk analysis dealing with navigation track definitions in the macro zone of salmon farming, principally financed through the Fishery Research Fund—Aquaculture—that depends on SUBPESCA.

3. SITE SELECTION

3.1 Definition of Farm/System Boundaries

Any sea farm needs to have an aquaculture concession or license to operate in the territory. The aquaculture concession or license is the administrative act through which the National Ministry of Defense gives to a person rights of use, for a period of 25 years renewable, over certain domestic goods (like sea bottom, water column, beaches or land-beaches) to carry out in them aquaculture activities. That period will be renewed unless half of the farm site environmental reports are negative or the farm presents infractions causing immediate termination according to the Law. Concessions and authorizations are transferable and in general susceptible to legal business, including leasing.

No one person can ask for licenses that represent more than 20 percent of the total surface included in AAA, discounting the surface already issued for other purposes than aquaculture and also discounting minimum distances between farms requested by regulations.

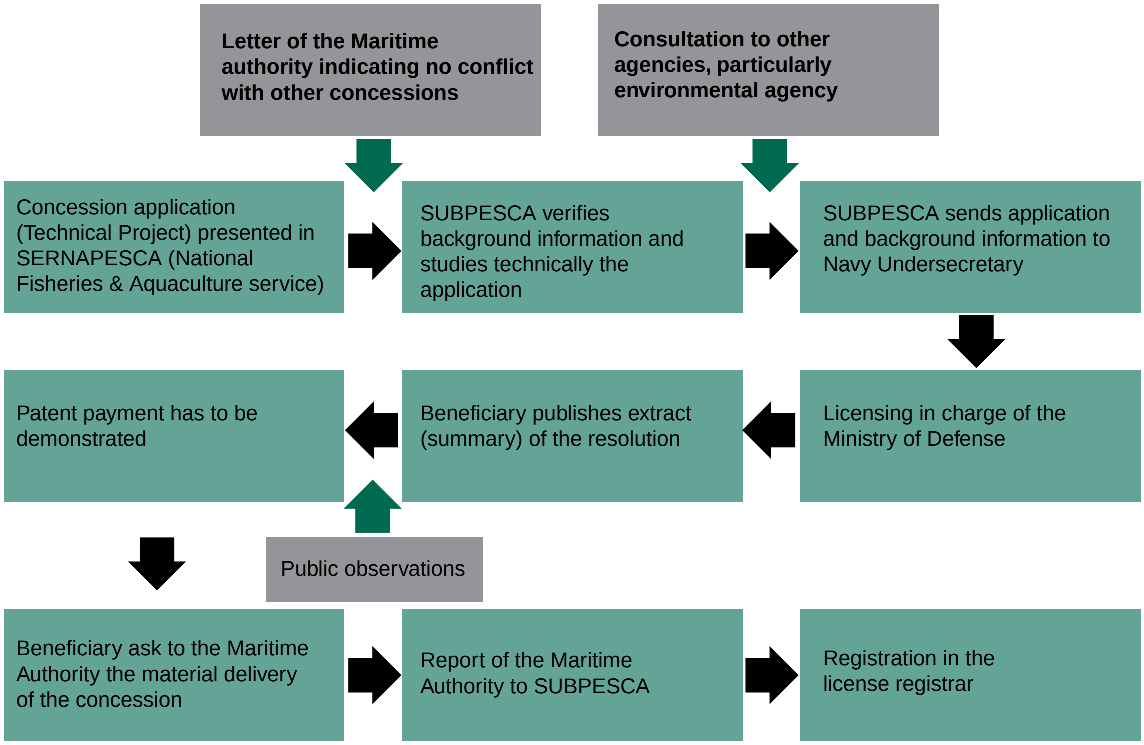
License applications must include a technical project and other information specified by the regulation, including its geo referenced location (boundaries polygon). The Navy Undersecretary will check plans and not overlap with other maritime concessions, validating these basic documents of the project. Eventual superposition and respect of minimum distances with other aquaculture and fishery licenses is checked by SUBPESCA. Opinion or objections from other agencies are considered in each region through the pertinent organizations (regional committees of fisheries and aquaculture). Once all processes are developed and verified SUBPESCA sends all background information to the National Defense Ministry—Undersecretary of the Navy with the respective technical report. The Minister of defense finally grants (or reject) the aquaculture concession dictating the resolution signed up by the Undersecretary of navy.

It is important to mention that the holder of the concession has to include in the background information a “Preliminary characterization of the site” containing environmental, topographic, and oceanographic studies in the area selected for the farm site where the aquaculture activity is planned to be developed. This information is fundamental for the EIA system that operates in this authorization process. In general the aquaculture operations will be subjected to the EIA System—General Law of the basis of environment. The process will determine, according to the preliminary characterization of the site, if the project has to be presented as an Environmental Impact Declaration or EIA study. The license Application process is shown in Figure 6. The EIA system is administered by a Regional Environment Commission and eventually by the National Unit if the environmental impact reaches more than one region.

According to the Environmental regulation of aquaculture (RAMA), intensive production farms like salmon, must maintain between them a minimum distance of 1.5 nautical miles. The minimum distance between these sites and other with extensive production systems should be 400 meters.

Historically site selection in sea cage farming at the beginning emphasized environmental conditions appropriate for sea farming in terms of bathymetry (presently minimum 40 m.), gross estimations of water renewal and giving particular importance to bad weather protection, site access and proximity to ports, road and other services. The initial small scale of farms created a good relationship with local communities because lodging, sea transportation, cage manufacturing, and labor were provided by them, principally in the Reloncavi Gulf and Chiloé territories. Operations

FIGURE 6. License application/approval process.



and the sea cages labor were not disruptive with the culture of communities. Owners and managers interacted with people around the farm operations constructing social capital and trust. Politically the industry was well accepted and in general supported.

Notwithstanding, the progressive overcrowding of farms, the installation of processing plans—with demanding routine work—along with the emigration of owners and managers, opened an increasing gap with the community. The arrival of managers, professionals and technicians without adequate coaching contributed to augment this undesirable gap.

Sites were initially designed to operate with 1 or 2 modules of 10–12 square cages each, using typically between 0.5 to 2.0 Hectares. General geometry and boundaries are determined by geomorphology of the site and bathymetry. Minimum distance between salmon farms is 1.5 nautical miles.

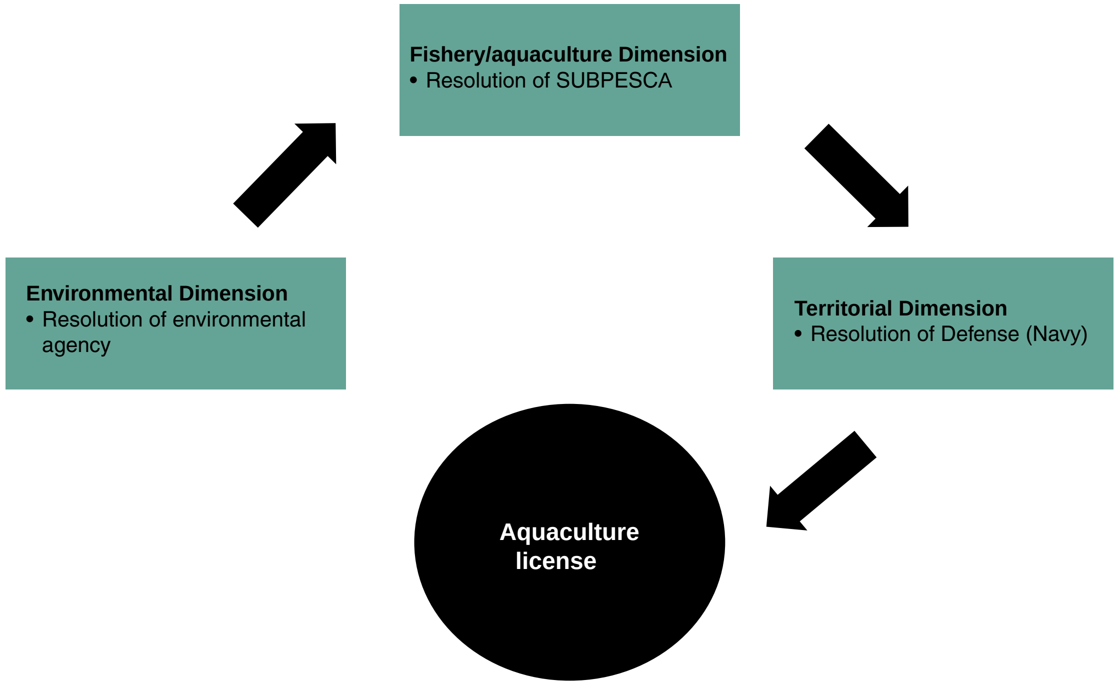
In summary, in a more integrated way, it has been estimated by some authors that the aquaculture licensing system in Chile has three dimensions according to the present legislation as is shown in Figure 7. In this system there are three basic ambits of authorizations: one related to environmental dimension, which verifies compliance essentially with EIA requirements coordinated and resolved by the Environmental Agency; the second, which verifies compliance with the Fisheries and Aquaculture Law, coordinated and resolved by SUBPESCA; and the third one which verifies compliance with the use of the coastal zone and related regulations, coordinated and resolved by the Undersecretary of the Navy (Ministry of Defense).

3.2 Complying with Administrative/Legal Procedures during Operation

In addition to the requirements, procedures, and steps specified above, it should be added that:

- Deadline to begin operations is one year counted since the physical delivery of the concession. Operation is recognized when the activity of the center is equal to or greater than the minimum operating levels by species and area established by regulation.

FIGURE 7. Ambits of authorizations involved in aquaculture licensing.



- It is understood that operation exists when the facility must comply with the rest period or temporary cessation of activities determined by resolution of the authority (counted as operation).
- The License holder may detain operations for two consecutive years and may apply for extension of equivalent of twice the time of operation that preceded the stoppage, with a maximum of four years.
- Transfers, leases and any act involving the transfer of rights of aquaculture concessions or that enables its exercise must be recorded in the Register of Aquaculture Concessions. The Registry of Concessions is public and is available for consultation on the website of SUBPESCA.
- License mortgage may proceed following the requirements indicated by the Law.
- License holders pay annually a unique patent of 20 "tributary units" (indexed unit) per month per hectare, in the case of exotic species, like salmon. This payment will finance INFAs and aquaculture research for regulation, among principal destinations.
- In case of a high risk disease in a given site, AMAs, the authority in virtue of the regulation on protection measures to control them, can order isolation of sites or AMAs avoiding/minimizing risk of propagation. Special measures can include elimination of specimens in the farms, special biosecurity measures, restrictions and or additional measures on transport, cleaning, processing, disinfection, use of antibiotics, other products to control pathologies and plagues, and any other activities related to species farming.
- Some of the most important causes of license termination (anticipated expiration) are:
  - Use of the license for a different purpose (for instance other species farming).
  - Patent is not duly paid.
  - Sanctioned 3 times within 2 years (next to the first infraction).
  - Introduction of exotic species or GMO without authorization.
  - Operations not initiated within the initial of 1 year or stop operations for more than 2 consecutive years (there are some exceptions explicated in the regulation).
  - Suspension of operations not respected.
  - Three sanctions in 3 years (density, resting period, vaccination), release of exotic species, classification with low biosecurity immediately after a suspension of operations.

- Licenses in strips between macro zones and that are not requested re localization.
- Licenses will not be renewed to holders of licenses who have not paid fines caused by unfair or anti-union practices. Either concession will not be renewed to the holder of a license that accumulates 3 infractions for the same reason in 3 continued production cycles (same farm).

3.3 Consultation with Stakeholders

The applicant has to obtain *Maritime authority* validation of plans and certification of no overlap with other concessions. Then SUBPESCA analyzes that the application entered complies with all legal requirements and additionally consults *all stakeholders at regional levels* (normally through the Regional Office and Commission). In this consultation usually intervenes: *Artisanal Fisheries, Communities involved, Indigenous People organizations, Tourism organizations, Ports and Maritime chambers,* among others. Eventual objections are evaluated at the regional level and then sent to central SUBPESCA to continue the process. The project pre-evaluated is subjected to the EIA system. Having passed these stages the project has to publish and the public can present objections. These are finally resolved and the process continues for the final approval and registrations. Under present regulations the process should take around 9–12 months, but many past applications are still pending.

Sites categories and carrying capacity. The GLFA establishes that farms must operate not exceeding maximum carrying capacity of the environment. The environmental specific regulation, RAMA, establishes that to initiate operations the applicant must present a preliminary characterization of the site (CPS) which has to demonstrate that the sediment has aerobic conditions and define that during the operation, through environmental reports (INFA), the environmental condition of the site has to be monitored verifying that the farms have not surpassed carrying capacity of the water body, a situation that is reached when the sediment shows anaerobic conditions.

The companion resolution of RAMA N° 3612/2009 sets methodologies to develop CPS and INFA. Environmental parameters and their thresholds for both CPS and INFA are specified in order to determine environmental condition of the site. For this purpose, the resolution classifies farms in 8 categories considering production, depth, production system (intensive or extensive), and type of sediment, associating to each category a explicit number of environmental variables that have to be monitored. In function of the characteristics of the farm (or the bottom below it), farms can have more than one category (Bustamante, 2010).

In the past, INFAs were directly in charged by the companies to private authorized consultants. In order to increase transparency, the modified GLFA established that since April 2011, the National Fishery Service (SERNAPESCA) will elaborate INFAs. The law also authorized SERNAPESCA to contract qualified and registered third parties to do technical studies, which have to be selected through a public tender process.

Categories of aquaculture sites, CPS, INFA are detailed in the Companion Resolution of RAMA, i.e., Resolution Ex. 3612 (2009). This last had a recent modification in June 2014.

3.4 Adjustment of Maximum Production Plan According to Carrying Capacity Estimates of the Selected Site and Other Indicators

According to present regulation carrying capacity of a site is reflected by the oxygen condition of the sediments below the site. Accordingly, when the site presents anaerobic conditions in the sediments as per the specifications and methodology established in the environment regulation of aquaculture (RAMA), then the site cannot receive fish until an aerobic condition is recovered. Evaluations are annually done when the site is at maximum biomass charge. It is important to highlight that a farm cannot receive fish until the farm has the new results of INFA that demonstrate that it is satisfactorily operating in levels compatible with the capacity of the water body.

Additionally according to the GLFA, SUBPESCA establishes for each licenses group (neighbourhood) maximum density per species or group of species. This topic as well as classification based on biosecurity will be considered in the AMA's chapter below.

4. AQUACULTURE MANAGEMENT AREAS (AMA) AND MACRO ZONES

4.1 What Are the AMAs and Why Are They a Need?

AMAs were recognized as a need as early as 2004 when INTESAL, based on the best oceanographic information available, identified the first 12 "Environmental Areas." INTESAL defined them as bodies of water where predominant oceanographic conditions were similar enough as to determine them as identifiable water bodies. This was the first attempt to establish some monitoring and coordinated management of salmon farms in function of the characteristics of the water bodies. This was the base of a voluntary system applied in the industry which reached as an average participation less than 50 percent of the farms. After the ISA crisis the Industry and the Government realized the importance of applying a system like this and designed a mandatory approach.

Presently (GLFA, LAW 20, 434/2009) the *AMAs* also known as *Neighbourhoods* are *Groups of Concessions* (licenses) located inside an AAA in a sector that presents epidemiologic, oceanographic, operational and geographic characteristics that justify its *coordinated sanitary management by a group of species (as per the declaration of SUBPESCA)*. In consequence AAAs have different AMAs inside depending on all mentioned elements based in studies ordered by SUBPESCA.

Defining the boundaries of the AMA for new and existing farms. The INTESAL AMAs established for a voluntary system of the industry pretended to identify management measures as per the characteristics of each of them. The idea was to gradually advance towards specific regulations and practices congruent with environmental characteristics and carrying capacity of each water body.

The new AMAs defined as a consequence of the ISA crisis are the result of a veterinarian view, emphasizing disease control and logistics aspects. With the oceanographic and environmental information available it was possible to reach more than 60 neighbourhoods or groups of licenses. Distinction was clearly influenced more by logistic considerations and interest of the company than objective oceanographic information, particularly considering that associated to the neighbourhood system, resting periods were planned impacting companies who had all or almost all their sites in one or two neighbourhoods. Because this was the case, what is not acceptable after that is to take measures assuming that each AMA really represents an environmental distinguishable area.

The design of the AMA system after ISA partially considered the zoning done by INTESAL but in the discussion process, first internally in the industry, added some other information contributed by other actors like Plancton Andino, and also included the views of the companies. The authority accepted both, the proposition of the industry for AMAs and also the resting periods programming for all areas, which demanded long discussions between farmers.

So, the system principally purposed to coordinate treatments to control diseases, essentially caligidosis, isolate or impose restrictions to group of licenses in any affected AMA in order to avoid propagation, principally of ISA, and to establish a rest period system that would allow sites to recover their sanitary conditions for next production cycles.

Presently the authority establishes both, coordinated treatments and resting periods per neighbourhood. Also SUBPESCA can accept additional management measures adopted by the farmers in a given neighbourhood, becoming mandatory once they are agreed on.

The declaration of groups of licenses or AMA will not affect free boat transit, fishing operation of benthic resources management areas or other maritime or aquaculture licenses. Neither will it affect tourism activities or the rights recognized to specific coastal space of indigenous people.

Finally, it is important to mention that Groups of licenses exclusively dedicated to fish smoltification, broodstock maintenance and genetic management can be specifically authorized.

4.2 Developing an Ecosystem Approach to Aquaculture (EAA) Management Plans for AMAs

Considering that 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 accordingly (FAO, 2010), it is possible to say that this is still a pending task in Chile. Some transitions from a conventional approach to an ecosystem approach have occurred, but others have not. On the right track are: participation, agreement on multiple objectives, multiple (nested) scales, adaptive approach, public/transparent; but not much progress has been done in interaction with other sectors, extended knowledge and incentives cited as part of an ecosystem approach (FAO, 2010).

No doubt, that the intentions of the original AMAs voluntarily defined by INTESAL were conceptually closer to the purpose of generating a correspondence between the ecosystem limits and management areas, and consequently a higher level of harmonization across planning structures (FAO, 2010). But the crisis moves the focus again towards disease control, which is not the remedy but the symptom of more basic disruptions. The present system has to be reviewed along with AAAs as sectors of the industry, government and community are demanding. AAA's and AMA's boundary reviews supported by the best available environmental information is a must, independently of the gradual character of the future adjustment process. This is a task that should be run in parallel to the present system operation.

Beyond the criticism to the present system, the situation is better than the one applied in the past which did not recognize areas others than the original AAA. Yet more emphasis should be applied in the next industry stage to a closer integration with neighbourhood communities and other sectors interacting with the industry like indigenous people, artisanal fisheries and tourism, among the principal ones. Some companies and SalmonChile have initiated programs that move in that direction creating new bridges with these sectors and also supporting educational plans in the southern regions. CORFO (The National Agency for Economic Development) will set a macro regional program for salmon, mussel and seaweed industries, based in public-private governance that should support to close fundamental gaps of these activities during the next years including scientific, technical, social and economic factors limiting sustainable development of these industries.

Although there are no large scale IMTA initiatives in Chile, several authors have studied and promoted benefits of introducing this system integrating salmon and mussels and/or seaweed (Aquahoy, 2011; Barra, 2013). Some other authors have studied IMTA potential for abalone or seaweed (Macchiavello, 2014).

Process to establish AMAs. This has been essentially an industry/authority process in which stakeholders and public participation has not been considered. This has happened probably under the understanding that they were established essentially to control diseases, implicitly understanding this as an "internal" problem. On the contrary the AAAs and the licenses have passed through stakeholders and public scrutiny. At August 2014, there were 78 groups of concessions for salmon in the Regions X, XI and XII, that include all together 1,302 concessions (SUBPESCA, 2014). These are summarized in Table 2.

Figure 8 shows groups of licenses and licenses at August 2014. Magallanes is not shown but it has 16 groups of licenses and 88 concessions.

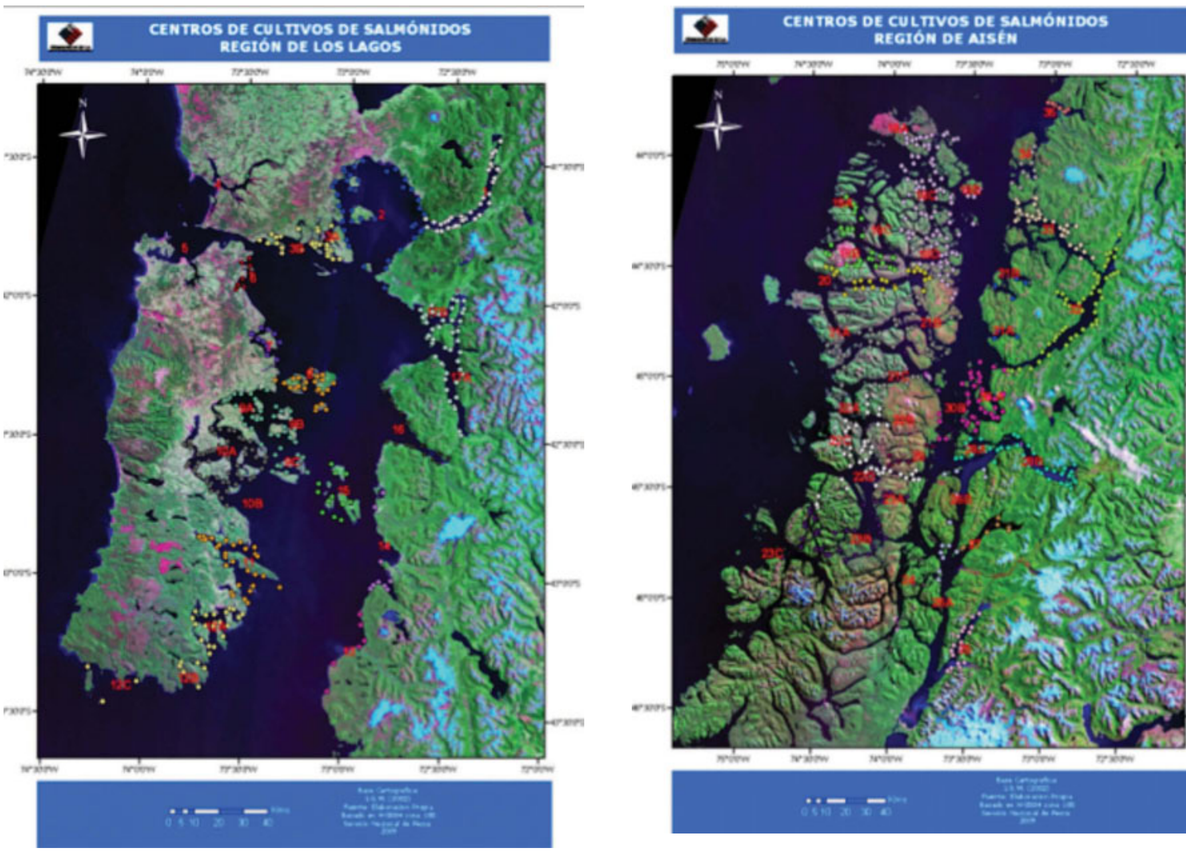
4.3 Developing Management Measures for the AMA

Sanitary and environmental measures. The coordinated sanitary resting system is the measure applicable to AMAs that consists in a period of time during which the farms that are part of the respective AMA must stop their operations and withdraw all

TABLE 2. Salmon AMAs or groups of licenses per region including number of licenses.

Region	Groups of Concessions	Number of Concessions
Los Lagos (X)	25	505
Aysen (XI)	37	709
Magallanes	16	88

FIGURE 8. Groups of licenses (identified with red numbers) and salmon farms (concessions in yellow dots) in X and XI Regions.



specimens from the site, being prohibited the entrance and keeping of fish. SERNAPESCA approves the resting program for AMAs controlling coordinated harvest (with a specified deadline) and also the fish entrance in a period of time in the number approved for each AMA. Also SERNAPESCA can establish programs of epidemiologic vigilance when necessary.

The authority (SERNAPESCA) establishes coordinated treatment in AMAs for sea lice, determining and controlling the program, which include periods of baths and oral administration treatment as well as rotations of products in order to mitigate potential resistance development.

Services of holding cages (before harvest) in coastal zones can be regulated by SERNAPESCA to minimize risk of disease.

SERNAPESCA will prohibit transit of boats from a higher risk AMA to other of minor risk except, that boats are disinfected in authorized stations by SERNAPESCA or follow other mitigation measures duly authorized by SERNAPESCA.

In order to manage online environmental parameters of groups of concessions these AMAs should apply a technology able to register and transmit at least indicators of conductivity, salinity, temperature, depth, currents, density, fluorescence and turbidity, as per the respective regulation.

License holders in a group of licenses can agree on environmental and sanitary measures additional to those established in virtue of the regulations. These should be specific for the AMA in question and not affect environment or the normal development of other activities in the zone. All measures adopted will have public character and will be informed in the SUBPESCA website. The authority will enforce measures agreed and duly informed.

4.4 Production and Carrying Capacity Measures

Although carrying capacity estimations are not in place for AMAs, there are measures limiting densities in all farms of an AMA and even reduction of fish intake according to the previous production cycle sanitary performance.

In fact, maximum density for a given license is done regulating the maximum intake number of fish in any site of the group of licenses. This is done based on sanitary conditions of each specific concessions group. Procedure Applied is:

- SUBPESCA develops a proposal which is sent in consultation to SERNAPESCA and the Institute of Fishery development (IFOP). SUBPESCA analyzes and includes observations and sends the proposal to the farms (companies) involved in the AMAs under analysis. After receiving their observations, SUBPESCA issues a final resolution with the densities for the AMAs.
- Farming density is the existent biomass of fish per used area at the end of the on-growing phase in the sea. To materialize the density requirements a maximum number of fish intake is established at the beginning of the on-growing stage.
- The groups of concessions are also classified in terms of biosecurity based on the application of an accepted model by Resolution of SUBPESCA. All sites classified in medium and low categories in a given neighbourhood are mandated to reduce fish intake for the following period.
- As it has been mentioned above the authority can ban fish entrance temporarily or indefinitely to an AAA, affecting all AMAs in the area. In the X Region an indefinite ban has been applied; meanwhile in the XI and XII Regions temporary prohibitions were applied in past years, subjected to some conditions that were satisfactorily accomplished.
- Procuring to reduce concentration of farms in some zones, farms can be relocated within a given AMA or moved to others complying with the specific requirements established by SUBPESCA or SERNAPESCA.

4.5 Certification Potential and Social and Economic Indicators of AMAs

Potential for certification to AMA products. International certification systems in aquaculture are requesting the farms to participate in AMA systems or at least demonstrate efforts to establish AMA with other farms close to them. In that sense, Chile's present system has been acceptable for these certification systems and has contributed to facilitate Chilean farms certification.

Using social and economic indicators to monitor economic (AMA costs and benefits). Although there are not known public evaluations on this aspect, it can be said that the cost of stopping production in resting periods is more than compensated by improvement in sanitary conditions of the area of the farm and the benefit of coordinated treatment against sea lice (otherwise not effective). Probably the most beneficial effect of the AMA system has been the demonstration that cooperation in sea farming is not an option but a need in light of the long-term projections of the industry that undoubtedly rest on social capital construction.

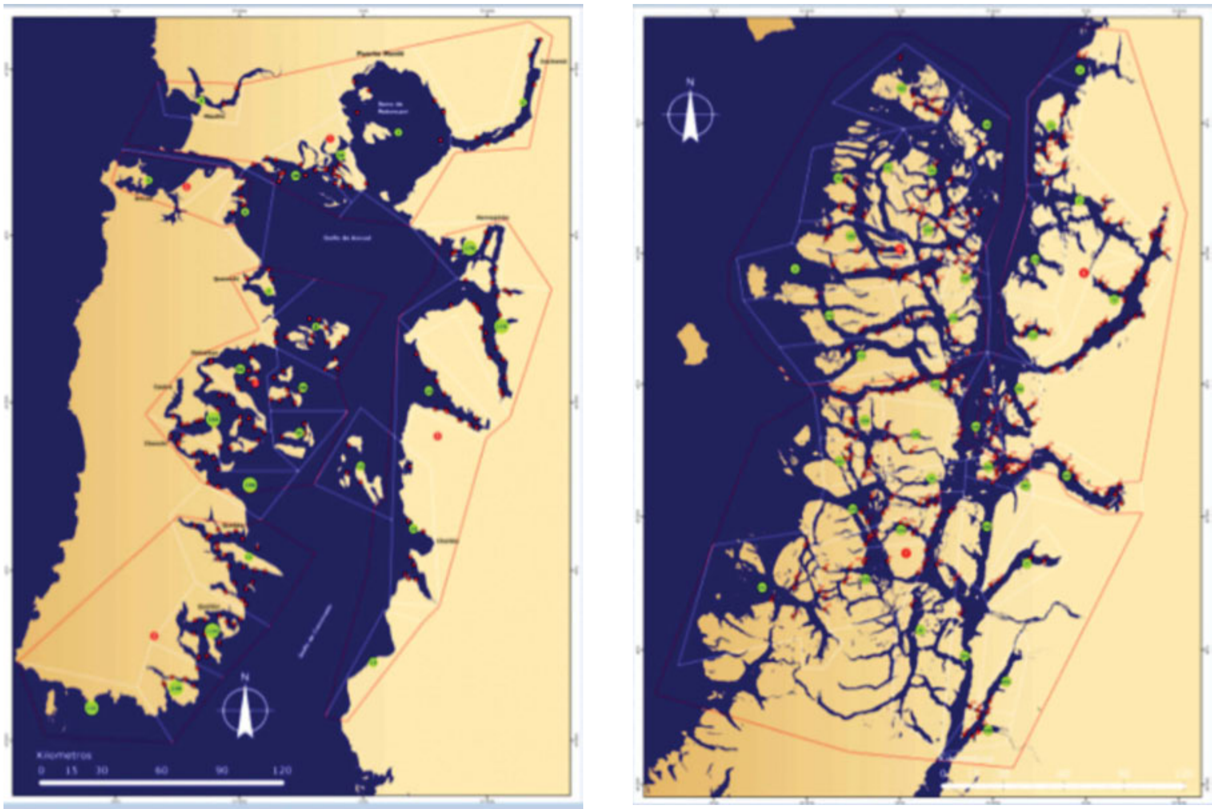
More regular interaction, exchange of information and share monitoring and research efforts reduce conflicts and open a stronger private-public interaction.

Most of the procedures developed under the new regulations in Chile, particularly those dealing with environmental and sanitary monitoring, have been standardize and certified through the INN (National Institute of Normalization) which improves transparency and quality of procedures and services.

4.6 Macro Zones

SUBPESCA establishes macro zones according to the procedures indicated in the GLFA and the D.S. 319 (sanitary regulation—RESA, 2001). In fact, based on a technical report (SUBPESCA, 2012) and consultation with an expert panel, SUBPESCA defines macro zones and the minimum distance between them. The basis are oceanographic (essentially hydrodynamic model), epidemiologic and logistic information. The objective

FIGURE 9. Macro zones (red boundaries) and Neighbourhoods (white boundaries) in the X Region (courtesy of MundoAcuícola, Chile).



of these zones is to favor bio contention in front of a sanitary emergency, contributing to avoid dissemination of a disease. The establishment of the macro zones has to be based in oceanographic information.

Macro zones include 2 or more AMAs and their boundaries consider oceanographic conditions and existence of coastal facilities allowing boats transit without passing through other Macro zones. At least 5 miles separate Macro zones between them. The farms that interrupt the distance of minimum 5 miles between macro zones can be relocated.

In front of a sanitary emergency immediately will operate a restriction of boats transit supporting farms between macro zones. Macro zones of the X and XI Regions are shown in Figure 9.

5. CONCLUSIONS

Chilean salmon farming has shown an impressive growth. In around 25 years the country became the leader as farmed trout producer and the second as farmed salmon producer. In general, regulations moved back of the industry growth generating several gaps that did not help in preventing environmental/sanitary problems. In fact in 2007 the ISA crisis caused enormous impact on the industry with important socioeconomic consequences. This fact pushes for a rapid and profound change in regulations triggering the spatial management that complement the initial Appropriated Areas for Aquaculture (AAA) and licenses. Then groups of licenses (AMA's or neighbourhoods) were established and also macro zones.

Presently an integrated spatial management system is in place which in spite of its weaknesses has contributed to coordinate efforts to control diseases, improve efficacy of measures in front of a sanitary risk and create better conditions for environmental/sanitary recovery of the macro zone. Notwithstanding, improvements have to be done to move closer to an ecosystem approach to aquaculture, principally emphasizing carrying capacity studies and tools, interaction with communities and other sectors and also increasing participation and developing an incentives regime. Highest contribution of the AMA's system has been the increase in social capital in the industry and the development of highest levels of public-private interaction.

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ANNEX 1

Annex 1 "Case study effectiveness matrix for Chilean sea cage farming" is presented in the next pages.

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Estimated Costs (annual base)
Phase 1 Step 1 Scoping					
Definition of the ecosystem boundary (spatial, social and political scales)	In general done in the context of the Appropriated Areas for Aquaculture (AAA). However it still needs more and better environmental studies, definitions and precisions.	More and better environmental studies supporting spatial boundaries.	Basic studies done by Undersecretary of Fisheries and Aquaculture, followed by consultation process. Mapping presently updated.	4	Cartographic system update and re definition of boundaries have demanded costly studies financing supported by Government. (Integrated to cost estimate indicated below).
Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	In general terms done, particularly dealing with regulations in place. Some advancement in water quality standards, minor advancements in ecosystem quality standards.	Ecosystem studies to improve ecosystem quality standards and indicators.	There are national policies referred to environment, natural resources, use of the coastal zone and aquaculture. Basic regulations are those included in the general basis of environment law, fisheries and aquaculture general law; specific regulations bodies applicable to licenses, fish disease control and environmental management in aquaculture, among the principal ones. There are specific environmental standards for water bodies and liquid discharges into them.	3	Environmental studies and updated studies connected or useful for legislation requested by authority (ecosystem analysis, indicators development, water quality standards, etc.): **US$1,0 Million** (1).
Phase 1 Step 2 Zoning					
Zone selection based on selection criteria	Done for AAA selection criteria which have evolved.		The law establishes selection criteria for AAA.	5	
Gross estimation of potential areas and production	Done (referred to salmon production), based on available AAA area, proportion of use of them by salmon farming, withdrawal periods, and present technology: Salmon production should reach as maximum around 2 million tonnes, with all regions producing at max. capacity under present regulations.		Estimations are based in proportion area used for salmon farming in AAA, and considering that no new licenses can be issued in the X Region.	4	

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Estimated Costs (annual base)
Phase 1 Step 2 Zoning					
Allocation of the zone for aquaculture purposes	Done. There are defined AAAs in all regions (12 over 15), with the only exception of two with almost no mariculture activity (XV and V) and the XII (metropolitan not coastal region).		In each region AAAs have been defined. This has been done under a participative process.	5	
Phase 2 Site Selection					
Carrying capacity estimation	The law establishes the way to estimate carrying capacity based on the bottom/sediment condition. This is done evaluating aerobic condition and other complementary parameters. Annually farms have to do these evaluations and report to authority.	No carrying capacity models per water body are in place.	Using oxygen concentration in sediments. Still pending use of models and predictive-holistic tools.	3	Cost estimate below.
Set license production limits within zone or water body carrying capacity	In general done. However carrying capacities for water bodies are not yet established.	Carrying capacity models for water bodies not in place.	Site production limit is established in the authorized technical project when the license is issued. On the other hand maximum densities are established for the 3 species per license groups (or AMA). However these limits are not based on estimates of water body carrying capacity. At present oceanographic studies are under development to meet information from different neighbourhoods to move on with carrying capacity models for water bodies.	3	

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Estimated Costs (annual base)
Phase 2 Site Selection					
Allocation of licenses and permits	Done. The system is operating in general in good terms.	Just regularization of licenses location under new cartography is under process.	Regularization of licenses location still under process under the new cartographic system.	4	Patent of License at present: 12 UTM/Month/Hectare = US$71/Month/Hectare (salmonid species). Total annual app.: **US$10,2 Million** (1). This amount should increase up to US$17,0 Million in 2017 (1).
Phase 3 Area Management					
Identify management area boundaries	Done. AMAs have defined boundaries and a list of licenses included in the respective AMA or neighbourhood.		Licenses are grouped in neighbourhoods, which is an area sharing environmental general conditions.	5	Several oceanographic, epidemiologic, logistic and risk analysis studies supported by the Government. (Cost estimate below).
Estimate total carrying capacity if appropriate based on the different risks	Very partially achieved.	There is only an estimate for farming sites, based on oxygen concentration in the sediments.	Some oceanographic studies are in place in order to progress towards carrying capacities estimates in neighbourhoods.	2	

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Estimated Costs (annual base)
Phase 3 Area Management					
Organize a formal association of all farmers in that area	Done. Farmers have to collaborate in coordinating sanitary treatments and biosecurity measures. Additionally they can develop additional measures beyond those established by the regulation.		There is a formal general association, SalmonChile, grouping over 70% of total producer companies. Additionally there are regional associations. In the case of neighbourhoods, companies have to collaborate under the present regulations in all those actions specified.	5	Companies have to pay a member fee based on a fixed amount per export tonne (taken as base the prior year). Total is around US$3 Million/ year. Approximately half of this amount is directed to scientific and technical studies, and evaluations necessary for regulations and practice improvement **US$1.5 Million** (1).
Agree on common management, monitoring and control measures	Done. Presently there are mandatory densities by species, coordinated treatments in order to control sea lice, and common biosecurity measures. Farms in each AMA can agree on additional measures.		They have to cooperate in coordinated sanitary treatments, apply biosecurity measures and immediately inform to other companies when a risky pathogen is detected associated to disease impacts. Additionally they can monitor and share oceanographic conditions and report to each other phytoplankton conditions (alerting of Noxious algae blooms and oxygen depletion, when detected early).	5	
Monitor and enforce management measures	Done. There are mandatory densities, coordinated treatments and biosecurity measures. Additional voluntary measures agreed in the AMA will become mandatory and they will also be enforced by the authority.		There are mandatory sanitary and environmental monitoring protocols that have to be applied and informed by farmers. Also they have to receive at any time announced visits of SERNAPESCA inspectors. In case of a positive fish disease finding they have to report immediately following the procedure established in the regulation.	5	

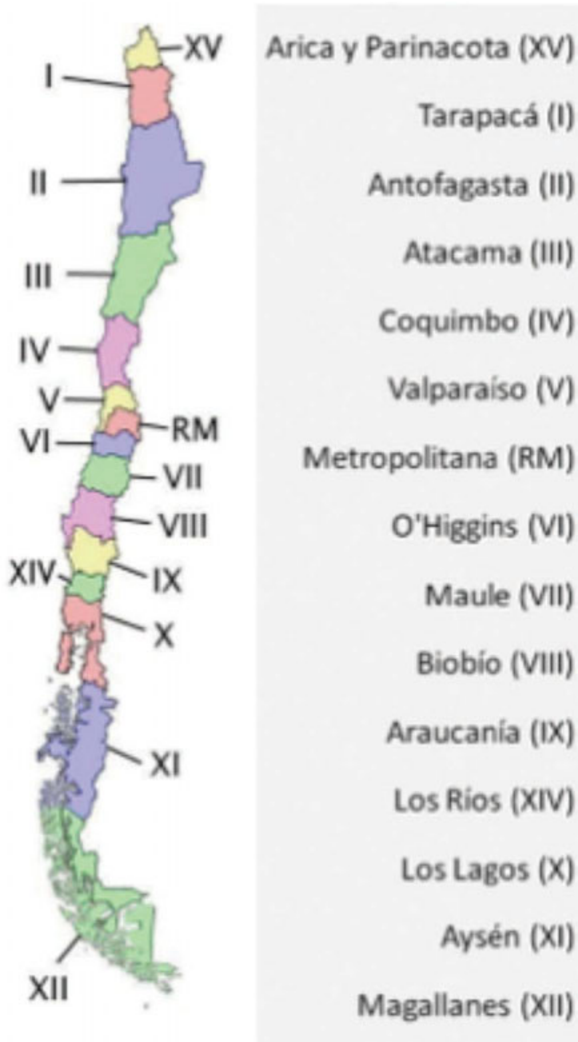
Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Estimated Costs (annual base)
Phase 4 Monitoring and Review					
Regular monitoring and evaluation	Done. Each farm is subjected to mandatory environmental (INFAs) and sanitary condition of fish. Results in terms of mortality will determine maximum fish entrance in the respective AMA.		Yes. There are several monitoring efforts requested by the authority. However farmers in the neighbourhoods can agree on additional monitoring efforts that once established acquire mandatory character.	5	Environmental: INFA's evaluations annually is around **US$1 Million.** Sanitary evaluations: annual cost on regular and special studies is around **US$1,5 Million.** Total: **US$2.5 Million**
Periodic review and adjustment	Done. Industry and authority regularly evaluate these measures. Based on joint analysis, the authority order support specific studies to technical agencies like (IFOP) (Fishery Technical Institute). These are usually financed by the Fisheries and Aquaculture Fund (FIPA) , The National Economic Development Agency (CORFO) and The National Science and Technology Commission (CONICYT).		Monitoring results review id normally coordinated by the Technological Institute of Salmon who inform to all farmers in a given neighbourhood. There are periodical meetings of technical committees to review, adjust or order new monitoring programs.	5	Oceanographic, sanitary and other special studies useful for regulation and spatial management is around **US$2,5 Million.**

Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs and licenses (in parenthesis)**	**Approximate production from each aquaculture zone or AMA**
Number of zones and range of implementation	25 in the X Region (505) 37 in the XI Region (709) 16 in the XII Region (88) : Total 78 Groups of licenses or neighbourhoods (AMAs) and 1,302 licenses.	Year: 2013 (total 3 species) X Region: 371 000 tonnes XI Region: 383 000 tonnes XII Region: 25 500 tonnes

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Estimated Costs (annual base)
Other notes	**Positive issues**		**Negative issues**		
(especially social issues)	After ISA crisis progress have been observed in several aspects of the industry. In terms of spatial use of the sea, zoning and limits to general production (introducing withdrawal periods) and more recently density limits, diminish risk of overuse of territories preventing stress that triggers diseases. Additionally, spatial monitoring of critical variables and coordinated treatments also prevent environmental and disease risk. In the same direction can be considered the obligation to vaccine and evaluate sanitary conditions of all fish being stocked in the sea. Several companies have initiated more comprehensive plans of interaction with local communities, cooperating with them in line with their needs. In addition transparency has been increased by the companies and authorities, publishing information that in the past was not open, like licenses operating and producing, mapping, monitoring results, and periodical reports on industry.		More emphasis should be given to improve the allocation of zones for aquaculture (neighbourhoods) in accordance to environmental factors, and carrying capacity estimates should be conducted within these allocated zones. Companies should emphasize collaborative plans with local communities and other activities like artisanal fisheries and tourism in order to contribute to social capital building, essential for integrated progress of these regions.		

(1) Author estimate

ANNEX 2. CHILE'S REGIONS



GLOSSARY

AAA: Appropriate Areas for Aquaculture. Areas where aquaculture (not only salmon farming) can be developed in the jurisdictional sea of Chile according to the General Law of Fisheries and Aquaculture (Law 18,892 or GLFA, vers. 2013, Law 20,657). An AAA includes macro zones, neighbourhoods and farming sites (also mentioned as licenses or concessions).

AMA: Also named Salmonid groups of licenses or Neighbourhoods (NEI). Group of aquaculture concessions within an AAA situated in a sector that presents safety, epidemiological, oceanographic, operational or geographical features that justify its coordinated sanitary management by species group (for instance salmonid species), as per SUBPESCA declaration (LGPA, vers. 2013). Neighbourhoods include farming sites or licenses.

AMICHILE: The principal and most representative association of mussel producers, processors and suppliers in Chile.

CORFO: The National Agency for economic development.

CPS: Preliminary characterization of the site. A procedure to characterize a site or concession to apply for approval and establish a baseline for future evaluations of eventual impacts on it. Categories of aquaculture sites, CPS, INFA are detailed in the Companion Resolution of RAMA, i.e., Resolution Ex. 3612 (2009). This last had a recent modification in June 2014.

D.S.: Supreme Decree. It is a written order of the President of the Republic, issued within the sphere of his/her competence, bears the signature of or ministers of respective State and is subject to a special procedure.

D.S. N° 223 (1968) OF THE DEFENSE MINISTRY (NAVY): Regulation on Marine Concessions.

D.S. N° 175 (1980) OF THE MINISTRY OF ECONOMY ON FISHERIES ACTIVITIES: Reglamento para realizer actividades pesqueras (Regulation for fisheries activities).

D.S. N° 162 (1985) OF THE MINISTRY OF ECONOMY: Aprueba reglamento sobre control de enfermedades de peces de la familia salmonidae y otras especies hidrobiológicas y deroga Decreto n° 291, de 1985. Regulation to control diseases in salmonid species as well in other species.

D.S. N° 99 (1988) OF THE MINISTRY OF ECONOMY: Modifica D.S. N° 175 del Ministerio de Economía y Turismo. Status: Derogado. It modifies D.D. N° 175 of the Ministry of Economy and Tourism. Status: repealed.

EIA: Environmental Impact assessment system. It is considered in the General Law of the basis of environment. Particularly in the case of aquaculture, has to do with preliminary characterization of the site, and according to its results if the project needs an EIA study or just an EIA declaration.

ENVIRONMENTAL AREAS: Areas defined by INTESAL IN 2004 that were similar enough as to determine them as identifiable water bodies.

GLFA: General Law of Fisheries and aquaculture (Law 18,892, 1991), with several amendments after 1991. Presently (GLFA, LAW 20,434—2009), and again under review (2016).

IMTA: Integrated multi trophic aquaculture.

INFA: Annual reports on the environmental status of a license (sea farming site), with defined monitoring and analysis of specified variables. Categories of aquaculture sites, CPS, INFA are detailed in the Companion Resolution of RAMA, i.e., Resolution Ex. 3612 (2009). This last had a recent modification in June 2014.

INTEMIT: Technological institute of the mussel industry in Chile. It depends of AMICHILE.

INTESAL: The technological institute of salmon, in charge of R&D necessary for the salmon industry. It depends of SalmonChile.

ISA: Infectious salmon disease. It affected severely the Chilean industry in 2007.

LAW OF THE GENERAL BASIS OF THE ENVIRONMENT: Law 19,300 enacted in 1994 defining regulations for a sustainable use of natural resources of the country and protection of its natural reserves. It contains norms for Environmental Impact assessment in the different sector, establishing when an EIA study or declaration are necessary, among others.

LAW 20.434 (2010): In this legal body it was introduced the option to declare AAA for a group of species. The same law closed new license applications in the X Region except for seaweed farming; it closed temporarily, for 2 years licenses for salmon species farming in the XI Region and also temporarily closed applications in the XII Region until the modification of the AAA for group of species in the period of 12 months. In 2012, due to the high farm concentration in the X Region, particularly of salmon and mussel, the Sub-Secretary of fisheries declared the AAA of the X Region not available for new licenses request, the only exemption being seaweed farming (R.EX. 825—2012, Undersecretary of Fisheries and Aquaculture).

LICENSE: Concession for a farming site installation and operation. Derived from the administrative act through which the National Ministry of Defense gives to a person/entity rights of use of a resource (water column, sea bottom, coastal site, etc.), for a period of 25 years renewable, to carry out in them aquaculture activities (GLFA, vers. 2013).

MACRO ZONE: Zone defined by the Authority (SUBPESCA) to avoid dispersion of a given disease or infection in any farmed species activated under an emergency situation (not always operational). (GLFA, DS 391, 2001). When activated a macro zone includes AMAs (neighbourhoods) and farming sites or licenses.

MINISTRY OF DEFENSE: It is in charge of the defense of the country. It has Subsecretaries for the Army, Navy, Air Force and Police. The Subsecretary of the Navy is the one related principally to fisheries and aquaculture permissions, enforcement, safety and environmental aspects.

MINISTRY OF ECONOMY AND TOURISM: The Ministry dealing with fisheries and aquaculture. SUBPESCA AND SERNAPESCA are part of this Ministry.

NATIONAL COMMISSION OF THE COASTAL ZONE: This is a commission with participation of several Ministries responsible for proposing to the President of the Republic, actions that promote the implementation and enforcement of the national policy for use of coastal zone. The commissions are integrated by representatives of different sectors dealing with: the aquaculture industry, other economic sectors, indigenous people (Law 20249, 2008, creates marine space of original people), local communities, regulation and enforcement authorities, research institutions and NGOs related to environmental and social protection.

NATIONAL POLICY FOR THE USE OF THE COASTAL ZONE: D.S. 475 (1995) of the Ministry of Defense, establishes regulations to define areas of preference uses in the different regions of the country and other matters related to the best use of the coastal regional sea.

OCEANOGRAPHIC SERVICE OF THE CHILEAN NAVY (SHOA): This is an agency of the Navy of Chile which provides oceanographic and meteorological information for ports and navigation. Also it develops studies, research and monitoring associated with its mission. It gives scientific and technical support to the Subsecretary of the Navy in relation to space management of aquaculture.

RAMA: The environmental regulation for aquaculture defined in the GLFA. It specifies prodedures and criteria for CPS and INFA.

REGIONAL COASTAL ZONE PLANS: Sectorial planning. AAAs have been integrated in the context of the coastal zone management plan established in different regions. In fact, the regional plans recognized different zones of preferential use (National Commission of the Coastal zone use, www.ssffaa.cl/comision-nacional-de-uso-del-borde-costero-cnubc/).

REGIONS: Territorial units of the political divisions of the country; in Chile there are presently 15. (See Annex 2).

RESA: The fish health and sanitary regulation for aquaculture defined in the GLFA.

SALMONCHILE: The association of the industry of salmon in Chile.

SERNAPESCA: National Fisheries and Aquaculture Service. Agency under the Ministry of Economy and Tourism. It is the agency essentially responsible for enforcement.

SUBPESCA: Undersecretary of Fisheries and Aquaculture. Institution under the Ministry of Economy and Tourism. It is the institution essentially responsible for regulation.

Zonal Aquaculture Management in China and Indonesia

Anton Immink, Han Han, Pamudi and Jack Morales[1]

ABSTRACT

The best examples of zonal management are seen in the salmon industry and were developed, particularly, in the pioneering countries of Norway and the United Kingdom of Great Britain and Northern Ireland. Detractors would certainly claim the systems are still far from ideal, but they have helped protect the environment, minimise disease impact and support the industry to flourish in a sustainable manner. Sustainable Fisheries Partnership (SFP) is using the broad zonal management model developed in Scotland, the United Kingdom of Great Britain and Northern Ireland to apply to tilapia, pangasius and shrimp industries in Asia through what are known as Aquaculture Improvement Projects (AIPs). Zonal management developed in salmon production is a response to both chronic and acute disease outbreaks, production issues over continuous use of the same sites and continued external pressure over environmental impacts. The geographic translation to Asia mandates a shift in cultures, species, capacities and systems. There certainly are challenges interpreting lessons from a relatively low farm density region to areas with almost contiguous production; and from cages to ponds, but these challenges need to be overcome in order to ensure sustainable production in all senses—for the industry, the environment and the local population. SFP is working with local aquaculture sectors in China, Indonesia, Thailand and Vietnam to strengthen the scientific advisory to support effective policy for realistic industry development and to ensure the producers themselves use better practices on farms and are organised to enable them to have a unified voice in their future. Case studies on progress in China and Indonesia are provided.

GENERAL BACKGROUND TO DEVELOPMENT OF THE ZONAL AQUACULTURE APPROACH

Any major production industry faces challenges when it reaches scale. One solution is to isolate production units from each other and from the environment to minimise disease risk and environmental impact, but this approach has not been widely adopted by aquaculture to date because of the significant technical challenges and associated costs. However, there are a few good examples of where aquaculture sectors have taken a lead in tackling the risks through a scientifically-based planning, licencing and

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

Immink, A., Pamudi, H. H. & Morales, J. 2017. Zonal aquaculture management in China and Indonesia. In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document*, pp. 198–221. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

management process that is a partnership between commercial and regulatory stakeholders. These systems developed principally as a response to environmental challenges and disease outbreaks. The hope is that such lessons can be shared with developing sectors before they face major problems.

Sustainable Fisheries Partnership (SFP)[2] identifies these approaches as 'zonal management', whilst FAO has labelled them as "area management" following 'the ecosystem approach to aquaculture'. The two approaches are very similar, with many identical components—particularly around the development or strengthening of aquaculture sector management structures. For practical purposes we are talking of the same thing and could use both terms interchangeably, but as the approaches have developed their own identities over time, we will continue to refer to zonal management in the remainder of these case studies.

The best examples of zonal management are seen in the salmon industry and were developed as a response to both chronic and acute disease outbreaks, production issues over continuous use of the same sites and continued external pressure over environmental impacts, particularly in the pioneering countries of Norway and the United Kingdom of Great Britain and Northern Ireland. Detractors would certainly claim the systems are still far from ideal, but they have helped protect the environment, minimise disease impact and support the industry to flourish in a sustainable manner. SFP is using the broad model developed in Scotland, the United Kingdom of Great Britain and Northern Ireland, to apply to tilapia, pangasius and shrimp industries in Asia through what are known as Aquaculture Improvement Projects (AIPs). This geographic translation mandates a shift in cultures, species, capacities and systems. There certainly are challenges interpreting lessons from a relatively low farm density region to areas with almost contiguous production, and from cages to ponds, but these challenges need to be overcome in order to ensure sustainable production in all senses—for the industry, the environment and the local population. SFP is working with local aquaculture sectors in China, Indonesia, Thailand and Vietnam to strengthen the scientific advisory to support effective policy for realistic industry development and to ensure the producers themselves use better practices on farms and are organised to enable them to have a unified voice in their future.

AIPs are not about stopping aquaculture. Where industries are beyond carrying capacity, positive solutions may include the enforcement of better farm management; and better knowledge of how disease can spread should inform a better industry structure, not necessarily meaning the removal of farms. On subsequent pages we share our experiences to date in two aquaculture industries and invite other industries and regulators to the take the lead to ensure the survival and sustainable growth of their own aquaculture sectors—regardless of scale, species or system. The two case studies should be read together because the activities and outcomes contribute to overall learning, rather than being comparable.

The Five Pillars of Zonal Management

In zonal aquaculture improvement projects there are five key focus areas:

1. Effective regulation based on sound science;
2. Active producer organisations guiding the industry towards sustainability;
3. Planning, licencing and management of industry development and production based on carrying capacity;
4. The use of epidemiology and other science to minimise disease risks during planning operational and emergency phases of the industry; and
5. A feed strategy based on reducing impact and risk to source fisheries providing fishmeal.

An overarching consideration is ensuring that all documentation relating to the planning, licencing and management of the sector is readily available in the public domain; such transparency is necessary to ensure appropriate use of public resources—in this case, particularly water.

The zonal aquaculture improvement projects highlighted in the case studies included here present the work that has been completed over the last two years. These projects are very much 'works in progress',

2 SFP is an international nonprofit organisation working with major seafood buyers to identify and minimise risk in global supply chains. Visit www.sustainablefish.org for more information.

able to respond to new opportunities that enable improvements within the broad zonal management framework. The main focus of the projects to date has been around pillar 2—strengthening local industries to engage in sustainable management and development. This has taken time, particularly where many producers are small-scale. Some work has started on the core technical foci of reducing local environmental impacts (pillar 3) and disease risks (pillar 4). However, the overriding approach to facilitate the local industry to take the lead in delivering improvements, rather than a third party doing that for them, has extended project horizons and means that, whilst components are being built, there is no overall management plan either for target zones or for industry sustainable development more broadly. This longer-term view should embed a strong understanding of the improvement process with the local industry and regulators. The process is participatory in that respect, although the drive for improvement usually comes from the supply chain.

There has been some movement towards strengthening the policy development process (pillar 1), but in the two examples given there has been little specific engagement on improvements in feed (pillar 5). Feed is being tackled in other ways in SFP, principally through fishery improvement projects (FIPs) in the fisheries that supply fishmeal to the aquaculture feed industry. They are not reported on here, but information on the projects can be found at www.sustainablefish.org.

The two project case studies have faced different challenges working with industries at different stages of development and therefore the lessons described below should not be compared, but combined to give a more complete picture and not compared.

SFP's Approach to Reducing Risk in the Supply Chain

SFP works with retailers to identify and reduce risks in international seafood supply chains in order to improve sustainability. The main focus is around environmental sustainability, but this in turn feeds into economic sustainability and increasingly includes the social elements of sustainability. Once the supply chains are identified an assessment is made of the issues that need addressing and this is published on FishSource (www.fishsource.com). Key players within these supply chains are engaged in a range of improvement activities: Groups of major suppliers with regional sourcing needs work together to support producers, processors, regulators and scientists in countries or zones to deliver improvement projects locally.

Certification and Traceability

Zonal management goes beyond the current industry focus on farm-level certification to tackle the cumulative risks and impacts of aquaculture. SFP is working with standards to identify how zonal management can be effectively and efficiently certified. However, farm-level certification provides a reasonable proxy indicator of the engagement of producers and processors in improvement and certainly offers a closer link between buyers and producers. If an industry has a high percentage of certified farms you could expect it to be well run, but there are examples of such situations with high levels of certification where the industry and regulators are failing to tackle the shared disease risks and environmental impacts of the sector. This is a major risk for the farms, the local economy and the international supply chain.

Zonal AIPs all require international supply chain commitment in order to help move industries forward and ensure that changes are maintained by market engagement. Within zonal AIPs there is an expectation that farms of all scales will become formally licenced, and be active participants in the development of better internal management mechanisms within industries. Therefore, as AIPs become more widespread aquaculture production should be more easily tracked through the international supply chain. Indeed, traceability should become the norm, rather than being largely reserved for certified products. But there is recognition that an increasing percentage of production is likely to stay in Asia, and SFP is already working with retailers in the region to engage in improvement projects in both aquaculture and fisheries.

Defining Zones for Zonal Management—Thinking Water Is Critical

The concept of zones or zoning is familiar in terms of identifying where would be best for aquaculture development to take place, based on criteria such as access to water, markets, infrastructure and labour.

However, there are very few examples where the location of farms or the total amount of production within such zones is determined using scientific evidence like carrying capacity or disease risk assessment. OIE (the world animal health organisation) uses the term zone to identify discrete areas for disease management and control. From a planning and management perspective this is a useful reference point as we consider the need for zonal **management,** which builds on basic zoning to take into account disease risks and environmental impacts to define the boundaries of individual management units (zones). Environmentally these zones would have watershed-based boundaries, butwhere watersheds are very large, e.g., the Mekong delta, administrative boundaries would probably represent the limit of control of each zone. Comparisons can be made to fisheries management, from local to highly migratory stocks. This comparison requires the recognition that aquaculture management units (zones) are based on the need to sustainably manage the shared common resource of water rather than fish. Whilst individual farms are private enterprises (like boats in a fishery) they are entirely reliant on the goods and services of the common pool resource of water (like the fish in a fishery). Rather than assessing stocks there is a need to assess disease risks and the ability of water to process additional nutrients added to the water rather than subtracted (in the case of fisheries). For the effective development and control of aquaculture national governments and industries need to define aquaculture zones in their countries using the best available science and develop zonal management institutions to ensure future sustainable production, in the same way that fisheries management exists.

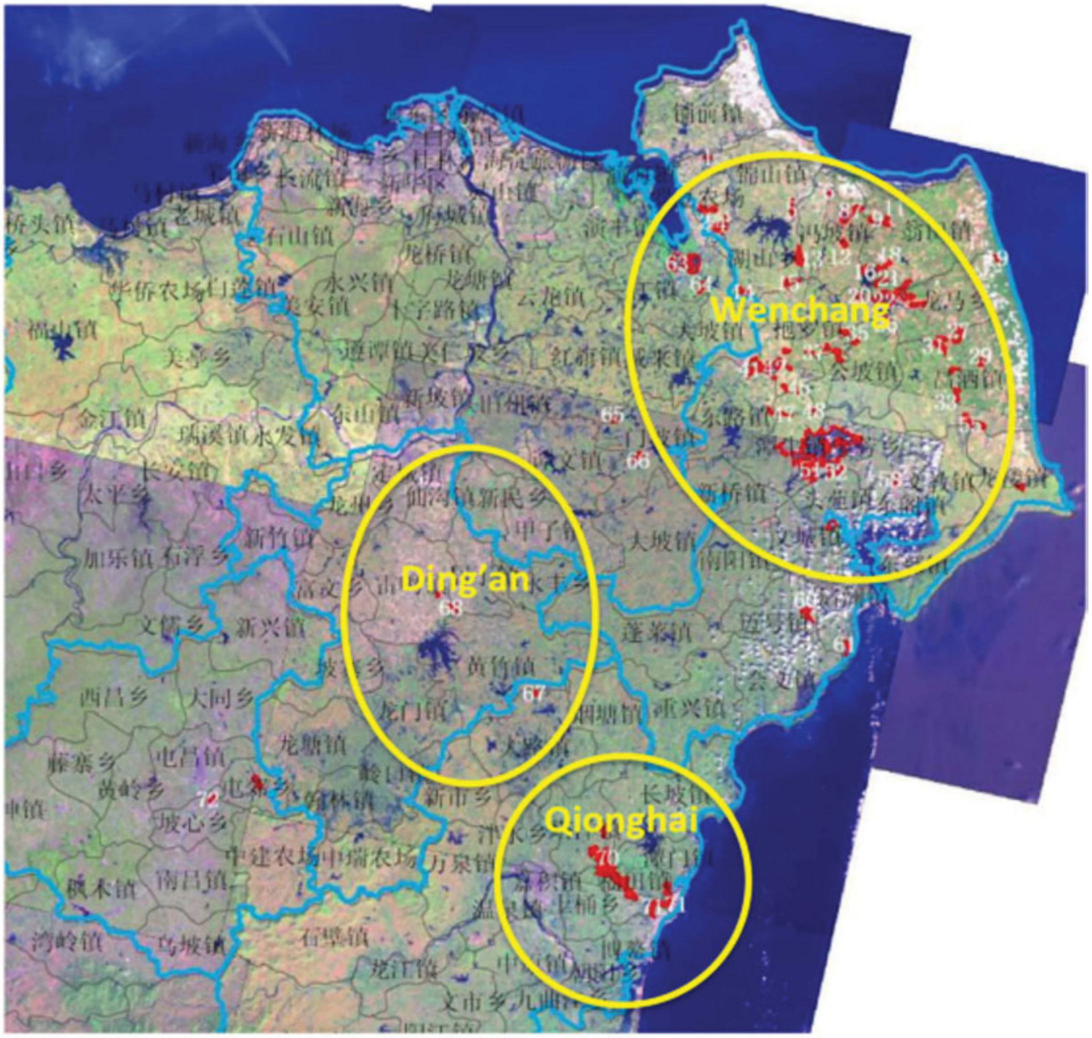
HAINAN TILAPIA AQUACULTURE IMPROVEMENT PROJECT

Background

Hainan variously vies with its neighbour for the position of the number one tilapia production and export region in China. The tropical island at the southern

FIGURE 1. Location of Hainan province within P.R. China and location of main producing counties within Hainan.

FIGURE 2. Distribution of tilapia farms in the three main producing counties of Hainan.



tip of China produces around 340 000 tonnes of tilapia per year and exports most of this, with around 80 percent going almost equally to the U.S. and Europe. Production is in ponds, dams and cages across three counties in the north of the island. Wenchang has the highest volume and density of production, followed by Qiong Hai and Ding'An.

SFP's initial engagement with the tilapia industry in China was at the request of a retail partner with a focus on farm-level certification. However, it soon became evident that there were bigger issues to tackle and no one really tackling them. With the support of the Packard Foundation and some industry interest, SFP established a pilot zonal Aquaculture Improvement Project in Hainan in 2011. Initial engagement with producers and processors around certification and broad studies assessing environmental impacts helped build relationships locally, but it is only in the last couple of years that the project has really taken off. Key players in the local industry have understood the shared risks the industry is facing and the need for the industry to develop a unified voice. A desire to stand out as a responsible producer of a quality product has also helped to give the industry the confidence to take a lead. SFP continues to support what is now known as the Hainan Tilapia Sustainability Alliance (HTSA), driven by a group of leading local companies covering seed, feed, technical support, farming and processing, and increasingly involving more of the local industry.

Water Quality Management

The industry has faced the classical challenges of disease outbreaks particularly in the warmest months, but there has been little assessment of environmental impact. The ownership structure of many of these farms and the value placed upon water and nutrients means that many of the farms have very little discharge; however, balancing this desire to retain valuable resources with the need to maintain good water quality, particularly at times of high temperature, has led to innovation. Farmers typically discharge less than 10 percent of the total water held on farms each year. Losses to evaporation are replenished, but the nutrient-rich water is too valuable to flush to the environment and so is transferred from one pond to the next during the harvesting period. Many farms are situated within irrigation schemes, where water needs to be paid for. Discharged water is usually used on agricultural crops where the additional nutrients are beneficial, but tilapia farmers are not rewarded for this.

Supporting Farmers

Farmers receive a range of technical and financial support, from commercial providers and from government extension officers. Commercial support comes from feed companies, hatcheries and processors, but a large part of the support to some farmers comes from the supplying and buying companies that support trade distribution—more classically known as middlemen. Some of these middlemen are in fact sizeable businesses that have substantial stakes in the success of the industry. Leading middlemen companies provide expert advice in a timely manner, actively supporting farmers to ensure success. There are examples of such companies developing technical databases to enable farmers to refine their farming practices according to their local needs. This level of detail is helping to build real management in an industry that is still made up of a large number of small-scale producers.

Quality

The additional hook for the industry was identifying a shared ambition. Environmental sustainability is a noble goal and the idea of overcoming disease problems through collaboration with your neighbours is something that farmers understand, but find a challenge in reality. Such goals also put all the emphasis on farmers, when in fact there are many other players who are critical to the success of the overall industry. In Hainan the main driver to bring the industry together was a desire to identify themselves as different from all the other tilapia being produced in China, indeed in the world. Presenting their output as a quality product is a mechanism to engage all parts of the industry and makes use of the natural environmental quality of Hainan. This approach is certainly reminiscent of the Scottish salmon industry's approach to setting itself apart from other producers. But the challenge for the tilapia industry in Hainan was how to build the mechanisms (both industry and regulatory) to ensure any claims of being a better product were backed up with identifiable actions.

DEVELOPING ZONAL MANAGEMENT

Wider Dialogue and Engagement (Taking Zonal Management Pillar 2 to a National Level and Feeding into Pillar 1)

As fits with SFP's model of change, the dialogue to date has predominantly been with the local industry, and through their engagement the inclusion of local researchers and government staff as required. However, SFP has also maintained a good relationship with HAPPMA (Hainan Aquatic Products Processing and Marketing Association) and CAPPMA (the Chinese Aquatic Products Processing and Marketing Association). The HTSA provides a complementary focus to these two organisations. HTSA's efforts lie more with sustainable production in support of the wider marketing aims of HAPPMA or CAPPMA. It is envisaged that stronger ties will develop between all interested parties as the industry moves forward, and that producers, processors, regulators, scientists and others will take part in roundtables to sustainably drive the industry forward. As all actors become more confident, and as markets demand it, more data covering production, health management and environmental quality should become available in the public arena.

As the demonstration approach in Hainan is better understood and documented, it is likely to be replicated in other areas in China and farther afield. There is current interest from the other Chinese tilapia production regions, and some of the leading participants in the HTSA also have business interests in other provinces.

Building Trust (Zonal Management Pillar 2)

The farm scale of most producers is only a few ponds within a few hectares. There are larger farms that have the internal management systems in place to enable them to attain international certification, but the majority of farms are reliant upon the supply chain for support. SFP typically uses the processors as an entry point for fisheries improvement projects. Aquaculture improvement projects also work with processors, but they soon realised the opportunity to effectively engage producers through feed, seed and technical input companies, who often have longer-term relationships with farms. The challenge has been that many of SFP's retail partners have little direct interaction with these support industries so building trust and dialogue between different parts of the sector has been a key goal. Finding a champion who could bring the industry together has been critical. In Hainan that lead has come from a middleman company.

Ensuring regular meetings take place between different parts of the industry at both local and provincial levels has also helped to develop trust. This process is discussed later in the 'Industry Voice' section, but these meetings and the establishment of a recognised representative organisation for the industry have helped to develop belief that improvement projects are not short-term solutions, but offer positive structural change for aquaculture industries.

Industry Voice (Zonal Management Pillar 2)

Within an AIP there is a need to raise the voice of different parts of the sector to take part in effective dialogue with each other. Except in the smallest of sectors, it is impossible to expect that all farmers will be able to directly take part in planning and dialogue, but it is important that their voice is represented. In Hainan there are whole production areas where the industry has no shared voice. Some counties do have active farmer associations, and these tend to be where the native population has taken up tilapia farming and a few leading local business people feel that a support network would help strengthen development. However, in areas with multiple small-scale producers who are typically not native there are no associations. The AIP has facilitated a few farmer meetings now and attended existing meetings in order to share information on zonal management and the development of a shared goal for the industry at the provincial level. In the areas where new meetings have taken place, farmers have been inspired to continue informal regular meetings and are especially excited about the idea of building the shared reputation of Hainan tilapia as a quality product. As these groups formalise, their representation at the provincial level will increasingly lend weight to the voice of the tilapia industry, which faces competition for land and water from many other sectors, but especially from tourism as Hainan is China's holiday island.

Farm-Level Training/Engagement (Zonal Management Pillar 2, Contributing to 3 and 4)

It is not possible to continually engage all farmers on the promise of a shared utopia. Indeed, improving production practices at the individual farm scale is an essential component of zonal management. Training on best practices and information about new technologies to be applied on farms are key components of industry-wide improvement. The key champions in the Hainan Tilapia Sustainability Alliance (HTSA www.hntsa.org) and with donor and supply chain support the tilapia industry is improving:

- water quality management,
- feed efficiency,
- disease control, and
- farm data collection and assessment.

The cumulative impact of these farm-level improvements, alongside the industry-wide actions being developed to review environmental impacts and strengthen health management planning, is helping to reduce risk to the industry as a whole.

Code of Good Practice (Zonal Management Pillar 2, Contributing to 3 and 4)

Members of the HTSA have developed a Code of Good Practice that contains guidance on the application of the five pillars of zonal management across the industry and specific guidelines for farms, hatcheries, feed plants and processors, covering industry inputs, production and post-harvest. The blueprint for the development and proposed management of the Code of Good Practice (CoGP) can be seen in what Scotland, the United Kingdom of Great Britain and Northern Ireland, has done across the finfish industries www.thecodeofgoodpractice.co.uk. All members of the various Scottish aquaculture producer associations (salmon, trout, marine finfish) are required to follow the code, which is independently audited and reported against. Again, although not considered perfect, it is the best in the industry and a suitable model for translation by other sectors.

Members of the HTSA are developing sections of the CoGP relevant to their areas of expertise. Each section will be reviewed by local peers before being finalised. This review process and the engagement of local universities and research institutes to conduct studies to support the development of zonal management are helping to build an effective scientific advisory system to support current and future dialogue and policy development processes. Hainan University has conducted environmental and disease risk assessments, and the Pearl River Institute is sharing its experience and knowledge from the epidemiology assessment of the carp industry in Guangdong.

Disease and Environmental Management (Pillar 3 and 4)

Defining zones should be relatively straightforward in Hainan because there are clear watersheds where the bulk of production takes place. As HTSA is strengthened and the industry becomes more organised and engaged with local researchers and government officials, there will be increasing use of environmental and health management science as the basis for planning and managing industry development. Carrying capacity assessments and epidemiology studies will inform the effective limits of zones and how farms must engage with each other within those zones in order to minimise risk.

Supply Chain and Donor Support (Overall Approach, Contributing to Pillar 3 and 4)

SFP has facilitated several supply chain and donor visits to see the progress the industry is making in improvements. These visits have helped drive active support for the improvement process, not just financially, but also the closer linkage between producers and the end market. Opening up these dialogue channels is improving farmer understanding of the final consumers demands and educating buyers as to the challenges farmers really face. For example, when the market demands a different size of fillet there are challenges not so much in the technical production issues, but in changing producers' confidence that they will still receive a good income if they alter the length of time they raise the fish. The risks and impacts in terms of environment and disease management also need to be taken into account, but effective dialogue and a sense of common purpose helps speed up this process.

Summary for Hainan Tilapia Aquaculture Improvement Project.

Zonal Criteria/Action	Successes	Challenges	Future Actions
Regulatory engagement	Dialogue with local extension service and informal discussion with local government	Building strong working relationships between HTSA and regulators	Initiate roundtable process
Industry involvement	Champions now leading new alliance. County-level groups developing or strengthening	Ensuring improvements are shared with all producers	Continue to strengthen HTSA to lead the industry. Encourage replication in other areas in China
Environmental impact	More efficient production at some farms is reducing waste	Scaling up best practices to all farms will be challenging when margins remain minimal	Conduct full carrying capacity assessments for each zone
Health management	Clear understanding in the local industry and scientific advisory for coordinated action	Translating this developing industry knowledge into action and regulation	Support further studies. Initiate closer dialogue with local government
Feed ingredients	Good engagement of local feed industry	Understanding feed ingredient sources	Work with local industry towards sustainable ingredient sourcing
Data disclosure	Local associations publishing some production data on the web	Widening reporting, particularly around water quality	Support public data platform development
Code of Good Practice development	Agreement across industry to develop	Confidence required for industry to self-define best practice	Deliver code in coming months
Scientific advisory	Pearl River Institute and Hainan University actively engaged	Expanding inclusion to other scientists	Support further research as identified by HTSA
Stakeholder roundtable/ forum	Provincial level meetings held	Broadening active participation	HTSA to lead wider engagement

CONCLUSION

The industry has embraced the idea of collaboration, helping them to move towards a stronger, self-determined future that is sustainable environmentally, socially and economically. Whilst this cooperation was promoted on the basis of presenting Hainan tilapia as a quality product, it has the added value of driving improvements in production practices to minimise risks and impacts across the industry. There are some strong champions who are keen to drive the HTSA forward and develop closer partnerships with the local government, researchers and other stakeholders, whilst strengthening supply chain engagement to support improved production efficiencies. It is still relatively early days in this demonstration of AIPs, but there is already strong interest from the industry in other provinces in China. Challenges remain in building effective zonal management into the regulatory structure both in Hainan and nationally, but the Code of Good Practice being developed by the industry is providing sound foundations for a constructive dialogue on the sustainable future of this valuable industry.

EAST JAVA SHRIMP AIP

FIGURE 3. Location of Muncar, within Banyuwangi district, East Java, Indonesia.

BACKGROUND

As with many other places in Asia the shrimp industry in Indonesia has seen a dramatic shift in production over the last 20 years from extensive, traditional systems to more intensive, high investment systems and from a native to an exotic species. These changes have enabled the industry to scale-up and initially remove some of the disease risks associated with the farming of the native black tiger shrimp, but across Asia new diseases have caused major impacts—most notably and recently early mortality syndrome (EMS)—although Indonesia apparently remains free of this problem.

One of the areas in which Indonesian shrimp farming first started developing on a larger, more commercial scale was in East Java. In the late 1980s Banyuwangi was one of the first areas to develop and still has a wide mix of small and larger-scale farmers, some still operating the same farms since that time. Many farms have closed and there are clear signs of dereliction and legacy issues of production taking place in former mangrove areas, but there are signs of revitalisation and a growing commitment to ensure that lessons are learnt and acted upon. Although not perfect, there is industry representation across the country and a working relationship between the industry and regulators at both local and national levels.

SFP's engagement with the industry in Banyuwangi started with a request from a shrimp buyer to review the potential for farms in the area to meet international certification standards. This was followed with some engagement to help the farms to improve, alongside the efforts of other local and international NGOs. In the last two years SFP have scaled up their engagement and recruited a dedicated member of staff to support the industry and regulators to develop zonal management at both the local and national levels.

DEVELOPING ZONAL MANAGEMENT

National Engagement (Zonal Management Pillar 1)

The shrimp AIP in Indonesia has had the most effective engagement of the national industry and regulators of all projects to date. This is in part due to the historical linkages across the industry of the project manager, but is also testament to the interest and engagement of the government officers and industry leaders concerned. Key officers in the Ministry of Marine Affairs and Fisheries (MMAF) are involved in regional and national FAO projects that are highlighting the need for zonal management: the FAO-RAP office in Bangkok is developing an aquaculture planning and management toolkit; Indonesia has been identified by FAO as a pilot country for the Blue Growth initiative, so there is further incentive to actively engage across the fisheries and aquaculture sectors.

MMAF staff have been particularly keen to maintain Indonesia's EMS-free status and have worked closely with SCI touring all shrimp production regions of this expansive country to alert farmers to the risks of EMS and encouraging them to report any concerns. These actions demonstrate real commitment from senior and field officers to the sustainability of the industry, but are still required to be backed with contingency plans developed in partnership with all stakeholders should a new major disease issue arise.

In an effort to improve traceability MMAF is also launching a program called "Aquacard" that should enable buyers to trace shrimp back to their production at the farm level. This idea is not without its challenges in the complex supply chains where production from numerous small producers is often consolidated. To help this initiative to succeed there will need to be dialogue between all stakeholders.

'Informal Meetings' (Zonal Management Pillar 1)

A true innovation of this AIP that needs to be widely promoted is the development of 'informal meetings' between MMAF, SCI and the national processor organisation AP5I. These meetings were initiated to encourage industry support for the ban on the import of shrimp from EMS-affected countries. The ban was brought in as Decree 32/2013 and is a logical response for Indonesia to retain its EMS-free status, but is only effective in emergency situations. Given the high value of shrimp in the market place of 2013, there was commercial pressure from the processors to bring in shrimp for reprocessing, but understandable nervousness from producers about the risks of importing EMS with such shipments. The innovation was for the responsible MMAF staff to call an informal meeting in which all parties could voice their concerns and reasoning freely. This allowed for dialogue and engagement that would not have been possible if the meetings were formal roundtables. In essence the process mirrors the stakeholder roundtables at the core of the AIP model, but the fact that they were initiated as informal meetings removed some of the barriers to dialogue. Government staff in the meetings, even at the most senior levels, were asked by their colleagues to spend the time listening only, allowing the industry to dialogue and develop actions towards solutions. Only if no suitable resolution could be agreed would the government intervene. The first meetings brought about agreement that shrimp would not be imported from other countries and some containers were turned away from ports as a result. Indonesia remains EMS-free.

The meetings continue. Other occasional stakeholders join, but this will be regularised to include scientific advisory, NGO (social and environmental) and other industry stakeholders in due course. The challenge will be to retain the informal nature of the meetings as they become a more regular feature in the industry and government calendar, but this regularity will be offset by the familiarity of those attending with both the process and each other.

Small-Scale Producer Involvement (Zonal Management Pillar 2)

The local branch of the national Shrimp Club of Indonesia (SCI) identified the cluster of smaller-scale producers in Muncar as a good potential model for developing and demonstrating the zonal management model. The farms in Muncar are generally of older construction, and at the time of starting the aquaculture improvement project some of them were no longer used to produce shrimp, but produced crabs or finfish instead. Amongst the producers that remain there is a strong, informal association under the guidance of one shrimp trader who lives and still farms in the area.

This local group was encouraged to improve their access to the support that was available from the local government, as well as making more productive use of their combined power. The first step they chose was to formalise the group structure to demonstrate their commitment to work collectively and contribute time and money to future joint tasks. It was also hoped that this formalisation would reinvigorate the sense of belonging amongst local producers as many ponds have changed owners and operators. As a result of government support, shared canals have been improved, and through their own contributions the group has built a meeting hall and water quality testing laboratory that is slowly being fitted out with equipment. The group has received training on improved farm and zonal management practices, taking into account the risks they pose to each other and how to start overcoming some of these issues. The national government has also supported the group to replant mangroves as part of restoration efforts and as a waste treatment approach.

Muncar provides a small working focus of the wider aims of the zonal aquaculture improvement project (AIP). Whilst there is still a long way to go to improve the zonal management in Muncar, it has enabled both the local and national governments to understand in practice what could be started at the zonal level.

'SCI Cares' (Contributing to Pillar 2)

The local SCI branch is generally made up of larger-scale, but still family-run shrimp producers. These farmers have been growing shrimp for many years now and believe that their farms are generally well run, although there are clear improvements that they would need to make to meet international certification requirements. Following many hours of workshops, informal dialogue and attendance at their branch meetings, these industry leaders came to understand that effective zonal management in Banyuwangi province needed their active engagement too if the shared risks and impacts were to be effectively overcome. Recognising that helping their smaller-scale neighbours to become better farmers was something they needed to become engaged in on a regular basis minimised risks to their own farms too. But these busy farmers do not necessarily have the skills or the time to deliver these improvements on their own, so the local SCI branch contacted the regional extension agency to understand how they could most effectively work together to support all farmers in the zone to minimise risks. This inspiring piece of initiative has strengthened collaboration between the local government and the shrimp producers not only to support development—which is something familiar to most local government aquaculture departments—but to work in partnership to identify and minimise the risks and impacts of shrimp farming. The initiative has been badged 'SCI Cares' and will hopefully be rolled out nationwide shortly as additional industry support becomes available.

Local Promotion and Data Presentation (Overriding Pillar of Data Disclosure, Supporting Pillar 2)

A simple tool that is helping develop engagement and pride in the work taking place locally in Banyuwangi, and also directly supporting one of the aims of the AIP, is the development of a website for the local SCI group and the wider shrimp production from Banyuwangi, www.sci-banyuwangi.org. The website is primarily in the local language, Bahasa, and used as a vehicle to inform farmers and the wider world on the improvement actions in the AIP as well as a shrimp newsfeed more generally. This provides control locally over the information that is shared about the industry and provides an opportunity to promote shrimp production from Banyuwangi more widely.

Code of Good Practice (Pillar 2)

Indonesia has its own shrimp farming standard. The standard is focused around good practice at the farm level, but it could form the basis of a Code of Good Practice that also included zonal management elements for the entire industry. Within the AIP the industry is not currently developing a specific Code of Good Practice, but is working with the government to explore including zonal management elements in future revisions of the national shrimp farming standards.

Challenges (Overall Approach, Supporting Pillar 2)

Long-term relationships with international buyers are less common in the Indonesian shrimp sector than in other countries. A lot of sourcing has typically taken place on the spot market, although this is starting to change as buyers need to source from additional markets and as the management of production at both the national (regulatory) and farm level is improving. The SFP model of using supply chain leverage to encourage improvement has been challenged in this AIP, but the engagement of the government and local industry has generally been strong because of the alternative motivators like the FAO projects mentioned above, the long-term relationship the AIP manager has with the industry and the history of effective results SFP has with fisheries in Indonesia. There is a lot of potential to grow production again in Indonesia and certainly a lot of apparent appetite from key stakeholders to do that following the zonal management principles. This is an important crossroads for Indonesian shrimp and serves as an interesting model for other industries in Asia where the champion exists readily in the government system, able to steer the industry into the calmer waters of maturity regardless of market pressure. This is particularly critical as greater demand for product comes from Asian markets that do not yet have the same sustainability demands as Western markets. But it also highlights an essential role for FAO and other international organisations to play in building capacity in government systems to effectively control aquaculture development for long-term sustainability rather than short-term, boom and bust, production gains.

Carrying Capacity (Pillar 3)

Industry and project engagement with the local government planning department (BAPPEDA) has been positive since the start. Roundtables bringing industry, regulators and scientists together have identified opportunities for improvement and specific actions for key parties to take. One such proactive move has come from BAPPEDA Banyuwangi to support a carrying capacity assessment to establish a mechanism to understand the environmental limits for total shrimp production.

At present the development of shrimp farming is still decided on the basis of suitability of land and access to key infrastructure. This classical approach to zoning only provides a guide to the areas where production might be most suitable. It does not provide any guidance on how much production the area can sustain, most typically in terms of the nutrient loads that could be processed effectively by the environment. In relatively dispersed and open systems like coastal plains leading into the ocean, these sorts of calculations can be challenging and expensive. The BAPPEDA-supported study aims to provide information locally on ecological carrying capacity whilst also developing a usable, valid, low-cost approach that could be replicated elsewhere. SFP was able to obtain donor support to bring some international expertise in to support the University of Brawijaya is who the local technical lead on this carrying capacity project. The approach is based on understanding water quality at key points where water enters and leaves the zone, along with calculating the nutrients added by aquaculture and other water users within the zone. The outcome is an indication of total nutrient loads that can be used to guide total amounts of production and how the industry to manage wastewater discharges through local dialogue.

Replication (Overall Aim, Covering All Pillars)

Since the start of 2014 SFP is also supporting local industries to develop two other shrimp AIPs, one in Vietnam and one in Thailand, with a mix of donor and supply chain support. The overall aims and approaches for these projects are the same as seen in Indonesia shrimp and Hainan tilapia. The projects focus on the five pillars of zonal management, but will respond to opportunities on the ground to engage the industry locally in the process of improvement. These projects are in early stages, but in Vietnam in particular are showing signs of great progress, including already the development of carrying capacity assessments and supply chain visits. In Thailand the local industry is still determining the scale of initial pilots.

In Indonesia a major shrimp buyer from the USA has collaborated with the Global Aquaculture Alliance to develop AIPs around the Best Aquaculture Practices new group certification model. This model requires an internal control system that would need to include elements relevant to zonal management. SFP is collaborating in the process and sharing our experience from supporting the progress made in Banyuwangi and wider Indonesia already. It is hoped that other buyers will be able to follow this model as it is bolted onto a certification process that they readily understand and have already often committed to supporting.

Having additional zonal AIPs established locally in different parts of Indonesia contributes to strengthening the industry to come together to take responsibility for its future and work effectively with other stakeholders. With this approach in mind, and being conscious of the need to engage farmers in improvements at the farm level, SFP has obtained support from the charitable arm of a major global retailer to support the training of small-scale farmers in improved production practices and the initiation of local zonal management groups.

CONCLUSION

The demonstration zonal aquaculture improvement project site in Banyuwangi serves as a good model of how knowledgeable neighbours who could potentially be impacted by other producers in the zone can come together to support education and access to resources to minimise risks and maximise potential for all. The industry has strengthened linkages with the local government, who in turn have understood the value of science in underpinning planning approaches. The carrying capacity assessments commissioned by BAPPEDA Banyuwangi should provide a workable tool for replication across Indonesia, indeed across Asian shrimp culture.

National ministry staff have demonstrated dedication and maturity in dealing with potentially difficult situations to enable not only positive short-term outcomes, but the establishment of a multi-stakeholder roundtable process that is at the core of effective zonal management. From these foundations it should be possible to build improved production practices and supportive regulation that is focused on sustainable, scientifically

Summary for East Java Shrimp Aquaculture Improvement Project.

Zonal Criteria/Action	Successes	Challenges	Future Actions
Regulatory engagement	National ministry and local government planning department actively supporting zonal management	Ensure the success with current post holders is carried over to other staff	Initiate dialogue with provincial government elsewhere in Indonesia
Industry involvement	Strong local and national associations already involved	Stronger local buy-in from producers needed to encourage/support farmers	Replicate actions with SCI branches in other provinces and districts
Environmental impact	Carrying capacity assessments initiated	Developing effective regulation	Finalise approach and share/ replicate
Health management	Biosecurity regulations acted upon through project activities	Emergency disease response action planning required	Encourage meetings to develop emergency plans
Feed ingredients	Other projects in place to address some feed issues	Encouraging action on something one step away from production without supply chain requests	Inform producers of future demands for greater transparency on feed ingredient sources
Data disclosure	SCI Banyuwangi website developed	Stronger publication of national production data	Work with industry and regulators to publish production, environment and health management data
Code of Good Practice	Some dialogue with ministry about revisions to farm standard	Agreeing criteria on the basis of good practice rather than achievability	Work with ministry and industry to improve standards and include zonal management
Scientific advisory	Engagement of University of Brawijaya in carrying capacity assessment	Geography of Indonesia may mean multiple specialists across the country	Build capacity in epidemiology assessment for aquaculture
Stakeholder roundtable/ forum	Informal meetings already successful	Formalising without losing effectiveness	Not to interfere too much in successful progress

validated growth that does not exceed the environmental carrying capacity or put the industry itself at risk of major disease outbreaks. The industry still requires effective licencing of producers at all scales.

In Indonesia the informal influence that the activities of international organisations can have on the success of industries is clear. The involvement of engaged ministry staff in FAO projects has helped move zonal management a step closer.

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The authors wish to acknowledge the guidance and input of other Sustainable Fisheries Partnership (SFP) colleagues in the development of the zonal aquaculture approach. We also wish to show appreciation for the significant engagement of the international supply chain that partners with SFP and the local producers, processors, regulators and scientists that have helped deliver and refine elements of the zonal aquaculture approach. This work would not be possible with commitment from key donors. This is still a work in progress, but we believe these joint efforts represent the strongest delivery of such an approach outside Europe and/or the salmon industry.

ANNEX 1. CASE STUDY EFFECTIVENESS MATRIX—HAINAN TILAPIA AIP

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	Three counties of producers identified within wider Hainan, some watershed zones defined.	Gov't/industry need to review boundaries/zones and develop appropriate data collection and management systems.	• AIP public report at www.hntsa.org/show_219.html	4	2,000—as part of preliminary scoping costs, but could be tens of thousands of dollars to do correctly for a whole country.
1.2 Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	Local policy context understood, regulators and scientists engaged.	Need stronger engagement of regulators in the AIP to move forward on more effective regulation.	• AIP public report at www.hntsa.org/show_219.html	4	3,000—as part of preliminary scoping costs, but needs much more investment to enforce or develop new zonal policies.
1.3 Setting the broad development objectives and identifying the main issues	Local staff with good understanding of local industry and ability to build relationships. Supply chain support to link to key industry stakeholders. Roundtable processes developed early on to dialogue on main issues.		• Communication, consultation, participation; • Assessment of available resources, needs and values; • Roundtable discussions.	4	2,000 per annum to cover meeting costs.

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.4 Zone boundary definition based on relevant criteria	Working with existing industry in zones based on production rather than management criteria.	Zones still need to be effectively defined in almost every country.	• Mapping and analysis using GIS and remote sensing data (e.g., water supply, water quality, climate, hydrological characteristics, soil characteristics, topography, sensitive habitats, protected areas, population settlements, etc.); • Carrying capacity; • Epidemiology;	4	Carrying capacity and epidemiology assessments would cost 10,000 or more.
1.5 Gross estimation of potential production/ area	Existing production areas were assessed, but no review of potential production to date.	Need formal assessments.	• Ideally would use carrying capacity and epidemiology assessments;	5	
1.6 Formal allocation of the zone for aquaculture purposes	Zones already identified by the local government, although significant criteria review required.	Aquaculture Zone Managers should be developed, mirroring fisheries management.	• Not set by the AIP. Working with predefined zones.	5	
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	Governed locally through land allocation, but currently does not take into account environmental and disease risks.	Need to move away from liberal development on perceived social need to licenced development based on sound science.	• Not set by the AIP. Working with predefined zones.	5	

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.2 Carrying capacity estimation	Environmental quality assessment reviewed overall nutrient loads to shared water bodies.	No formal carrying capacity assessment yet carried out. Local expert capacity needs to be developed.	• Environmental quality assessment of farm water and shared water bodies.	3	10,000 as part of environmental quality assessment study.
2.3 Set license production limits within zone or water body carrying capacity		Not yet established in Hainan.	• To be part of industry-developed code of good practice.	1	
2.4 Allocation of licenses and permits		Licences currently granted are not based on carry capacity.	• To be developed over time through industry dialogue with government as part of the AIP process.	1	
Phase 3 Area Management (Aquaculture Management Areas (AMAs), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant water body or source and that may benefit from a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries	Typically for the pond systems for tilapia the AMA is linked to an irrigation canal.	Industry still defining geographical boundaries. Current focus is county-level associations.	• Participatory consultations; • Maps.	3	Part of regular meeting agenda and other research.
3.2 Estimate total carrying capacity if appropriate based on the different risks	Total carrying capacity not defined, but tilapia ponds have limited water exchange and discharge into agriculture irrigation canals where some additional nutrients are beneficial.			4	10,000—part of environmental research and evidence for planning and management.

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant water body or source and that may benefit from a common management system including minimizing environmental, social and fish health risks)					
3.3 Organize a formal association of all farmers in that area	Farmers are well organized and there is an area management structure with identified leaders and supportive technical groups/services.		• Facilitated participatory tools.	5	10,000—staff time, plus regular meeting costs are met 50/50 by project and participants.
3.4 Set the broad development objectives and identify the main issues. Agree on common management,[3] monitoring and control measures	A Code of Good Practice is being developed by the industry at the provincial level and will be implemented locally in each zone.		• Code of Good Practice.	3	5,000 for engagement of technical experts and researchers.
3.5 Monitor relevant variables and enforce management measures	Monitoring will be done by support services as part of regulatory monitoring as well as on- and off-farm commercial monitoring to reassure international customers.	Aquaculture Zone Managers should be developed, mirroring fisheries management.	• Monitoring systems developed by stakeholders; • Enforcement discussed and endorsed by local communities.	2	10,000—monitoring could be farms to save money, or government or third party.
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.1 Regular monitoring and evaluation	Compliance with the Code of Good Practice will be a requirement of membership of Hainan Tilapia Sustainability Alliance. Compliance will be verified by third party.		• Will be reported in AIP public report at www.hntsa.org/show_219.html	3	4,000—annual cost per zone of updating public reports and arranging international supply chain meetings.

3 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.2 Periodic review and adjustment	Code of Good Practice will be reviewed regularly by Hainan Tilapia Sustainability Alliance.		• Will be reported in AIP public report at www.hntsa.org/show_219.html	3	
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**		**Approximate production from each aquaculture zone or AMA**		
Experimental development of zonal management in three counties of Hainan province	Three counties identified, with several zones in each expected, but not specifically defined yet. Each county has an active producer association.		The Aquaculture Improvement Project covers around 100,000 tonnes.		
Other notes	**Positive issues**		**Negative issues**		
(especially social issues)	Need to identify champions locally to take the process forward, and if no local associations exist they need to be created.		Engaging regulators can be challenging as they often believe that the industry should just follow the rules, not necessarily be engaged in making them.		

ANNEX 1. CASE STUDY EFFECTIVENESS MATRIX—EAST JAVA SHRIMP AIP

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	Demonstration zone in Muncar identified.	Gov't/industry need to review boundaries/zones and develop appropriate data collection and management systems.	• AIP public report at http://sustainablefish.org/aquaculture-improvement/east-java-shrimp-aip	4	2,000—as part of preliminary scoping costs, but could be tens of thousands of dollars to do correctly for a whole country.
1.2 Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	Local policy context understood, regulators and scientists engaged.	Need stronger engagement of regulators in the AIP to move forward on more effective regulation.	• AIP public report at http://sustainablefish.org/aquaculture-improvement/east-java-shrimp-aip	4	3,000—as part of preliminary scoping costs, but needs much more investment to enforce or develop new zonal policies.
1.3 Setting the broad development objectives and identifying the main issues	Local staff with good understanding of local industry and ability to build relationships. Supply chain support to link to key industry stakeholders. Roundtable processes developed early on to dialogue on main issues.		• Communication, consultation, participation; • Assessment of available resources, needs and values; • Roundtable discussions.	4	2,000 per annum to cover meeting costs.

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.4 Zone boundary definition based on relevant criteria	Working with existing industry in zones based on production rather than management criteria.	Aquaculture Management Zones still need to be effectively defined in almost every country.	• Mapping and analysis using GIS and remote sensing data (e.g., water supply, water quality, climate, hydrological characteristics, soil characteristics, topography, sensitive habitats, protected areas, population settlements, etc.); • Carrying capacity; • Epidemiology.	4	Carrying capacity and epidemiology assessments would cost 10,000 or more.
1.5 Gross estimation of potential production/ area	Existing production areas were assessed, but no review of potential production to date.	Need formal assessments.	• Ideally would use carrying capacity and epidemiology assessments.	5	
1.6 Formal allocation of the zone for aquaculture purposes	Zones already identified by the local government, although significant criteria review required.	Aquaculture Zone Managers should be developed, mirroring fisheries management.	• Not set by the AIP. Working with predefined zones.	5	
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	Governed locally through land allocation, but currently does not take into account environmental and disease risks.	Need to move away from liberal development on perceived social need to licenced development based on sound science.	• Not set by the AIP. Working with predefined zones.	5	

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.2 Carrying capacity estimation	University of Brawijaya carrying out carrying capacity estimation.		• Water quality on farms and in shared waters, current flows.	4	10,000 as part of environmental quality assessment study.
2.3 Set license production limits within zone or water body carrying capacity	Banyuwangi BAPPEDA (planning) office reviewing licensing procedure to take into account carrying capacity.	Awaiting scientific evidence.	• Carrying capacity assessment.	3	
2.4 Allocation of licenses and permits	Process under development by local planning office.	Licences currently granted are not based on carry capacity.	• Dialogue between local industry, science and regulatory stakeholders.	2	
Phase 3 Area Management (Aquaculture Management Areas (AMAs), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant water body or source and that may benefit from a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries	Aquaculture Management Zones of producers clearly identified in Banyuwangi.		• Participatory consultations; • Maps.	5	Part of regular meeting agenda and other research.
3.2 Estimate total carrying capacity if appropriate based on the different risks	Total environmental carrying capacity study underway.	Disease risks need to be considered.	• Maps, current charts, water quality.	4	10,000—part of environmental research and evidence for planning and management.
3.3 Organize a formal association of all farmers in that area	Farmers are well organized and there is an area management structure with identified leaders and supportive technical groups/services through local shrimp club.		• Facilitated participatory tools.	5	10,000—staff time, plus regular meeting costs are met 50/50 by project and participants.

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMAs), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant water body or source and that may benefit from a common management system including minimizing environmental, social and fish health risks)					
3.4 Set the broad development objectives and identify the main issues. Agree on common management,[4] monitoring and control measures	Improving farm management processes, replanting mangroves in shared waste water canals, moving towards local certification, sharing disease outbreak information, sampling shared water bodies, emergency disease response.	Still all relatively early stages, particularly emergency disease response planning.	• Regular meetings of the farmer group; • Support of technical experts.	3	5,000 for engagement of technical experts and researchers.
3.5 Monitor relevant variables and enforce management measures	Monitoring will be done by support services as part of regulatory monitoring as well as on- and off-farm commercial monitoring to reassure international customers.	Aquaculture Zone Managers should be developed, mirroring fisheries management.	• Monitoring systems developed by stakeholders; • Enforcement discussed and endorsed by local communities.	2	10,000—monitoring could be farms to save money, or government or third party.
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.1 Regular monitoring and evaluation	Zones of producers in an aquaculture improvement project required to report regularly on progress.		• AIP public report at http://sustainablefish.org/aquaculture-improvement/east-java-shrimp-aip	3	4,000—annual cost per zone of updating public reports and arranging international supply chain meetings.
4.2 Periodic review and adjustment	National level multi-stakeholders groups being established to review progress.		• AIP public report at http://sustainablefish.org/aquaculture-improvement/east-java-shrimp-aip	3	

4 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Phase/Step	Well Done/Achieved	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**		**Approximate production from each aquaculture zone or AMA**		
Demonstration zones in Banyuwangi province of East Java as model to rest of country	One main demonstration zone in Muncar developed, but engagement of producers from neighbouring zones to learn and support improvements.		The Aquaculture Improvement Project covers around 3,000 tonnes.		
Other notes	**Positive issues**		**Negative issues**		
(especially social issues)	Need to identify champions locally to take the process forward, and if no local associations exist they need to be created.		Engaging regulators can be challenging as they often believe that the industry should just follow the rules, not necessarily be engaged in making them.		

Spatial Planning of Marine Finfish Aquaculture Facilities in Indonesia

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ABSTRACT

This paper presents results of application of processes and steps for improving spatial planning of marine finfish aquaculture facilities in Indonesia. Emphasis is given to species cultured in floating net cages for export. The investigations were done at several sites in Indonesia. The effectiveness of the spatial planning tools adopted here is demonstrated for a grow-out facility in the northwest of Bali. Methods for site selection and estimation of carrying capacities based primarily on results of simulation models proved to be quite effective for sites with scarce data. Results of the assessment of the facility in Bali led to the identification of farms located outside suitable areas and exceeding ecological carrying capacity of fish farm production. Yet it was found that with proper siting and controlled increases in fish farm production, the overall aquaculture production in the bay could be increased without harming the environment. As the bulk of marine finfish aquaculture uses traditional technologies, the potential for expansion of the activity in the existing sites is ample. In addition to good environmental characteristics and conflicts with other activities, the selection of new sites should emphasize an access to markets and infrastructure. Siting and carrying capacities should be linked to licensing procedures at feasibility stages of developments. It is necessary to adapt the existing regulations for licensing and impact assessments to the technological advancements in the field. Basic biosecurity rules such as stricter control of seeds and cost-effective early warning systems for monitoring water quality parameters should be employed to ensure fish survival. Lack of qualified personnel remains a major constraint for enforcing technical and managerial procedures. Hence for the success of the industry, capacity building for strengthening individuals and institutions should be at the top of the agenda.

1. BACKGROUND AND OBJECTIVES

The tremendous development of aquaculture worldwide over the years has led to projections that in the next few decades aquaculture is bound to overtake open fisheries as the major source of fish protein. This is particularly true in Indonesia as the archipelago of the country offers excellent natural conditions for

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

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aquaculture activity. With over 14 million tonnes, Indonesia is currently the second largest aquaculture producer in the world after China. Approximately 90 percent of country fish production is consumed domestically. To meet food security and job creation targets, the Government of Indonesia (GOI) plans increasing overall national aquaculture production by an additional 2.5 million tonnes and 750,000 jobs in the next years. This will require significant expansion of the cultivated area. However, the adopted spatial planning and siting of aquaculture facilities currently in place is inappropriate. Hence the adoption of environmentally sustainable practices and managerial schemes in accordance with the guidelines of the ecosystem approach to aquaculture (EAA) is essential for enhancing sustainable development and expansion of the industry (FAO, 2010b); and it is also a pre-requisite to assure compliance with the existing regulatory framework (Soto *et al.* 2008). This paper focuses on procedures and steps for improving spatial planning of marine finfish aquaculture facilities in a feasibility stage of developments. Emphasis is given to techniques particularly suited for sites with scarce data typical of the sites in South-East Asia.

The most essential initial steps of an EAA are proper selection of sites for fish farms and estimation of carrying capacities (Ross *et al.*, 2013). Site selection of marine finfish farms is relatively straightforward but requires a sizable number of field data with good spatial coverage to assess their function. Estimation of ecological carrying capacity (ECC) still presents some constraints mainly due to the absence of in-situ data, complexity of the processes involved and uncertainties concerning the adopted sustainability criteria. To deliver proper spatial planning of marine finfish aquaculture operations, methods for site selection and estimation of ECC tailored to conditions in South-East Asia have been developed and applied (Mayerle et al., 2006, Windupranata 2007, Wulp *et al.*, 2010 and Niederndorfer, 2017). Investigations were done at sites in Bali, Batam and Pulau Seribu in the framework of a project commissioned jointly by the Indonesian Ministry of Marine Affairs and Fisheries (MMAF) and the German Ministry of Education and Research (BMBF).

In this paper, experiences from the assessments of several marine finfish aquaculture facilities in Indonesia are summarized. Processes and steps of the spatial planning applied within and integrated, ecosystem-based approach to sustainable marine finfish aquaculture are introduced. The effectiveness of the methods adopted and technological advancements in this field are demonstrated for an aquaculture facility in the northwest of Bali. Emphasis is given to the assessment of the existing fish farming operations with respect to farm location, ECC and biosecurity. A management plan with proper siting of farms, limits of fish farm production and an enhanced biosecurity framework is proposed for the site in Bali. Existing regulations are reviewed and recommendations are made for boosting the industry in Indonesia.

2. AQUACULTURE IN INDONESIA

2.1 The Aquaculture Framework

As the world's largest archipelagic nation with more than 17,000 small islands and a coastline of about 95,000 km, Indonesia has an enormous potential for aquaculture development. The aquaculture industry plays a central role in Indonesia as it enhances economic growth. Aquaculture is also an important contributor to the four national pillars of development recognized by the Indonesian government, as economic growth, the creation of job opportunities, reduction of poverty and environmental recovery and mitigation (KKP, 2010). The strength of Indonesia aquaculture is the availability of space, high biodiversity, favourable geography, climate and human resources (FAO, 2010a). Against its extraordinary geographical settings and long history of the sector, Indonesia's aquaculture revolves around another scenario involving complex policy and economic pressures, at both the national and international levels. Nationally, the main strengths are the rapid expansion of aquaculture vis/a/vis the slower growth of captures fisheries. This is coupled with a recent decentralized administrative process that has given the local administrative levels new and wider responsibilities (Nurhidayah, 2010). Internationally, the economic pressures are for gaining stronger markets, particularly in the USA and Europe, both of them demanding more stringent regulations for input from Indonesia.

2.2 Governmental Structure and Organization for Aquaculture in Indonesia

The institutional and legislative framework for aquaculture in Indonesia is huge and complex albeit somewhat uncoordinated, particularly at the local level. A number of ministerial authorities deal with aquaculture activities within all administrative levels, from central to provincial to local government. MMAF is the principal agency responsible for planning, management and administration of marine and fisheries sectors in Indonesia. The Directorate General of Aquaculture (DGA) is the government policy-making agency in charge of aquaculture development, whereas at the local level it is in the hands of the local fisheries services of the provinces and districts/municipalities. The Agency for Marine Affairs and Fisheries Research and Development (AMAFRAD) supervises research and development activities related to marine issues and fisheries on the national level. CARD, which coordinates the bilateral project on the Indonesian side, is one of the research centres under AMAFRAD. The municipal or regency level is the granted authority for 4 nautical miles (nm) seaward from shoreline. The provincial level has authority to manage the near coastal stripes between 4 and 12 nm seaward from the shoreline, while the central government is in charge of aquaculture operations 12 nm offshore (Nurhidayah, 2010). Emphasis has been given to the institutional development of groups of farmers to raise their role through extended activities, business counselling/guidance and training (Nurdjana, 2006). There are also several professional and commercial bodies working in close cooperation with the government and entrepreneurs. Despite these efforts, public/stakeholder participation in decision making is not yet fully established. Although the administrative and legislative/regulatory tools for an expanding aquaculture development are in place, some critical tools for zoning and the application of EIA procedures, etc., are still to be fully implemented.

2.3 Regulatory Framework of Marine Finfish Aquaculture in Indonesia

Policies dealing with environmental issues in aquaculture are based on FAO Code of Conduct for Responsible Fisheries Guidelines Nr. 4 on Aquaculture Development (FAO, 1997). FAO encourages administrative States to establish, maintain, and develop appropriate legal and regulatory framework for facilitating the development of responsible aquaculture. According to the current regulations in Indonesia, EIA of aquaculture activity applies only to large-scale intensive farming in seawater extending over 5 ha or having more than 1,000 cages. Besides, only new fish farms require an EIA whereas old or those farms expanding in size are exempt from it (Sugama, 2007 and Phillips *et al.*, 2009). Full EIA is not applicable as nowadays most farms cover small areas and have less than 1000 cages. EIA is issued according to the Ministry of Environment's Decree No. 17/2001 and closely linked to licensing procedures. Environmental monitoring is specified within the EIA but then again only required for larger farms.

National water quality standards have been established for aquaculture, but effectiveness and technical appropriateness is still lacking in Indonesia. Farm licences are issued by the local authority but are required only for large-scale intensive farming. Small-scale fish breeders and local farms are exempt from licences. As a result, EIA is not applicable to the bulk of aquaculture production in Indonesia. The allocation of licences is done taking into consideration farm location and size, fish species and carrying capacity. However, scarce data and inappropriate methods applied for siting aquaculture operations and estimating carrying capacity of fish farming at the feasibility level remains a major constraint. Site selection and estimations of local and cumulative carrying capacities should be done in the early stages of the developments. This would enhance decision making concerning the allocation of licences and enforcement of regulations, thus boosting investments.

2.4 Expansion of Marine Finfish Aquaculture in Indonesia

Overall aquaculture production of marine finfish for export in Indonesia amounts currently to about 25,000 t/year. The cultured commodities are mainly based on good economic sense, i.e., price and widely accepted markets. Grouper and Asia sea bass are the species most farmed. The exporting markets for live grouper are China, Hong Kong, Malaysia and Singapore. Sea bass is exported mainly as fillets to Australia, USA, Thailand and Hong Kong. Most of the production is cultivated in the centers of investment, Lampung, Batam and Bali, all of them close and/or with good access to target markets and production infrastructure. Farms use traditional technologies consisting mainly of floating net cages made of wooden rafts (see Figure 1), but there is a trend towards farms with several large circular cages (see Figure 2). In the centres of investment fish farms are predominantly medium-scale (farms with 20 to 100 cages) and large-scale (farms with over 100 cages). As most of these farms employ traditional technology there is ample scope for expansion of the activity in the existing sites. In addition the potential for expansion of the activity into new centres of investment is tremendous as according to estimates only about 1 percent of the suitable area for development of the industry is in use so far (Nurdjana, 2006). Several centers for expansion have been identified including Lombok, Sumbawa, Manado and Morotai. These coastal areas offer excellent conditions for marine finfish aquaculture but much of the areas are ecologically sensitive coral reefs and mangrove. Besides, the industry is likely to conflict with the tourism sector and global conservation initiates. Hence the use of state-of-the-art spatial planning tools is essential. In addition to good environmental characteristics capable of absorbing the waste from fish farm operations, aquaculture sites should be located dowsntream from important ecosystems and biosecurity assets. Much attention shall also be given to conflicts with other activities and access to markets and production infrastructure.

3. MARINE FINFISH AQUACULTURE FACILITY IN INDONESIA SELECTED FOR APPLICATION

The effectiveness of the processes and steps for improving spatial planning is demonstrated for a marine finfish aquaculture operation in Pegametan Bay in the northwest of Bali, Indonesia. The environmental characteristics of the site in question and information on cultured commodities are introduced. An overview of the high-resolution measurements and simulation models is provided.

3.1 Environmental Characteristics of Pegametan Bay in Bali

The area of interest covers about 35 km^2 along the coastal stretch of around 10 km (see Figure 3 and model domain in Figure 4). The site is characterized by a shallow inner coral reef platform in the centre, which partly falls dry at low tide. Two main channels flank the coral reef system (Figure 3). The flow in the bay is tide dominated with a maximum tidal range of 1.8 m. Current velocities are up to about 0.15 m/s and 0.4 m/s respectively during neap and spring tides. The channel to the west is shallower and current velocities are smaller. The channel in the centre of the bay reaches water depths of about 25 m and current velocities are higher as the channel is open to both ends of the bay (see Figure 3). Wind speeds up to 12 m/s are observed in the northwest of Bali. The annual water temperature and salinity ranges from 27 to 31°C and 28 to 35 PSU respectively. From July till September during winter months in Australia, water temperature in the bay may drop to around 26°C. Prevailing sediments are medium and coarser coral sands, and coral detritus. An outer reef belt protects part of the bay from the waves in the open sea. Outside the bay water depths rapidly increase to several hundred meters.

3.2 Cultured Species and Fish Farm Production of Pegametan in Bali

The northwest of Bali is one of the main producing centers of marine finfish aquaculture in Indonesia. Total fish production nowadays ranges between about 900 and 1,100 t/year. Currently there are two main sites in operation, namely Pegametan Bay and Patas, producing respectively ca. 55–70 tonnes/month and 20–25 tonnes/month. Marine finfish aquaculture has been practised in Pegametan Bay since 2001 and has grown to a total of 30 farms in 2015. Species cultured are mainly Asian Sea Bass (*Lates calcarifer*), Humpback Grouper (*Epinephelus altivelis*) and some species of ornamental fish. Figure 6 shows the location of the farms in Pegametan Bay. There are 10 medium-scale farms (20 to 100 cages) and 16 large-scale farms (more than 100 cages). The floating net cages of most farms consist of wooden rafts, kept afloat by plastic drums (Figure 2). Each cage typically measures 3 m × 3 m × 3 m. Cages are connected together forming a floating raft in order to reduce the effects of waves and currents. The two largest farms in the bay (see farms numbered 21 and 30 in Figure 6), comprise

FIGURE 1. Traditional fish farm in Pegametan Bay.

FIGURE 2. Fish farm in Pegametan Bay using several circular cages.

FIGURE 3. Pegametan Bay.

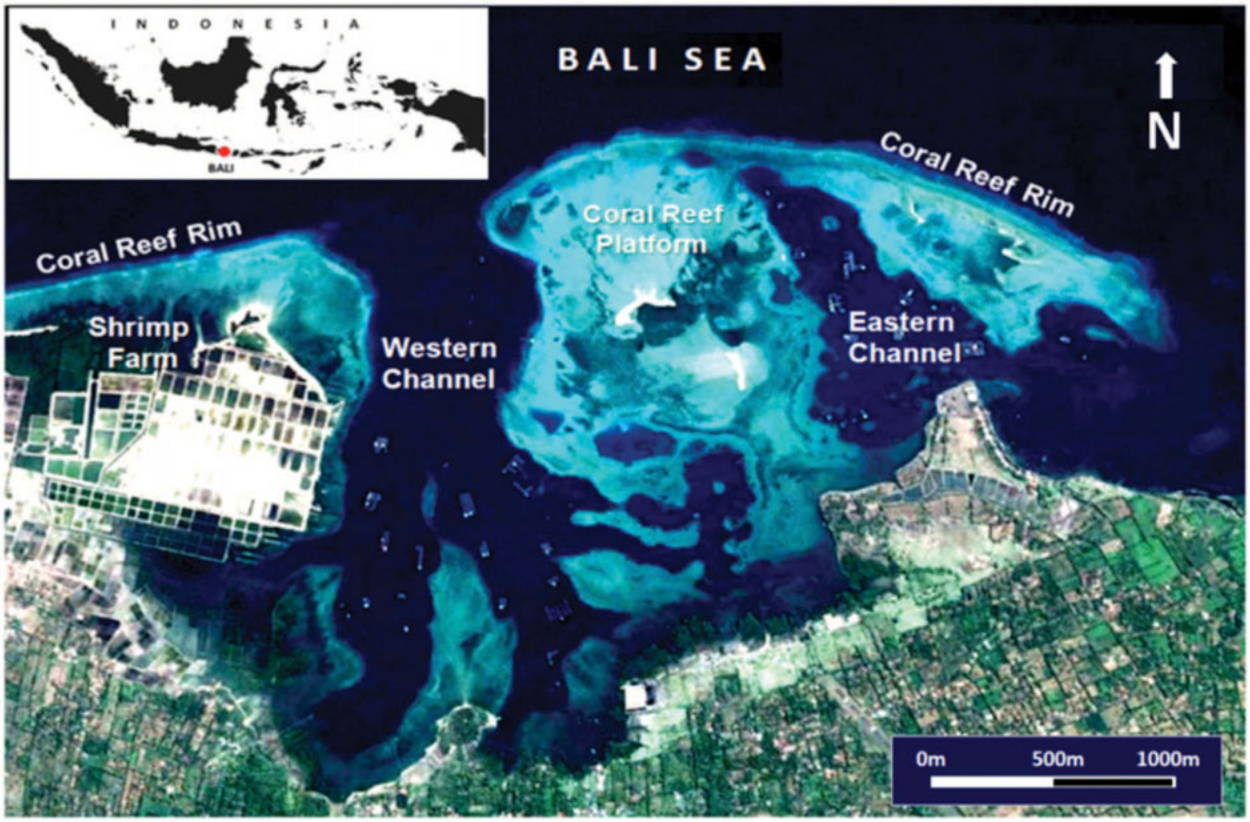
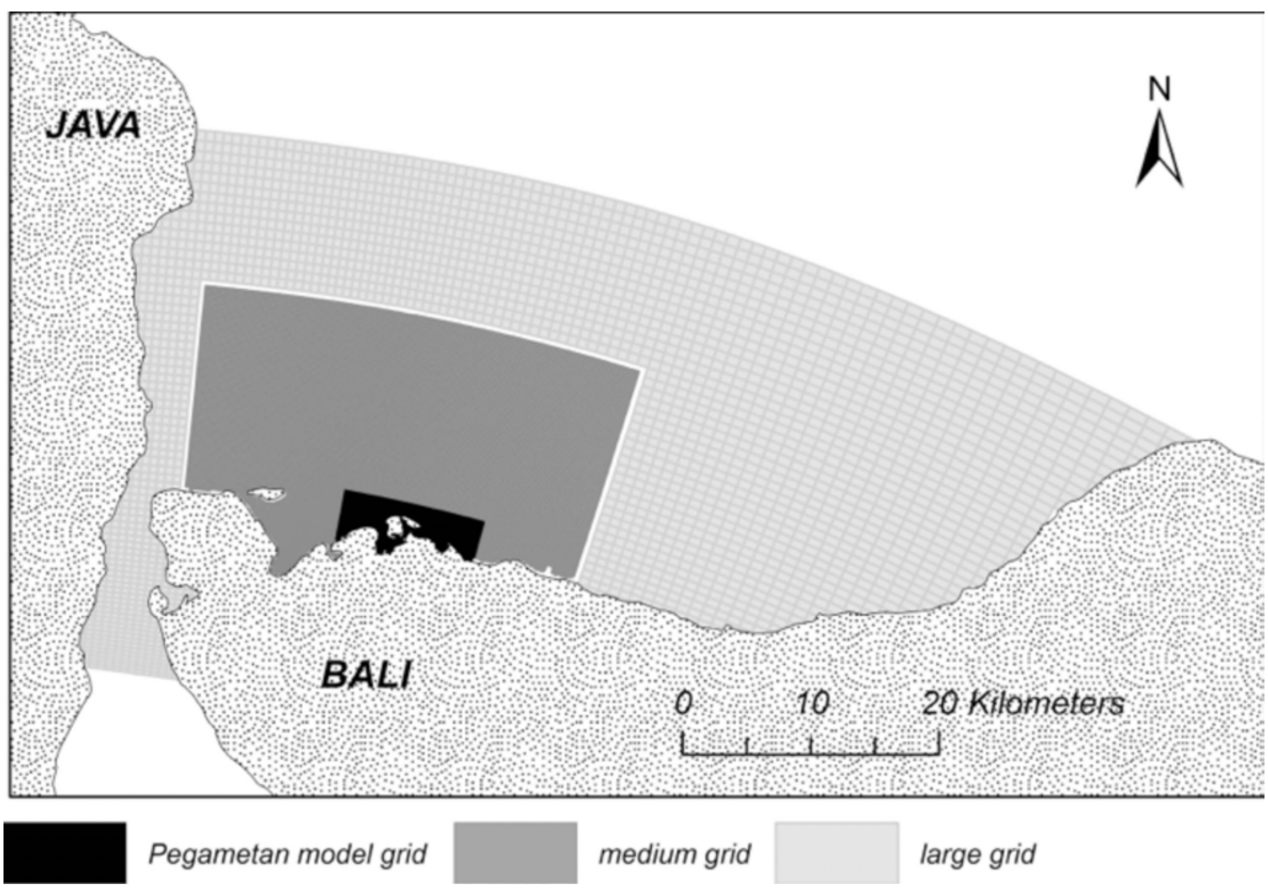


FIGURE 4. Grids of Pegametan Bay model.



of 7–8 circular floating units made of high-density polyethylene for nursery and on-growing (see also Figure 2). The cages are 20 m diameter each with a cubic capacity of about 2,000 m^3 per cage.

The overall standing stock of the 30 farms in Pegametan Bay was about 345 t during the assessment in 2015. Table 5 lists for each farm the number of cages, farm volume and estimated standing stock of farms. On the western channel there are 18 farms with less than 400 cages each (see farms numbered 1 to 18 in Figure 6). The total farm area is ca. 2.2 ha. The standing stock of the farms varies from a few hundred kilos to 20 t. The overall standing stock in the western channel is about 130 t. On the central channel there are 10 typical fish farms with up to 320 cages and two larger farms with 7–8 circular cages (farms numbered 21 and 30 in Figure 6, see also Figure 2). The total standing stock in the central channel is ca. 210 t and the area covered by the cages is ca. 1.8 ha. Fish production in the two largest farms is in the order of 45–55 t/month corresponding to over 3/4 of the total production in the site.

In addition to grow-out activities, there are several backyard hatcheries along the coastline to the east of the bay. About 90 percent of the seeds sold in Indonesia stem from these hatcheries. There are also small amounts of algae, pearl oyster and shrimp being cultivated in and along the bay. In the vicinity of the inner coral reef platform dividing the two channels, small amounts of seaweeds (*Euchema* and *Glacilaria*) are cultivated. To the east of the bay, there are two big cages growing pearl oyster (*Pinctada sp*) and on the southeast a few pearl rafts are placed. At present there are approximately 800,000 shells for inoculating core of pearl. Along the coastline there are a few shrimp farms stocked with Pacific White Shrimp (*Litopenaeus vannamei* and *Penaeus vannamei*). The location of the shrimp ponds, covering an area of about 130 ha, is shown in Figure 3. Shrimp production per pond varies between 8 and 15 t/cycle.

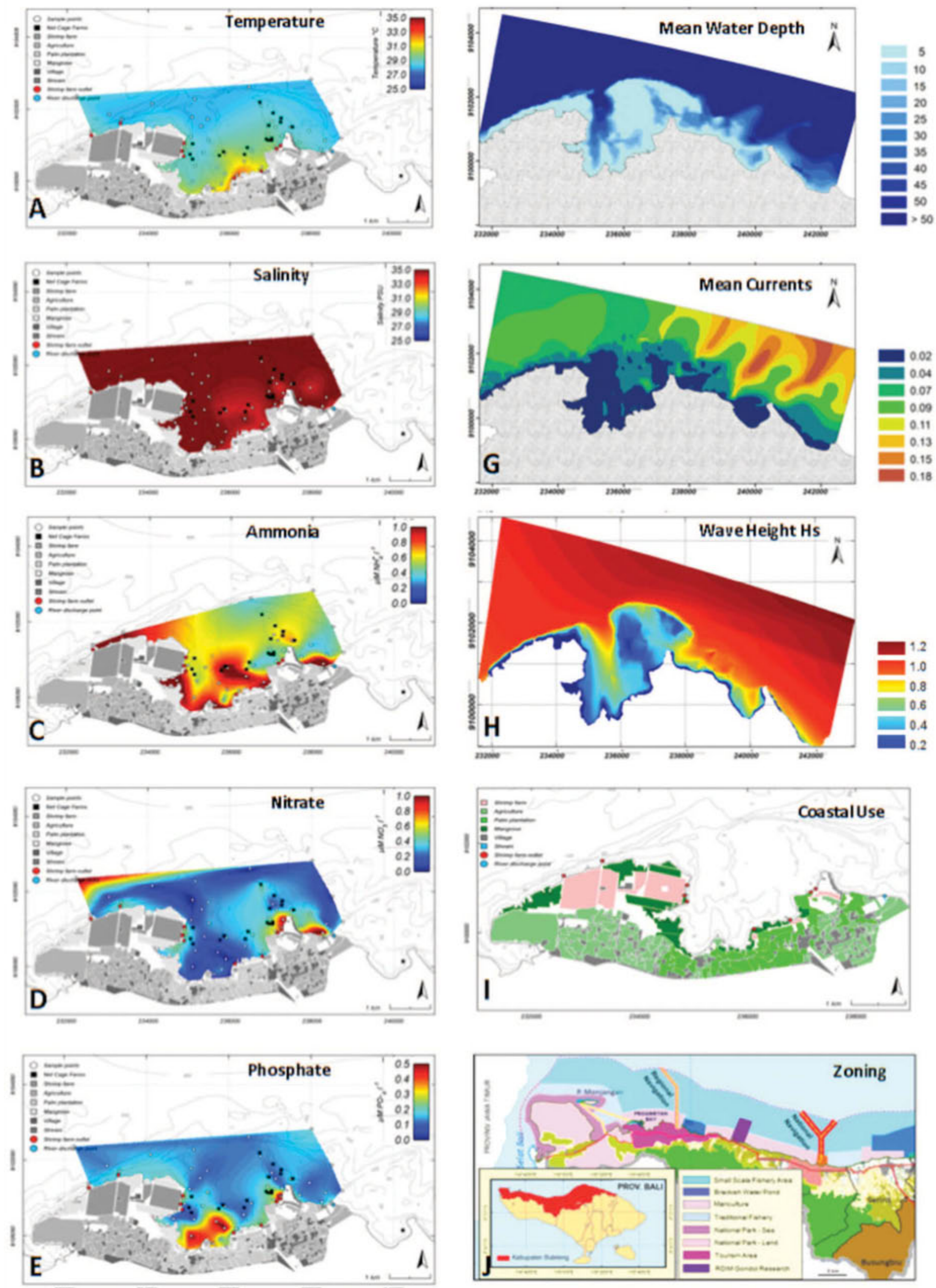
3.3 High-Resolution Measurements at Pegametan Bay in Bali

An array of high-resolution surveys and mapping technologies was used to assess the interactions between the environmental conditions and fish farms. Data from existing databases and large-scale global models was supplemented with remote sensing information of farm locations, bathymetry and tidal constituents. Gaps of information were identified and several measuring campaigns carried out. Emphasis was given to the data required for the development of simulation models and for gathering chemical data for site selection. Measuring campaigns were carried out in January 2008 during the rainy season, September 2011 towards the end of the dry season. Bathymetry in the bay was measured with a vessel mounted echo-sounder. A tidal gauge was installed within the bay for continuous measurement of water levels for calibration and validation of the flow model. Vessel mounted CTDs were deployed in conjunction with Niskin bottles throughout the entire bay for water quality. To obtain high-resolution information on the spatial variability of nutrients about 50 surficial water samples were taken in Pegametan Bay. Maps are shown on the left hand side of Figure 5. Seabed sediment samples were taken underneath several farms and away from fish farms for reference in December 2015 and January 2016. Sediment samples were analyzed for RedOx potential, grain size distribution, and particulate C and N.

3.4 High-Resolution Simulation Models of the Pegametan Bay in Bali

A three-dimensional coupled flow and wave model was developed for the site under investigation. Model development was based on the Delft3d model suite (Roelwink and van Banning, 1994). The model covers parts of the southern Bali Sea and the Bali Strait as shown in Figure 4. In the outer parts, model development relied on data from global databases and large-scale models. The bathymetry was developed using data from the General Bathymetric Chart of the Oceans (GEBCO) and the Indonesian National Survey agency (Badan Informasi Geospatial). Within the bay, data recorded from their own echo-soundings was used in the model. Sub-domain decomposition using three computational grids with increasing grid resolution towards the coast was adopted (see Figure 4). The grid resolution ranges from about 800 m in the Bali Sea to 25 m within the bay. Over the vertical 5 sigma-layers, each covering 20 percent of the water depth, were used. Astronomical tidal constituents from satellite altimetry were imposed at the open sea

FIGURE 5. Mapped layers adopted for site selection of marine finfish farming facilities in Pegametan Bay.



boundaries of the model. The model is forced with space and time varying winds and pressure fields from the NCEP/NCAR reanalysis database. Predicted water levels coincided with measured values with an average error of about 6 cm. Waves are simulated with the fully spectral model SWAN, developed at the Technical University Delft in the Netherlands (Booij *et al.*, 1999). SWAN accounts for wave propagation, refraction, and shoaling, wind-induced wave generation, wave dissipation and non-linear wave-wave interactions.

4. SPATIAL PLANNING PROCESSES AND STEPS APPLIED TO THE SITE AT PEGAMETAN BAY IN BALI

Results of the application of steps and procedures within an integrated ecosystem-based approach for enhancing spatial planning in Pegametan Bay are presented hereafter. The steps comprise of scoping, zoning, site selection and carrying capacity. Emphasis has also been given to biosecurity in particular to the measures being adopted to minimize fish diseases.

4.1 Scoping

Scoping comprises the establishment of the management objectives, boundaries and institutional as well as legal frameworks. Marine finfish aquaculture and tourism are the main activities with economic relevance in the region. In the beginning of 2008, there were about 17 relatively small fish farms within the bay the majority of which containing less than 150 cages. The standing stock in 2008 was estimated as about 90 t. Groupers was the main farmed species and trash fish/low value feed the main feeding source at that time. Since then the number of farms duplicated and the sizes of farms increased significantly leading to a standing stock of about 345 t in 2015. Pegametan Bay is a typical example that aquaculture can help improve the livelihood of fish-farmers and fisherman living along the coast. In addition to the fish farms, there are also several backyard hatcheries along the coastline providing social and economic benefits to the local population.

Assessments of the coastal uses and ownership were also done. As fish farms are located within 4 nm from shore, the Marine and Fisheries Services of the Singaraja Regency (MFS) is granted authority to manage aquaculture. Further stakeholders in the region are the Farmers' Association and RDIM. AMAFRAD and RDIM assist the Farmer's Association with technical issues related to mariculture development and provide support on seed techniques and other matters. Currently fish farms in the bay have less than 1000 cages and thus exempt of EIA but subject to other licensing/permitting requirements such as voluntary measures and/or good aquaculture practice.

Regarding water quality, the aquatic environment is in good condition. The analysis was based on water sampling throughout the whole bay. Maps of nutrient distribution are shown in Figures 5C to 5E. Farm emissions were found to have only minor effects on the concentrations of nutrients within the bay. On the other hand small rivers and the outlets from the shrimp farms to the west of the bay showed locally slightly higher levels of DIN. Particularly the drainage of ponds under east-west longshore currents can have a significant impact on the levels of water quality in the bay. In general, the observed DIN values and levels of phosphorus remained below critical values that can impact on coral reefs (FAO, 1989 and Lapointe, 1997). Only in the near vicinity of the two larger farms (see farms 21 and 30 in Figure 6) a certain decrease of DO is observed in the layers closer to the seabed. Assessments of sediment quality indicate that there are clear signs of sediment degradation underneath the two larger farms (see farms numbered 21 and 30 in Figure 6). Underneath most farms and also at reference locations, sediments remain in good conditions.

4.2 Zoning

There are currently three legislated zoning schemes and procedures dealing with aquaculture development under the umbrella of MMAF. There is an inter-sectorial zoning scheme accounting for the majority of coastal uses, the Minapolitan zoning for centres engaging mainly on aquaculture activities and another scheme focusing exclusively on aquaculture issues. Table 1 summarizes the aims, legal instruments and agencies in charge of each scheme. The schemes have different objectives, though each and all of them together, serve a common purpose from different perspectives.

FIGURE 6. Suitable areas for marine finfish farming and location of farms in Pegametan Bay in 2015.

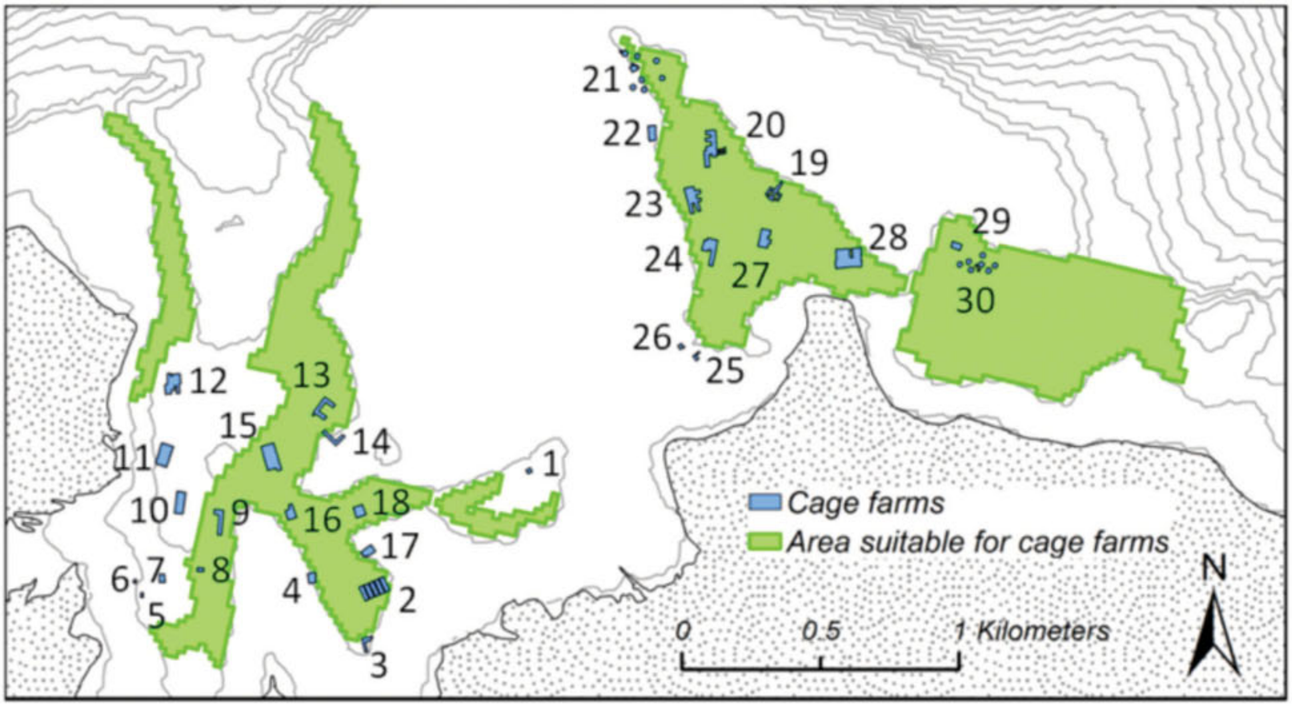


TABLE 1. Overview of zoning schemes for aquaculture in Indonesia.

Zoning Scheme	Legal Instrument	Agency of MMAF	Objective	Scale
Inter-sectorial	ICM Act of 2007 (Law No. 01/2014 on Coastal Zone and Small Island Management)	DG Coastal Zones and Small Islands	Hierarchical (national/subnational), sequential and linked, four-tier planning process for coastal and marine management. The goal is to develop plans having a multi-stakeholder approach. It determines which development activities are allowed, permitted with license, and/or prohibited in the region. Broad zoning categories and technical aspects concerning mapping are established.	National Subnational
Minapolitan	Decree No.35/ KEPMEN-KP/2013	DGA	Under the conceptual framework of region-based marine and fisheries development using cluster and spatial management systems, the Minapolitan objectives for aquaculture are to develop potential aquaculture areas as production centers by implementing extensive and/or intensive systems.	National Regional
Aquaculture	Decree No.35/ KEPMEN-KP/2013	AMAFRAD through CARD	Selection of areas suited for aquaculture development. The framework comprises the collection of data (primer and secondary) and data processing and analysis leading to zoning maps.	National Regional

TABLE 2. Criteria for coastal planning (Wiryawan and Tahir, 2013).

Seaweed Mariculture	Grouper Culture	Capture Fisheries	Tourism	Residential and Industries
Position, waves, currents, depth, bottom waters, salinity, temperature, pH, visibility, productivity, availability of seeds, infrastructure, pollution, security	Security, tide, currents, depth, dissolved oxygen, salinity, weather, the power source, sources of feed, availability of seeds, availability of labour, pollution	Depth, bottom topography, visibility, weather, conditions of coral reefs, abundance of target fish, pollution	Type of beach, coastal vegetation cover, visibility, temperature, reef crest type, roughness, coral cover, number of live form types, number of reef fish species, number of seagrass species, number of mangrove species, aesthetics, accessibility, safety, weather, availability of transportation, freshwater, infrastructure.	Slope, road infrastructures, freshwater availability, altitude, drainage, soil suitability, depth

The inter-sectorial zoning scheme is under the responsibility of the Directorate General of Coastal Zones and Small Islands. It was established to minimize conflicts among different coastal uses and stakeholders. It defines guidelines and activities that are allowed, permitted with license, and/or prohibited in the region. Table 2 lists the criteria considered for marine finfish aquaculture and other activities.

The Minapolitan zoning (*mina* from Sanscript for fish and *politan* from Greek for city) was tailored for sites with on-going aquaculture activity. The scheme was established by the DGA and it is part of the Minapolitan Program (MP). MP aims at promoting the designation of zones with multiple functions such as centre of production, processing and marketing of fisheries commodities, services, and/or other supporting activities. The selection of so-called "fish cities" takes into consideration the ongoing aquaculture and/or fishery activities, social infrastructure, and market conditions. The environmental characteristics are not accounted for in this scheme.

The aquaculture zoning is the responsibility of AMAFRAD through CARD. Sites preselected for marine finfish aquaculture activity on the basis of one above zoning schemes have to undergo this zoning scheme. Several factors and constraints relevant to aquaculture activities are accounted for. They include bathymetry, land quality, water quality, climate, sediment, and oceanographic aspects. Table 3 presents the criteria and threshold values adopted for marine fish aquaculture (Radiarta *et al.*, 2014a). Score factors are defined according to the level of importance to specific fish species. Suitability scores are ranked and classified in accordance with the procedure proposed by FAO (1977).

The resulting inter-sectorial zoning plan for the northwest coast of Bali is shown in Figure 5. Pegametan Bay has been designated for mariculture activities whereas the adjacent coastal areas mainly for tourism and natural conservation. Results of the present investigation have shown that Pegametan Bay is well suited for marine finfish aquaculture activity in accordance to the aquaculture zoning. An assessment of the physico-chemical properties presented hereafter shows that the bay meets all the requirements and threshold values for marine finfish aquaculture sites listed in Table 4.

4.3 Site Selection

Site selection refers to the identification of areas within a coastal environment, which are suitable for the installation of floating net fish cages. Based on literature review and present scientific knowledge, environmental suitability criteria and threshold values applicable for potential aquaculture sites have been identified. Table 4 lists the criteria and threshold values usually adopted for target finfish species in South-East Asia. Criteria taking into account physical characteristics, water quality standards and coastal uses and risks are considered (FAO 1989, Chou and Lee 1997,

TABLE 3. Requirements for marine fish cage culture (Radiarta *et al.*, 2014a).

Parameter	Unit	Suitability Scores			
		Most Suitable	Suitable	Moderately Suitable	Not Suitable
Bathymetry	m	10–20	20–25	25–30	<10 and >30
Current	cm/s	5–15	15–25	25–35	<5 and >35
Transparency	m	> 3	2–3	1–2	< 1
Temperature	C	28–32	25–28	20–25	<25 and >32
Salinity	ppt	31–35	28–31	25–28	<25 and >35
pH	mg/l	> 7	6–7	4–6	<4
Total suspended solids	mg/l	<10	10–15	15–25	>25
Dissolved oxygen	mg/l	>5	3–5	1–3	<1
Amonnia	mg/l	<0.01	0.05–0.01	0.10–0.05	>0.1
Distance to settlement	m	<3000	3000–4000	4000–5000	>5000
Distance to river	m	>1000	750–1000	500–750	<500
Distance to harbour	m	>1500	1000–1500	750–1000	<750

TABLE 4. Criteria and suitability thresholds for site selection applied to South-East Asia.

Indicator	Parameter (unit)	Unit	Allowable	Optimum	Source
Physical	Minimum water depth	m	> 10		Halide *et al.*, 2008
	Maximum water depth	m	< 30		Halide *et al.*, 2008
	Minimum (mean) current	m/s	> 0.01	> 0.05	Halide *et al.*, 2008
	Maximum (mean) currents	m/s	< 0.5	< 0.2	Halide *et al.*, 2008
	Exposure to maximum waves	m	< 1	< 0.5	Halide *et al.*, 2008
Water quality	Water temperature	°C	27–31		FAO, 1989
	Salinity	PSU	10–33	15	FAO, 1989
	Dissolved oxygen	mg/l	> 4	> 5	FAO, 1989
	pH	log H+	7–8.5	7–8.5	FAO, 1989
	Secchi depth	m	1–5	1–5	Halide *et al.*, 2008
	NH4-Ammonium	mg N/l	< 0.5	< 0.5	FAO, 1989
	NO3-Nitrate	mg N/l	< 200	< 200	FAO, 1989
	PO4-Phosphate	mg P/l	< 70	< 70	FAO, 1989
	Suspended sediment	mg/l	< 10	< 5	Chou & Lee, 1997
Coastal use and risk	Distance to harbours	km	> 0.5, < 8		Pérez *et al.*, 2005
	Distance to navigation lines	km	> 0.5		Scottish Executive, 1999
	Distance to touristic areas	km	> 0.3	> 2.5	Perez *et al.*, 2003

Scottish Executive 1999, Perez *et al.* 2003, Pérez *et al.* 2005, Halide *et al.* 2008).

Figure 5 shows the thematic maps used for characterization of the site. Figures 5A to 5E display respectively the spatial variation of water temperature, salinity and several nutrients namely ammonia, nitrate and phosphate. Maps were obtained from the analysis of over 50 surficial water samples throughout the entire bay. Figures 5F, G and H show the spatial variation of the main physical properties relevant for fish farming. It includes the depth of flow, current velocities and waves. Results of flow model simulations covering a full neap-spring tidal cycle are used for determining the spatial and temporal variation of water depths and current velocities. Waves are obtained from wave model simulations for storm events with different intensities. Simulations were done for different recurrence intervals of storms. In the figure modeled waves for a 10-year recurrence period are displayed (Figure 5H). Coastal uses derived from own assessments and obtained from the inter-sectorial zoning plan are shown respectively in Figures 5I and 5J. For each thematic map, templates are built using GIS tools embedded within the decision support system SYSMAR according to the threshold values listed in Table 4. The overlay of all the templates generates the suitability map for the marine finfish aquaculture facility in Pegametan Bay (see Figure 6). In the figure green colored areas indicate those areas suitable for finfish aquaculture. Water temperature, salinity and the main water quality properties resulted within the ranges found adequate for finfish cage aquaculture operations. Water depths, current velocities, waves and the regional navigation lane to the east of the bay turned out to be the main controlling factors for farm siting in the bay.

A total area of ca. 145 ha turned out to be suitable for finfish aquaculture within Pegametan Bay. More specifically 64 ha on the western channel and 81 ha on the central channel were identified as suitable areas. The total area of cages of the 30 fish farms currently in operation is approximately 4 ha corresponding to less than 3 percent of the suitable area. Figure 6 shows the location of the operational farms in conjunction with the identified suitable areas. It can be seen that despite the availability of space, several farms are located outside of suitable areas in Pegametan Bay. Particularly, farms numbered 10, 11 and 12 on the western channel are outside suitable areas and too close to the coastline. Results of an assessment of fish health revealed that these farms are generally subject to higher risks of fish disease and that fish growth was generally lower than in farms located within suitable areas. Therefore relocation of these farms to suitable areas can be regarded as one of the main priorities to enhance environmental sustainability in Pegametan Bay. It should be noticed that farms 5, 6 and 7 are also misplaced but fish production is sporadic and very low there (see Table 5). Hence it is recommended to monitor conditions in these farms before deciding for relocation.

Spatial planning of aquaculture is also essential to establish and maintain healthy animal stock through effective separation of farms and individual production units within the farms. Farm spacing in Pegametan Bay was assessed on the basis of transport distances of fish farm waste following Gillibrand *et al.* (2002). Current velocities at farm locations and a range of settling velocities of fish farm waste based on fish species and type of feeding (w_s) were considered. On the western channel transport distances barely reach 50 m. Hence no interactions among the farms is anticipated for the current farm layout and additional farms could be placed there. On the central channel, transport distances are up to 150 m. Despite the fact that there is sufficient distance among farms and much space left for placing new farms, attention should be given to farms 21 and 30. As fish production is very high, separation of individual production units for nursery and grow-out is essential for keeping the total amount of fish within carrying capacity of the environment, helping safeguard adverse effects.

4.4 Ecological Carrying Capacity (ECC)

ECC of marine finfish aquaculture is defined here as the magnitude of aquaculture production that can be sustained without significant changes to ecological processes, species, populations, or communities in the environment (Byron and Costa-Pierce, 2013). Environmental impacts associated with marine finfish aquaculture stem mainly from nutrient inputs from uneaten fish feed and fish wastes. High percentage

TABLE 5. Assessment of the marine finfish aquaculture facility in Pegametan Bay (Nov. 2015).

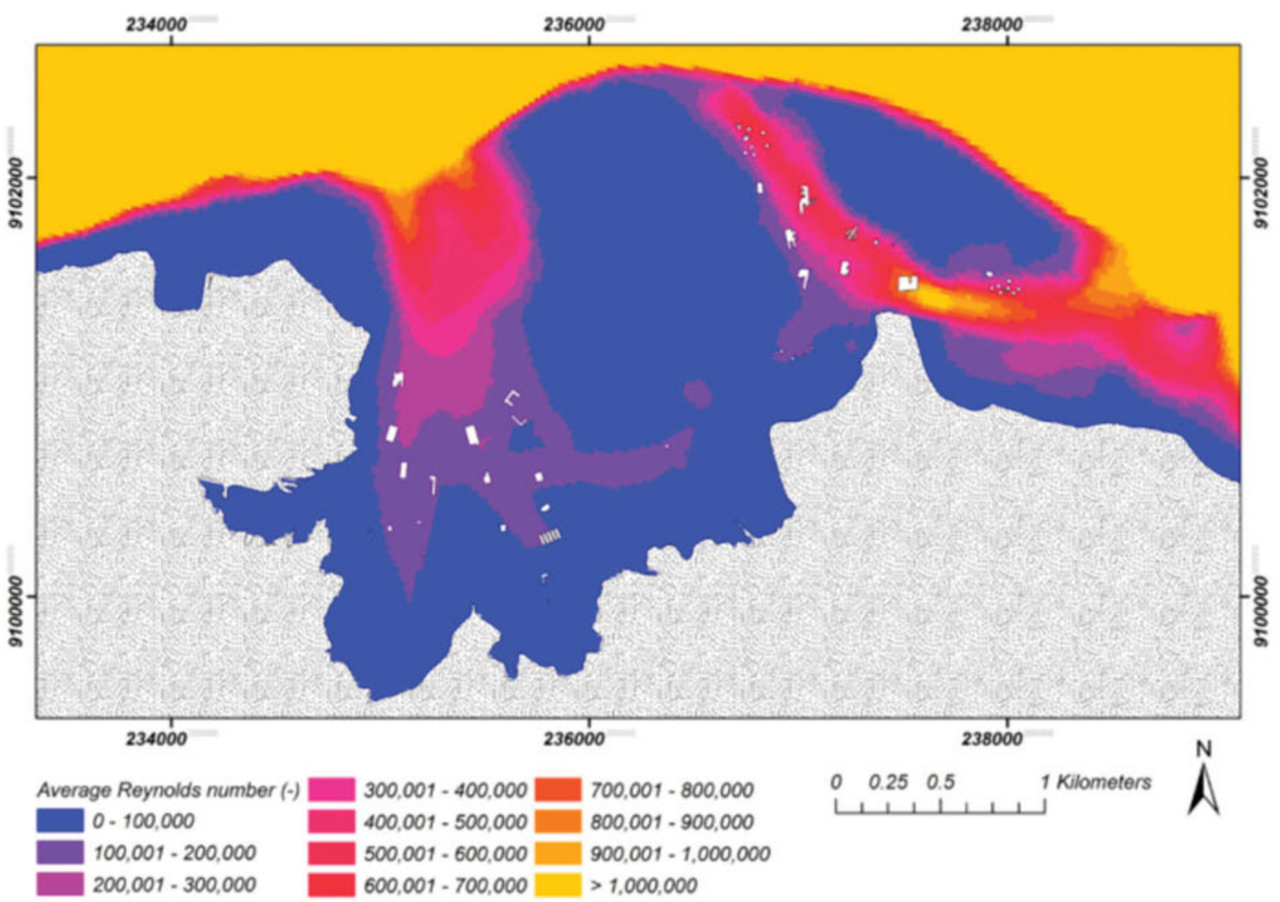
Farm Number	Channel (AMA)	Number of Cages	Cage Volume (m³)	Estimated Standing Stock (t)	Reynolds Number (Re)	Predicted Farm ECC (t)
1	Western Channel (AMA1)	16	192	0.4	97,700	16.5–21.0
2		250	9,375	18.8	61,400	16.5–19.5
3		60	1,620	3.2	39,400	16.5–18.0
4		63	1,701	3.4	68,800	16.5–19.5
5		8	216	0.4	39,900	16.5–18.0
6		6	162	0.3	39,400	16.5–18.0
7		40	1,080	2.2	78,900	16.5–21.0
8		32	864	1.7	76,600	16.5–19.5
9		120	3,240	6.5	76,900	16.5–19.5
10		166	4,482	9.0	121,600	16.5–22.5
11		380	10,260	20.5	132,400	16.5–22.5
12		290	7,830	15.7	130,800	16.5–22.5
13		166	4,482	9.0	123,100	16.5–22.5
14		90	2,430	4.9	76,200	16.5–19.5
15		320	8,640	17.3	139,700	16.5–22.5
16		100	2,700	5.4	171,500	18.0–24.0
17		84	2,328	4.7	66,400	16.5–19.5
18		168	4,536	9.1	99,400	16.5–21.0
19	Central Channel (AMA2)	84	2,268	4.5	308,200	32.5–47.5
20		319	8,013	16.0	333,000	32.5–47.5
21		7 cir. cages	14,707	58.8	280,600	32.5–45.0
22		50	1,350	2.7	117,500	27.5–37.5
23		212	5,724	11.4	145,100	27.5–37.5
24		212	5,724	11.4	95,900	27.5–35.0
25		30	810	1.6	82,000	27.5–35.0
26		15	405	0.8	107,700	27.5–35.0
27		182	4,914	9.8	243,200	30.0–45.0
28		321	8,667	17.3	586,800	37.5–57.5
29		60	1,620	3.2	172,400	27.5–40.0
30		8 cir. cages	18,850	75.4	328,600	32.5–47.5
	Overall values in Pegametan Bay			345	—	660–800

of phosphorus, carbon and nitrogen inputs are lost to the environment. These nutrient inputs may lead to localised water quality degradation and sediment accumulation underneath farms. In severe cases, in which standing stock exceeds ECC, environmental sustainability is undermined. Although the localized impact of smaller farms in South-East Asia is usually relatively small, the impact of the incoming larger farms and the cumulative impact of many farms on the environment can be significant. That is why this study has sought to adopt methods both for estimating ECC at the farm level and accounting for the cumulative effect of all the farms in the environment.

Farm ECC is based on sediment accumulation underneath farms. ECC are estimated based mainly on hydrodynamics from measurements and/or model simulations. The method implemented in SYSMAR estimates the maximum fish production for the given Reynolds number (Re) at the fish farm location, w_s and user-defined threshold loads in terms of carbon deposition in the seabed (Niederndorfer, 2017). Re is defined as the product of mean water depth and the mean depth-averaged velocity for a neap-spring tidal cycle divided by the kinematic viscosity of water. w_s is a function of fish species farmed and feeding method adopted in the site. Regarding the limits in terms of carbon loading underneath farms, field investigations of the impact of fish farms showed that adverse changes in the benthic community are observed for rates exceeding about 1 to 5 gC/m^{2}d (Angel *et al.*, 1995, Krost 2007, Hargrave 2010).

Figure 7 shows the spatial variation of the modeled Re for a neap-spring tidal cycle in Pegametan Bay. Values up to about 170,000 and 585,000 resulted respectively on the western and central channels. The higher Re in the central channel are due to the higher current velocities there. Based on Re and in-situ observation, farms sizes on the western and central

FIGURE 7. Modelled averaged Reynolds numbers for a mean neap-spring tidal cycle in Pegametan Bay.

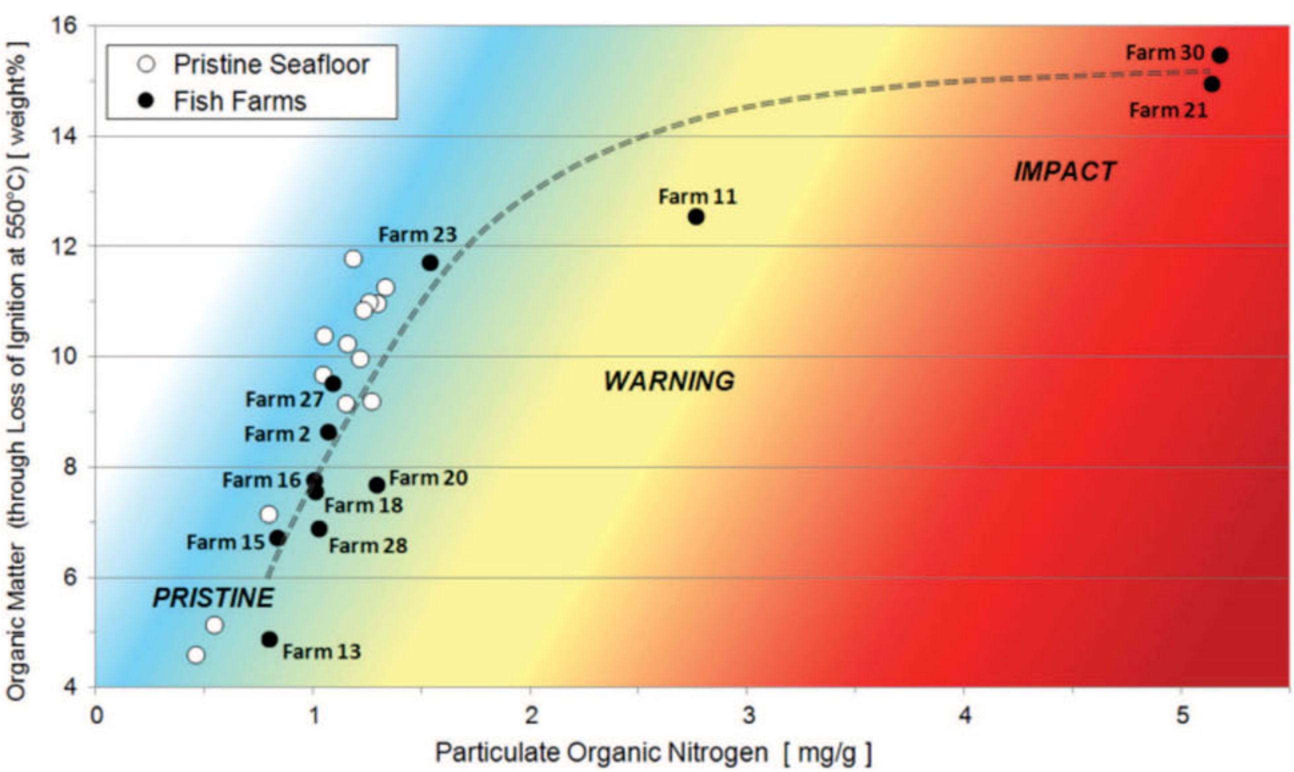


channels were limited respectively to 300 and 500 cages. Threshold values in terms of carbon deposition underneath farms of 5 gC/m²d are assumed here. To provide a good coverage of the farm waste of the site, w_s values ranging between 0.03 m/s and 0.10 m/s were considered in the estimation of farm ECC.

Table 5 lists for each fish farm the number of cages and volume, Re at farm location, current standing stock and ECC. The ranges of predicted farm ECC values reflect the adopted range of w_s. Predicted farm ECC values are compared to the current standing stocks of fish farms (Table 5). The results showed that so far farm ECC are exceeded only at the two larger farms (see farms numbered 21 and 30 in Figure 6). In the remaining farms, standing stocks are usually lower or comparable to the predicted ECC values. Hence according to the predictions, the standing stock of all the farms in Pegametan Bay could be up to about 660–800 t as compared to the current standing stock of about 345 t.

Model predictions were validated on the basis of the analysis of in-situ seabed sediments. Sediment samples taken underneath 11 farms and at 10 reference locations were used. Benthic conditions were assessed using video recordings and analysis of physic-chemical properties of surficial sediments. Figure 8 shows measured organic matter against concentration of particulate organic N of all sediment samples. The organic matter was determined through loss of ignition of sediment samples at 550°C. The effect of organic waste on the sea floor due to fish farming is evident underneath farms where deposition rate of organic waste exceeds the bacterial decomposition of the waste. In particular the sediments under farms 21 and 30 show high organic content, which is in good agreement with model predictions. According to the predictions the standing stock of these farms 21 and 30 is much higher than the predicted ECC values (see Table 5). Underneath farms where fish production is lower than predicted ECC values, impacts of organic waste are low or insignificant. Sediment samples are light grey and concentrations of N are just above natural conditions and/or comparable to the samples taken at reference locations (see Figure 8). Fish farm impact is also reflected on the levels of DO. At most

FIGURE 8. Assessment of sediment quality underneath fish farms in Pegametan Bay.



farms, DO profiles resemble natural conditions. However, near farms 21 and 30 there is a decrease of DO in the bottom layers.

Cumulative ECC is based on water quality degradation. ECC is dictated by the rate at which nutrients can be added without triggering eutrophication. It is assumed that the emitted load of dissolved inorganic nitrogen (DIN) from all farms within the site should not exceed 1 percent of the total amount of DIN load entering the water body (Weston, 1986). The rate of DIN entering Pegametan Bay is obtained from flow model simulations covering a full neap-spring tidal cycle in conjunction with measured concentrations of DIN measured just outside the bay. The limit of nitrogen emission is subsequently converted into the maximum allowable standing stock. According to the results, cumulative ECC of all the farms in Pegamentan Bay should not exceed ca. 500 t to 900 t of Grouper respectively for the lowest and highest observed nitrogen fluxes (van der Wulp *et al.*, 2010).

In summary, results of the assessment indicate that there are several farms currently out of suitable areas and that the two largest farms exceed ecological carrying capacity of fish farm production. Yet with proper siting of farms and controlled increases in farm production, the current whole aquaculture production in the bay, currently about 345 t, could be increased without harming the environment. As only a small percentage of the suitable areas is currently being used and most farms employ traditional technologies there is plenty of room for expansion. However, in view of the unknown ecosystem threshold and uncertainties in the predictions it is recommended to adopt a cautionary and adaptive approach based on regular monitoring to guarantee environmental sustainability.

4.5 Biosecurity Framework

The main reason of fish mortality in Pegamentan Bay is infection of seeds by Nervous Necrosis (VNN) and Irrido viruses. This is because fish seeds are not yet being thoroughly tested. To maintain healthy animal stocks, the GOI recently passed a regulation requiring that fish seeds, both from public and private hatcheries, must be Specific Pathogen Free (SPF) certified and have standard sizes for given ages. At the site in question, IMRAD Laboratory at RDIM has been responsible for certification. Farmers must request SPF certification and follow standard size before buying fish seeds, and only certified seeds can be sold. Currently real-time PCR is being adopted in the site to ensure that seeds are SPF (Mrotzek *et al.*, 2010). The establishment of quarantine offices for monitoring fish diseases and environmental conditions in aquaculture sites is another measure being demanded by the GOI to enhance biosecurity. By monitoring fish diseases at local hatcheries the quarantine office helps control fish diseases in the area.

Fish health and welfare in Pegametan Bay are also directly related to environmental conditions. It was found that disease outbreaks are associated to sudden drops in water temperature (Radiarta *et al.*, 2014b). In particular, changes in water temperature at the beginning of rainy seasons in Indonesia, from mid September to the end of October, and occasionally during winter months in Australia, from July till September, exacerbate fish diseases. Such temperature drops in conjunction with runoffs and wastewater from adjacent shrimp ponds, cause stress to the farmed fish and increase their susceptibility to diseases. To reduce risks, an operational system for real-time monitoring of water temperature was set up. Real-time data from three stations in the bay is transmitted to RDIM in Gondol and CARD in Jakarta. Early warnings are delivered to farmers by SMS, once sudden changes in water temperature occur. To increase immunity and reduce stress of fish during such conditions, fish are usually fed an artificial diet enriched by 1 percent of Vitamin C. The system proved to be quite effective in the minimization of fish diseases. Extensions of the system for monitoring additional water quality quantities such as salinity and turbidity have been proposed. This would enable detecting, for example, runoffs during the rainy season and waste water from the nearby shrimp farms.

5. PROPOSED MANAGEMENT PLAN FOR THE SITE IN BALI

5.1 Priority Issues

Relocation of farms to suitable areas is at the top of the agenda to enhance environmental sustainability of fish farming activities in Pegamentan Bay. Besides, as there are clear signs of sediment deterioration underneath farms numbered 21 and 30 (see Figure 6), fish production should be reduced there. Emphasis should also be given to the biosecurity framework, particularly concerning the effectiveness of the proposed measures to minimize fish mortality. Further measures include the adoption of improved feeding methods and establishment of a regular environmental monitoring program. This should be supplemented with regular assessments of fish mortality for the identification of sources of fish diseases. To facilitate the enforcement of regulations the current regulatory framework should be improved. In particular the requirements for EIA and associated environmental monitoring and licensing should be modified. Due to the relatively small size most farms are exempt of EIA. However the cumulative effect of farms in the site and the expanding size of farms could lead to significant environmental impacts. Therefore a precautionary approach concerning the increase in farm production based on regular environmental monitoring is recommended.

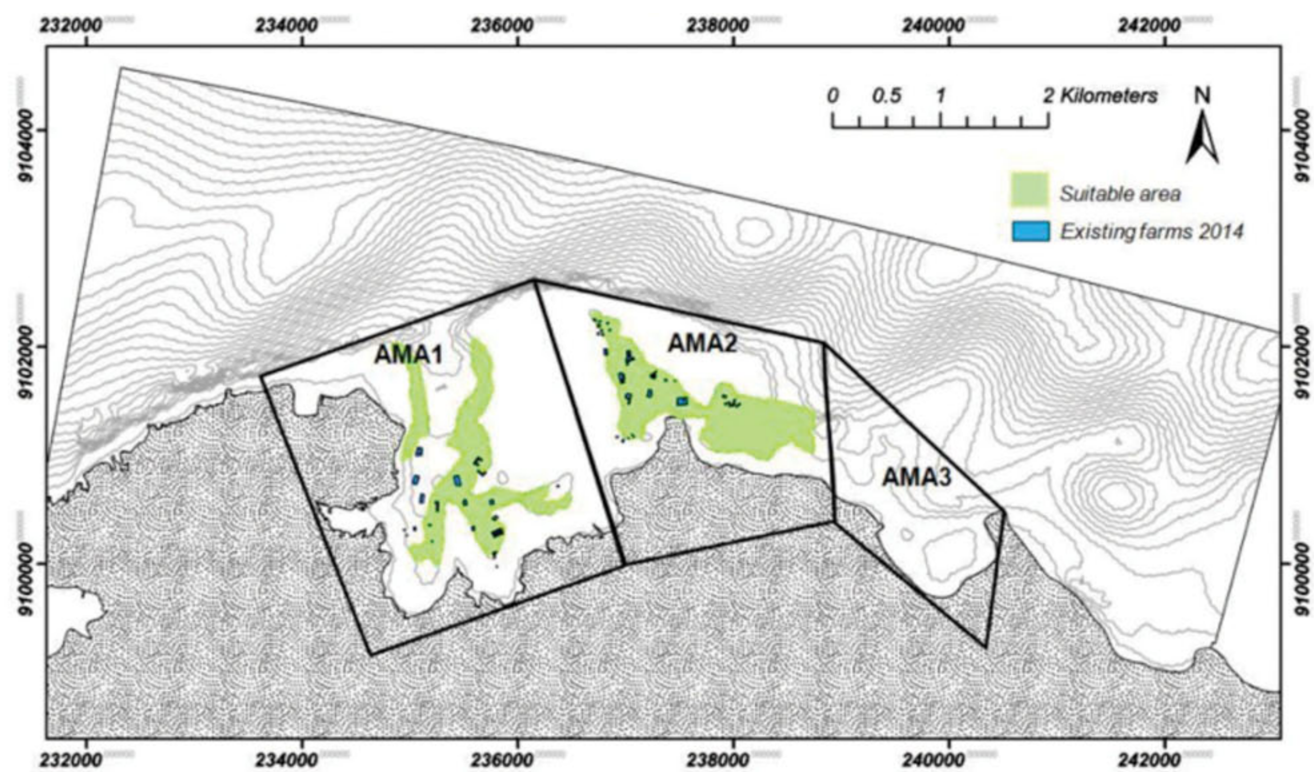
5.2 Aquaculture Management Areas (AMAs)

Three AMAs were designated for the Pegametan Bay. AMAs were defined mainly on the basis of the distinct environmental settings in the bay (Figure 9). AMA1 and AMA2 encompass respectively the western and central tidal channels where marine finfish farming takes place. As the current velocities in AMA2 are much higher than in AMA1, larger farms should be placed there. Both AMA1 and AMA2 are well protected by the outer reef belt so that agitation is reduced. AMA3 covers the adjacent area to the east of the bay. This area is more exposed to the open sea and currently dedicated exclusively for pearl culture. The impacts of the regional navigation channel and backyard hatcheries on the levels of water quality should be investigated.

5.3 Management Plan

Recommendations for improving operations of marine finfish farms in Pegametan Bay were made separately for the three AMAs. In AMA1 emphasis shall be placed on the relocation of farms to suitable areas. Farms numbered 10, 11 and 12 shall be moved to suitable areas and minimum distances among farms of about 100 m should be kept. Moreover buffer zones between the edge of the farms and the shoreline shall be

FIGURE 9. Aquaculture management areas for the Pegametan Bay.



maintained. Attention should also be given to periods of strong runoffs, and shrimp ponds should not be drained under east-west longshore currents due to the risks of pollution. Excess of fish farm production at farms 21 and 30 is the most relevant issue to account for in AMA2. Significant deterioration of sediment quality was observed underneath these farms. Therefore reduction of fish farming production is at the top of the agenda. As farms 21 and 30 comprise of several units for nursery and on-growing, the units should be separated to keep the total production within carrying capacity of the location in question. There is currently a concentration of farms on the western part of AMA2 (see Figure 9). It is recommended to spread farms throughout the entire suitable area. To avoid interactions, minimum distances among farms should be about 200 m. AMA3 is currently being used primarily for cultivation of pearl oysters. As the area is exposed to waves, the suitability of the area for cultivating pearls should be checked. Besides, the relevance of the impacts of the releases from backyard hatcheries and the regional navigation channel should be investigated.

5.4 Environmental Monitoring and Precautionary Approach

Continuous environmental monitoring is currently in place. Sediment monitoring is done every six months underneath farms in which, according to predictions, current standing stocks are close or exceed estimated ECC (see Table 5). The levels of DO along depth profiles, in the vicinity of the farms, are monitored every other month. Rates of fish mortality are being monitored regularly at several farms.

5.5 Evaluation System

The most relevant issues to improve fish farm operation in the bay and the proposed management plan have been discussed with the Farmer's Association. The plan is currently being evaluated by MSF of the Regency in Singaraja. It is envisaged to start implementing the proposed measures in 2016. An assessment of the effectiveness of the adopted measures should be done about a year later. RDIM/CARD will be responsible for monitoring and evaluating the implementation progress and outcomes. From now on, it is recommended to adopt a cautionary approach regarding the increases in standing stocks of the farms. On the basis of the results of monitoring, adjustments to the farm locations, to limits of fish farm production and to the biosecurity framework shall be proposed. Based on the results, further assessments of the management plan will be made.

6. CAPACITY BUILDING

Throughout the life of the project, particular attention has been given to the dissemination of techniques and associated results of the project as well as to a solid capacity building (CB) component benefitting the end users. The CB component delivered a number of CB interventions at different stages of the project. So far the CB component has been centred mainly with technical personnel of RDIM and CARD. Emphasis has been given to data collection and environmental monitoring, procedures for site selection and estimation of carrying capacity. From now on, the need for strengthening individuals and institutions to assume expanded responsibilities in the field of marine finfish aquaculture points out: a) the creation of a tailor-made CB model designed for Indonesia's aquaculture priorities; and b) strengthening the capacity of aquaculture operators and other stakeholders particularly at the local level.

7. CONCLUSIONS

- In this paper results of the application of the processes and steps for improving spatial planning and sustainable management of marine finfish aquaculture facilities in South-East Asia are presented. The effectiveness of the stepwise application with regard to scoping, zoning, site selection and carrying capacity is demonstrated for a site in the northwest of Bali, Indonesia;
- Methods adopted for site selection and estimation of ECC based primarily on hydrodynamics from simulation models enable assessments at the feasibility level in sites with scarce data. Methods proved to be effective to support and regulate the development of marine finfish aquaculture in sites where the activity is already well established as shown in the paper. In addition they provide guidance in the planning and identification of potential areas for expansion of the activity. Validation using in-situ observations

confirmed the adequacy of the methods for estimation of farm carrying capacities in sites in Indonesia;

- Marine finfish aquaculture is currently a small-scale industry in Indonesia, but as the majority of farms use traditional technology the potential for expansion in the existing sites is ample. As shown here with proper rearrangement and spreading of farms in conjunction with controlled raises in farm production using the proposed spatial planning tools, fish production could be increased without harm to the environment;
- Coastal areas in Indonesia offer excellent conditions for expansion of the activity. However, care should be taken in the selection of sites, as most of these areas are ecologically sensitive. Hence in addition to good environmental characteristics, sites should be located downstream from important ecosystems. Site selection should also account for conflicts with other activities and emphasis should be given on access to target markets and production infrastructure;
- The trend towards larger farms using several units with circular cages is demanding the adoption of new techniques for estimation of carrying capacities in the early stage of projects. Carrying capacities should be estimated at farm level and accounting for cumulative effects of all the farms in the environment. The allocation of licences and specification of EIA should be based on these assessments. Existing regulations for licencing and EIA in Indonesia are cumbersome and should be reviewed. Key criteria for impact assessment and acceptable limits of ecosystem change should be established;
- Basic biosecurity rules should be applied at farm levels. In particular stricter quality control of seeds and feeds, and extensions of the existing cost-effective early warning systems for detecting changes in water quality properties should be adopted;
- Regulations should be better enforced and complied with. More effective and efficient enforcement of technical and managerial procedures is needed to implement the available plans and to build the necessary capacity and manpower to address an array of old and new responsibilities. This requires scientific knowledge and technical and managerial skills, particularly at the local level;
- Capacity building has an important role to play in the years to come. Investment and efforts should create a cadre of personnel equipped with the necessary knowledge and skills in selected technical, scientific and management aspects of aquaculture. Capacity building should be based on a thorough identification of top priorities and the application of a mix of training and non-training approaches, plus practice and application of learning to a demonstration case.

8. ACKNOWLEDGMENTS

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ANNEX 1. CASE STUDY EFFECTIVENESS MATRIX FOR COASTAL CAGE AQUACULTURE IN INDONESIA

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	• The Ministry of Marine Affairs and Fisheries (MMAF) is the principal agency responsible for the planning, management and administration of marine fisheries and aquaculture sectors in Indonesia. • Managing authority: Central Government is responsible for the 12 nm offshore; Provincial level in charge of the near coastal stripes between 4 nm and 12nm seaward from the shoreline; Municipal/ Regency level: 4 nm seaward from shoreline.	Done	• Administrational documents; • Participatory meetings; • General bathymetric chart of the oceans.	4	
1.2 Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	• The Directorate General of Aquaculture (DGA) is the government policy-making agency in charge of aquaculture development, whereas at the local level it is in the hands of the local fisheries services of the provinces and districts/municipalities. • The administrative and legislative/ regulatory tools for an expanding aquaculture development exist. Some critical tools, such as zoning and EIA, are still to be fully implemented. Spatial planning tools currently being adopted are inappropriate.	Done	• Review of relevant policy and legal framework; • Institutional analysis; • Stakeholder analysis; • Consultations with relevant institutions.	4	

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.3 Setting the broad development objectives and identifying the main issues	• The Government of Indonesia (GOI) plans increasing overall national aquaculture production by an additional 2.5 million tonnes and 750,000 jobs in the next years.	Done	• Communication, consultation, participation; • Assessment of available resources, needs and values.	4	
	• Main issues have been widely identified through the *Blue Economy* initiative. Consultations or reviews to identify and prioritize problems/ issues *per se* have not been conducted. • Main issues are good environmental characteristics, conflicts with other activities, access to markets and production infrastructure. • Public/stakeholder participation in the decision-making process is not fully rooted as of yet.	Done to some extent as part of the *Blue Economy* initiative			
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.4 Zone boundary definition based on relevant criteria	• There are three legislated zoning schemes and procedures dealing with aquaculture development under the umbrella of MMAF: a) Inter-sectorial zoning scheme accounting for the majority of coastal uses, b) Minapolitan zoning for centres engaging mainly in aquaculture activities and c) aquaculture zoning focusing exclusively on aquaculture issues.	Done	• Development of plans having a multi-stakeholder approach. It determines which activities are allowed, permitted with license, and/or prohibited in the region. Broad zoning categories and the technical aspects concerning mapping are established. • Minapolitan aims to develop potential aquaculture areas as production centers by implementing extensive and/or intensive systems.	4	

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
	• The schemes have different objectives, though each and all of them together serve a common purpose from different perspectives. • Sites pre-selected on the basis of the inter-sectorial zoning and/or Minapolitan zoning have to undergo the aquaculture zoning to assess the adequacy of the site for aquaculture activity.		• Selection of areas suited for aquaculture development. The framework comprises the collection of data (primarily and secondary) and data processing and analysis leading to zoning maps.		
1.5 Gross estimation of potential production/ area	• The potential for expansion of the activity into new centres of investment is ample as only about 1% of the suitable area for development of industry is in use (Nurdjana, 2006). • In addition to the expansion of production in the existing sites (Lampung, Batam and Bali), several centers for expansion of marine finfish aquaculture have been identified. Potential sites include Lombok, Sumbawa, Manado and Morotai. • All sites offer excellent conditions for marine finfish aquaculture but much of them are ecologically sensitive coral reefs and mangrove.	Done	• Evaluation of production statistics; • Experience based on existing centres of activity in Lampung, Batam and Bali; • Communication with fish farms owners; • Satellite information.	4	

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.6 Formal allocation of the zone for aquaculture purposes	• Adoption of state-of-the-art spatial planning techniques is essential. • As the aquaculture industry is likely to conflict with the tourism sector and global conservation initiates much attention shall also be given to conflicts with other activities. • Access to markets and production infrastructure should play a major role in the selection of sites.	Done	• Participatory allocation process; • Communication and dissemination of allocated zones; • Preparation of Atlases and/or Web sites describing allocated zones along with maps, tables and charts.	4	
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	• Land tenure/use applications consulted. • Suitability thresholds for species and culture systems for the site defined and consulted. • Criteria and suitability threshold values for finfish culture practices in Southeast Asia adopted. • Recommendations regarding legislative aspects and coastal management taken into account.	Done	• Assessment of land tenure; • Participatory meetings; • Literature review and Internet searches; • Field data collection and measurements; • Model developments; • Mapping and analysis; • Mapping and analysis using GIS and remote sensing data.	4	
2.2 Carrying capacity estimation	• ECC estimated both at farm level and accounting to cumulative effect of all the farms in a given environment. • Adopted methods are based mainly on hydrodynamics from simulation models. ECC estimated using knowledge on currents, depth, benthic oxygen condition, and considering the disease risks and minimum distance between the individual farms.	Done	• Participatory processes; • Environmental Impact Assessment (EIA); • Risk assessment tools; • Methods for estimation of ECC suitable to sites with scarce data.	4	

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
	• Site selection and maximum allowable production done for various stocking densities. • Proposed methods applicable to new fish farm sites and for estimation and assessment of the potential environmental impacts of existing cluster farms.				
2.3 Set licence production limits within zone or water body carrying capacity	• Maximum production per AMA defined according to the estimated farm ECC. • Proposed maximum production for the whole site and for each AMA.	Done	• EIA • Risk assessment	5	
2.4 Allocation of licences and permits	• Licences required only for companies willing to establish medium-scale or large-scale farms. • Small-scale fish breeders and local farmers are exempt of licences. • Allocation of licences should take into account suitable areas and estimated ECC. Minimum distance between farms should also be accounted for.	Done/Available	• Not a participatory process; • Legislative/regulatory framework for aquaculture is complex; • There is a need to create a "single-window" for the processing of aquaculture licence.	3	

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant water body or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries	• Based on measured and modelled flow, waves and water quality conditions. • Risks on environmental threats assessed. • AMAs designated on the basis of suitable sites and ECC (local and cumulative effects). • Buffer zones between farms, coastline and the coral reefs set.	Done	• Participatory consultations; • Hydrodynamic + water quality models; • Depth and current maps; • GIS and remote sensing data and tools; • Risk maps; • Decisions made through participatory and well informed processes.	3	
3.2 Estimate total carrying capacity if appropriate based on the different risks	• Maximum production set for the site in Bali according to agreements on acceptable risks. • ECC for each individual farm, separately for each AMA and taking cumulative effects into account. • Assessments of ECC and fish farm production should be done at preselected potential sites to support GOI in the expansion of aquaculture production.	Underway	• Risk assessment, maps and relocations underway for the site in question. • Sites have been preselected in the majority of "Fisheries Management Areas." The location of the fish ports under planning should be taken into consideration.	3	
3.3 Organize a formal association of all farmers in that area	• Farmers already organized in an Association under RDIM and the local Marine and Fisheries Service in Singaraja.	Done/Existing	• Facilitated participatory tools	4	

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant water body or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
	• Area management structure with identified leaders and supporting technical groups/services exists. Leaders chosen by the farmers. • AMAFRAD and RDIM assist Association with technical issues related to mariculture development. • Management plan proposed for the Pegametan Bay.				
3.4 Setting the broad development objectives and identifying the main issues agree on common management,[2] monitoring and control measures	• DGA developed a plan for best management practice (BMP) on aquaculture. • BMP based on agreed measures (e.g., biosecurity scheme for the area), targets, indicators and resources (human and economic).	Done/Existing	• Proposed management plan discussed with Farmers Association and Marine and Fisheries Service in Singaraja. • Management plan under revision by the authority in charge.	3	
3.5 Monitoring of relevant variables and enforce management measures	• Monitoring of water and sediment quality at the site in Bali carried out regularly since 2008. • Early warning operational monitoring of water temperature for biosecurity done continuously at three stations within the site in Bali. • Monitoring of environmental and fish health conditions done at individual farms not yet to assess the overall condition of the area as a whole.	Underway	• Assessment of levels of water quality and sediment quality at farms in which ECC has been exceeded. • Extensions of the operational monitoring system of the site in Bali to account for other water quality properties such as salinity, turbidity, DO under planning.	4	

2 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.1 Regular monitoring and evaluation	• Proposed management plan currently under revision by the responsible local authorities. • Emphasis given to the relocation of farms, distances between farms, limiting production, buffer zones, regular monitoring program and continuous monitoring for early warning.	Underway		3	
4.2 Periodic review and adjustment	• Inter-sectorial zoning still under way. • 145 sites preselected in the framework of the Minapolitan Program for aquaculture development. • Aquaculture zoning so far carried out for only 35 of the selected 145 sites. Zoning should be extended to cover all preselected sites within the program. • Site selection, estimation of ECC and designation of AMAs should be done at the feasibility level of projects.	Underway		3	

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/ Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating	Approximate Investment for Each Step (US$)
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.3 Review of existing regulations	• Requirements for conducting EIA should be reviewed. Currently small-scale farms (less than 1000 cages) or old farms expanding in size are exempt of EIA. In this way EIA can be avoided in many ways. • Requirements for conducting gross estimations of ECC in the early stages of fish farm development and to set limits of production in designated AMAs should be included. • There is a need to enforce regulations more effectively and to create ways to intensify communication between public institutions and users at the local level.	Proposed		2	
Other notes	**Positive issues**		**Negative issues**		
Especially social issues	• Enhancement for aquaculture technology for local farmers around the *Blue Economy* areas. • Establishment of a formal fisheries association called: "Klinik IPTEK Mina Bisnis" (KIMBis) that facilitates communication with local farmers on relevant issues about aquaculture and the implementation models. • Backyard hatcheries along the coastline promote poverty alleviation and improvement of livelihood of fish farmers and fishermen. • Integrated multi-trophic aquaculture (IMTA) in the *Blue Economy* area under development. • Enhanced dissimination of aquaculture science and technology derived from research activities.		• Occasional vandalism on marine aquaculture facilities. • Social conflicts between aquaculture development and fishery activities. • Recently, enhanced movement from aquaculture to lobster collection due to high price of lobster seed.		

Shrimp Farming in Mexico

Giovanni Fiore Amaral[1]

ABSTRACT

The Mexican shrimp farming industry began in the 1970s in the northwest states (Sonora, Sinaloa and Nayarit) using rustic ponds with low densities. Current estimates indicate that the surface area of shrimp ponds in Mexico is around 70,000 hectares, however the technology has not changed considerably; modernization and regulation have been limited. Nevertheless, shrimp farming represents one of the most profitable aquaculture sectors in Mexico. Through the General Fishing and Aquaculture Law, the National Commission of Aquaculture and Fisheries (CONAPESCA) is responsible for the efficient regulation of aquaculture in water bodies of federal jurisdiction. On the other hand, the Secretariat of Environment and Natural Resources (SEMARNAT) is Mexico's environment ministry. One of SEMARNAT's core functions is to regulate the development of inland aquaculture (private property and federal marine-inland zone) by requesting environmental impact assessments for screening. Clearly, the development and regulation of shrimp farming has to be coordinated between these federal offices with their respective laws.

The Federal Government of México, through CONAPESCA, recognizes the importance and need for the aquaculture and fisheries sector to sustainably grow in order to meet rising food demands. To this end, and in recent years, CONAPESCA has allocated public resources to improve the fisheries and aquaculture sector through specific strategies; one of these strategies is *"The National Program for Aquaculture Management"* which was created to (i) enable an orderly and competitive aquaculture sector that is sustainable, and (ii) regulate and administrate the sector, using processes and tools such as the delimitation of aquaculture zones. Shrimp farming in Nayarit State is used as one example to illustrate how aquaculture is managed through Aquaculture Production Units (UPAs) or aquaculture zones.

This case study describes the methodology that is used in Mexico to demarcate and manage aquaculture zones based on the scoping of the aquaculture activity and the zone, carried by the Aquaculture Health Committee of Nayarit State with federal funds of CONAPESCA. Zoning results are presented in a spatial database (available on the Internet) to facilitate the regularization of UPAs through legal mechanisms between CONAPESCA and SEMARNAT.

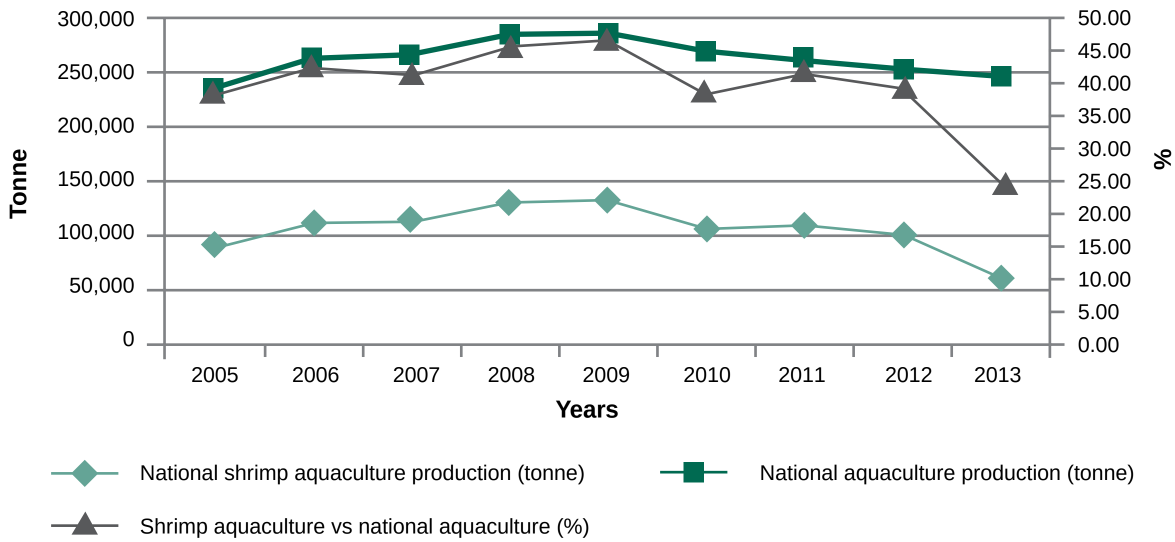
1. INTRODUCTION

Aquaculture in Mexico was started towards the end of the 19th century, as a complementary activity for social support in rural communities (Juárez-Palacios, 1987). It started with the importation of rainbow trout eggs from the United States (Arredondo, 1996). Although this activity initially evolved towards other freshwater

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

Fiore-Amaral, G. 2017. Shrimp Farming in Mexico. In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document*, pp. 253–270. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

FIGURE 1. Comparison of shrimp production (shrimp aquaculture vs national aquaculture) in México.



species, during the 1980s, mariculture was started at an experimental level with species such as spotted sand bass, snapper, snook, red snapper, seabass, pompano, totoaba, and sole (Avilés, 2000).

Shrimp aquaculture was initiated during the 1970s in the northwestern Mexican states of Sonora, Sinaloa and Nayarit, in earthen ponds at low densities. This continues to be the most widely practiced culture method, covering around 70,000 hectares generally under nonregulated Aquaculture Production Units (UPAs—Spanish acronym). Nevertheless the cultivation of this species is one of the most productive and profitable aquaculture activities as shown by the national fisheries statistics (Figure 1).

The Mexican federal authorities have developed a series of effective strategies to recover and improve shrimp aquaculture production due to the continued decrease of shrimp production since 2009 caused by different factors such as diseases, environmental degradation, climate change and irregularities in UPAs, among others. The federal government, through the National Commission of Aquaculture and Fisheries (CONAPESCA—Spanish acronym), head of the productive sector, recognizes that the development of national aquaculture is key to national food security, and thus has vested public resources with the purpose of improving this primary activity through specific strategies.

Since 2008 the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA—Spanish acronym) through CONAPESCA, has implemented the National Aquaculture Management Program (PNOA—Spanish acronym) to develop and conduct the National Policy for Sustainable Fisheries and Aquaculture. The objectives of this Program are: (i) to achieve an orderly and competitive, sustainable aquaculture sector industry; and (ii) to provide public policy instruments able of regulating and managing the activity.

However, within the Mexican legal framework, CONAPESCA only has administrative powers such as issuing permits and concessions for aquaculture projects to be undertaken in federal waters (seas, dams, rivers, etc.). On the other hand, the Secretariat of the Environment and Natural Resources (SEMARNAT—Spanish acronym) is responsible for regulating inland aquaculture undertaken on land (private property, federal maritime-terrestrial zones, protected natural areas, etc.), as well as aquaculture of protected species.

This case study was carried out by the State Committee on Aquatic Health of the State of Nayarit (CESANAY—Spanish acronym) sponsored by federal resources in the study area called Pericos-Pimientillo (P-P) in Nayarit. The following activities were undertaken: (i) comprehensive literature search to develop the characterization of the area; and (ii) surveys in each aquaculture production unit, and a participatory workshop involving all stakeholders of the aquaculture sector in order to obtain reliable information for a comprehensive diagnosis. With this information, and using Geographical Information Systems, the suitability of sites for shrimp aquaculture was determined, as well as estimating the potential surface areas to undertake new aquaculture projects.

The target population was the shrimp aquaculture communities in need of regularization and administrative strengthening models. Regarding the study area, seven farming communities were identified where activities are developed by producers from 9 different towns: 163 shrimp aquaculture production units (WCU) operated by 488 producers, which generate a production estimated at around 1,600 tonnes. Shrimp aquaculture activities in the study area created a total of 583 permanent and 1,237 temporary jobs; 481 people were direct beneficiaries and 2,290 indirect beneficiaries.

Aquaculture suitability for shrimp farming was determined in the study area. 5,368.00 hectares showed high aptitude, 3,661.00 hectares showed medium aptitude and 2,817.00 hectares present low aptitude for shrimp aquaculture. Regarding growth potential of aquaculture in the P-P study area, high aptitude was determined in 3,741.59 hectares (31.33 percent of total surface area), under current regulations.

2. OBJECTIVES

2.1 General Objective

To prepare the project titled "Aquaculture Planning in the State of Nayarit: Regularization of Aquaculture Production Units" which would provide elements to design public policy instruments aimed at regulating and administering aquaculture.

2.2 Specific Objectives

- To create a characterization and integral diagnosis of aquaculture in the study area P-P, showing the prevailing conditions of its productive environment as well as the main problems this sector faces.
- To create databases for aquaculture production units (WCU) facing regulation needs regarding permits and concessions.
- To determine suitable areas for aquaculture activities enabling the development of shrimp aquaculture within the study area.
- To generate a proposal to be presented to the relevant authorities in order to undertake the regularization of the productive units.

3. METHODOLOGY

The National Aquaculture Management Program (PNOA—Spanish acronym) is carried out through the implementation of aquaculture projects at state levels, pointing out the need to include educational institutions such as universities and research centers or private consultancies with expertise in aquaculture matters, which would provide the appropriate tools in order to facilitate decision-making. CESANAY was responsible for the execution of the present case study.

The proposed aquaculture management program for shrimp farming in the area of the P-P Nayarit study initially consists of two stages: (i) characterization of the study area, and (ii) comprehensive assessment of the aquaculture sector of the study area. These stages are governed by four components and 30 variables (Table 1) which must be determined by bibliographical research, application of polygons and images, attribute tables, surveys and participatory workshops.

Enough information resulting from close coordination among CONAPESCA and SEMARNAT was obtained based on the characterization and diagnosis stages; it was used to prepare a proposal for the regularization of shrimp aquaculture UPAs, as well as to obtain the following documents:

1. CONAPESCA: (i) National Registry of Fisheries and Aquaculture (RNPyA—Spanish acronym).
2. SEMARNAT: (i) Use of surface waters, (ii) Surface water disposal, (iii) Resolution regarding environmental assessment, (iv) Concession over federal maritime terrestrial zone* and (v) Permit for land use change*.
   *If applicable

TABLE 1. Terms of Reference for an Aquaculture Management Project.

Stage	Component	Variable
CHARACTERIZATION OF THE STUDY AREA	Physical characterization	Study area
		Hidrology
		Soil types
		Climate
		Geomorphology
		Topography and slopes
	General socioeconomic issues affecting aquaculture	Localities and population
		Economically active population in aquaculture
		Productive activities
		Social marginalization
		Housing characteristics
		Education
		Roads
		Electricity
	General biological aspects	Vegetation
		Fauna
		Protected species
		Protected Natural Areas
INTEGRAL DIAGNOSIS OF AQUACULTURE SECTOR OF THE STUDY AREA	Census of Aquaculture Production Units (UPA) and their location	Database
	Status of aquaculture in a comprehensive context	Environmental
		Technology
		Regularization
		Socioeconomic
		Commercial
		Sanitary
	Participatory workshop	Attributes
		Conflicts
		SWOT Analysis
		Issues
	Spatial analysis	Aquaculture suitability
		UPAs Georeferencing

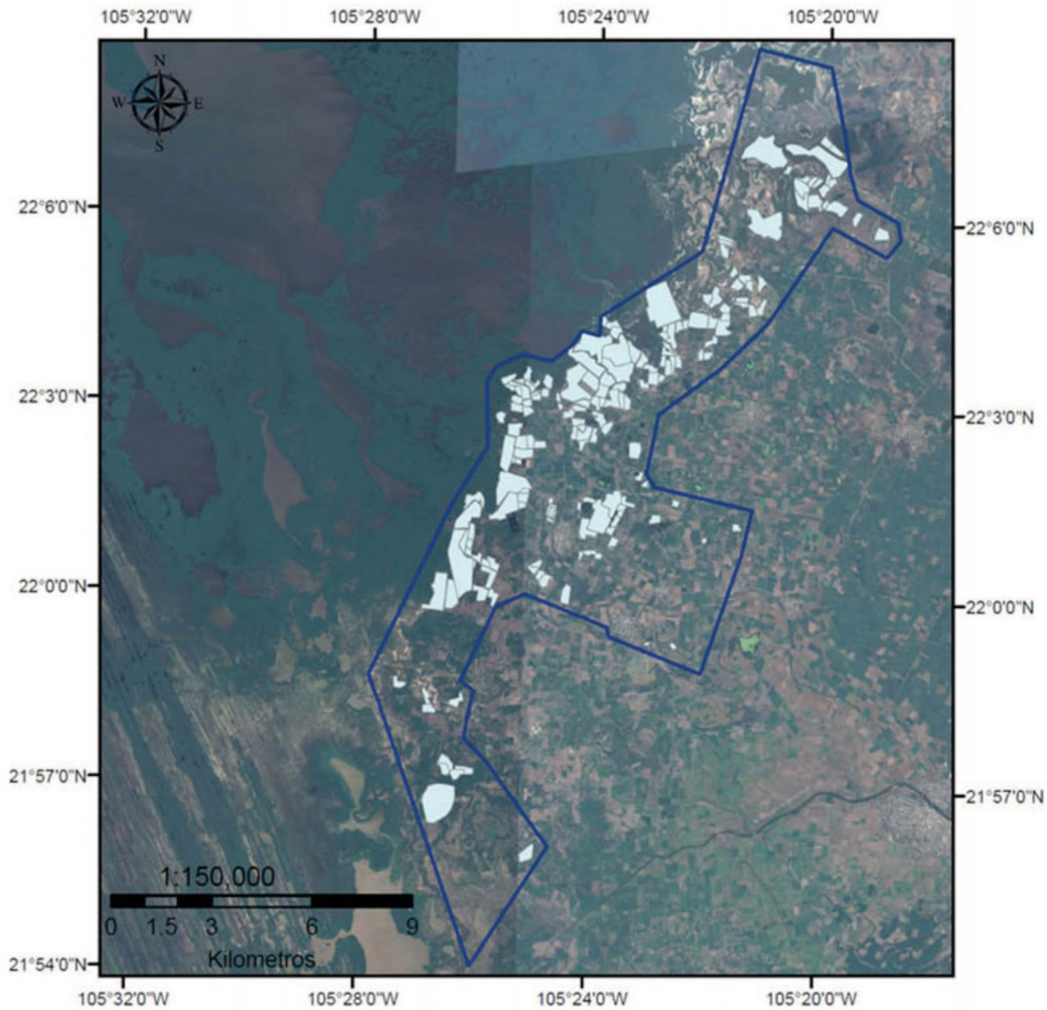
3.1 Characterization of Study Area P-P, Nayarit

3.1.1 Physical Characterization

Study Area: Located on the coastal plain of the northern part of the state of Nayarit, the total surface of the study area P-P is 11,845 hectares. The extreme coordinates are: 22° 09′ 11″ north, 21° 57′ 06″ south, 105° 21′ 01″ east and 105° 26′ 30″ west. It was defined taking into account the water body (marsh), its proximity to towns, highways and rural roads, as well as the distribution of operating UPAs, using ArcGIS 10 (Figure 2).

Hydrology: The study area is located in the basins of the Acaponeta River and the San Pedro River, draining fresh water. These rivers have a markedly seasonal

FIGURE 2. Boundaries of the study area in the State of Nayarit, Mexico.



behavior and are found within the Teacapan-Agua Brava lagoon system, which records seasonal salinity variability, showing big contrasts between drought and rainfall seasons; greater variation happens in rainfall (Sánchez, 1994). Salinity drops sharply to 8 percent in autumn during the rains, and reduces to 0 percent in the lagoon and its tributaries (Alvarez *et al.*, 1986). Low temperature values (23°C) were recorded during winter, while higher values were recorded (32°C) during spring.

Soil types: Eutric Cambisol, Solonchak, gleyic and Solonchak, orthic.

Climate: Warm weather prevails in the coastal area with a highest annual average temperature of 25°C, classified as humid warm with summer rains of medium humidity. Maximum temperature is 33.9°C and minimum is 17.9°C.

Geomorphology: The study area is mainly coastal brackish lagoons and delta plains.

Topography and land slope: The study area has flat soils with average slopes below 2 percent and it is thus suitable for aquaculture.

3.1.2 General Socioeconomic Issues Affecting Aquaculture

Localities and population: The total population of the study area is 8,105 inhabitants (INEGI, 2010), living in 7 localities that support shrimp aquaculture in the region.

Economically active population in aquaculture: 3,203 people, 86.73 percent male and 13.27 percent female.

Productive activities: Productive activities are mostly agricultural. Agriculture is the activity that demands the most jobs; it is followed by livestock and fisheries.

Social exclusion (marginalization): According to social standards (based on insufficient access to social rights, material deprivation, limited social participation and a lack of normative integration), the study area is considered as "medium" in social exclusion.

Housing conditions: Within the study area, 2,267 houses are inhabited, none of which have dirt floors; 2,306 have electricity connection, 2,226 have sewage and 2,250 have piped water.

Education: Within the study area there are educational preschool, primary, secondary and high school facilities.

Roads: Good paved roads lead to the localities, but access to UPAs is by dirt roads in bad conditions, which worsen during the rainy season.

Electricity: The localities are connected to power lines; however, there is a lack of lines in the area where the UPAs are located.

3.1.3 General Biological Issues

Vegetation: The main vegetation is low thorny deciduous forest and mangrove.

Fauna: In the study area, wildlife is virtually nonexistent due to the proximity of human settlements and economic activities, mainly fisheries and aquaculture. However, in the National Wetlands in Nayarit, which adjoins the study area, 240 species of vertebrates have been reported, 60 of which are under protected status. The presence of two native aquatic species (white shrimp and mangrove oyster) and one exotic species (Tilapia) within the area is noteworthy; their cultivation is feasible.

Protected species: The Mexican norm NOM-059-SEMARNAT-2010 aims to identify species or wildlife populations at risk in Mexico; 14 species within this norm have been identified in the study area.

Protected Natural Areas (ANP): The study area adjoins the protected natural area known as the Nayarit National Marshes Biosphere Reserve, which comprises the municipalities of Acaponeta, Rosamorada, Santiago Ixcuintla, Tecuala and Tuxpan in the state of Nayarit.

3.2 Integral Diagnosis of Aquaculture in the Study Area P-P, Nayarit

With information derived from the participatory workshop as well as bibliographical research on the P-P, Nayarit, the following conclusions were reached:

3.2.1 Census of Aquaculture Production Units (UPA) and Location

163 shrimp production farm units were identified; production was estimated at around 1,600 tonne. Shrimp aquaculture farms generate 583 permanent and 1,237 temporary jobs. There are 481 direct beneficiaries from the project, who are members of the UPAs and 2,290 indirect beneficiaries, both permanent and temporary workers. The total area involved in shrimp aquaculture farms within the study area is 2,263.26 ha while the productive area is 1,964.20 ha.

3.2.2 Conditions of Aquaculture in a Comprehensive Context

Environmental conditions: The study area is an important conservation region due to the high concentration of aquatic fowl as well as migratory or semi-aquatic residents, vertebrates and endemic insects. It has a large extension of well-preserved mangroves. It is limited by the mangrove areas and the water bodies. The following environmental problems have been identified, caused by anthropogenic activities:

- Destruction of mangroves and wetlands.
- Unplanned development for shrimp farming on a large scale.
- Salinization of agricultural land.
- Silting of estuaries and pumping channels.

Technological conditions: Producers lack the necessary resources to technologically upgrade and develop their production units. Since 100 percent of the UPAs is legally irregular, they cannot access financial support from federal programs handled by SAGARPA-CONAPESCA. Only the semi-intensive system is employed, having moderate stocking densities of 8–15 org/m^2. The UPA's operative infrastructure includes 311 earthen ponds with dikes irregularly shaped. Ponds are fed surface waters from adjacent estuaries and coastal lagoons. 67 percent of the UPAs is productive only once a year during the summer-winter season, while 33 percent of the units carry out two production cycles per year (winter-spring and summer-autumn). The UPAs undertake a range of activities for production:

- Pond preparation.
- Pond water filling.
- Acclimatization and stocking.
- Feeding.
- Water quality and biometrics monitoring.
- Harvesting.

Regularization status: Due to technical and policy ignorance, UPAs have been created with no order or legal compliance, resulting in disorderly growth of aquaculture in this region. Within the study area, none of the UPAs comply with legal regulations due to:

- Ignorance of the legal framework and current regulations.
- The scarcity of resources only allows stakeholders to build their aquaculture facilities.
- Few extension technicians provide technical assistance to support those interested in initiating an aquaculture project within the legal framework.
- High cost of assessment studies required for the application procedures for some permits.
- Difficulty and time to obtain the required permits and licences for shrimp farming.

Socioeconomic conditions: There are 473 shrimp aquaculture stakeholders in the study area. 419 are male (89 percent), and 54 are female (11 percent). Currently there are 575 permanent and 1,213 temporary jobs.

Commercial conditions: Marketing is usually done by producers, whole, fresh at the UPA farm gate; nonetheless, the State of Nayarit has processing plants that add value to shrimp production (frozen with head, in blocks with head, dried with head).

Health conditions: The Nayarit State Aquatic Health Committee (CESANAY—Spanish acronym) is responsible for monitoring the sanitary conditions of UPAs in the study area. Visits are made to the various shrimp aquaculture production units, with the aim of monitoring the organisms' health through various laboratory tests. UPAs utilize bactericides such as Onmicron and Timsen. When a sanitation problem arises, a sanitary protocol is implemented for stocking, on-growing, harvesting and post-harvest of shrimp. There is an official agreement in place for a sanitary dryout in the UPAs lasting from December 1st to the last day of February, aimed at reducing mortalities caused by the white spot disease.

The following diseases have occurred in the study area: White spot viral disease, the Taura virus, and IHHNV virus. Since 2013, atypical mortalities have been reported related to acute hepatopancreatic necrosis syndrome at the initial stages of shrimp cultivation.

3.2.3 Participative Workshop/Meeting

A participative workshop was held on December 16th, 2013, starting at 10:00 AM, at the facilities of the Ejido Commissary of Pimentillo. It was organized by the project executor (CESANAY) in order to assess key environmental attributes, conflicts with other sectors, a SWOT analysis of aquaculture in the study area, and the issues presented by the aquaculture sector on the site. 43 people attended the workshop, including 33 farmers from the study area and 10 aquaculture technicians responsible for the UPAs surveyed.

Environmental attributes: The shrimp farmers operating in the study area identified five essential environmental attributes[2] (Table 2) for shrimp aquaculture; water availability being the most important.

Conflicts: Shrimp aquaculture in the study area faces four conflicts with the following sectors: (i) agriculture,

2 Only environmental attributes were considered at this stage of the analysis, having been prioritized and included in the spatial analysis. Social and economic factors were included in the conflicts, in the SWOT analysis, and under issues. Governance was evaluated in the UPAs survey (legal and document status) but this information was only included in the diagnosis report.

TABLE 2. Environmental attributes for shrimp aquaculture in Nayarit State, Mexico.

Attribute	Producers Priority	Notes
Water availability	1.	The main attribute is water availability.
Salinity	2.	Have access to salt and fresh water to regulate salinity.
Temperature	3.	Temperature in the study area is beneficial; ideal conditions prevail for significant production.
Land use	4.	Land use.
Roads	5.	Every farm has road accessibility; most of them are in bad condition.

(ii) fishing, (iii) conservation-forest, and (iv) human settlements. The greatest conflict is with agriculture, and particularly in relation to shrimp aquaculture, due to the use of agrochemical fertilizers and pesticides which drain to water bodies as well as unlimited use of water by farmers. Another important conflict is with the fishing sector striving for the use of environmental resources since both activities are developed in the same area.

SWOT Analysis: The SWOT analysis enabled the identification of five main strengths, weaknesses, opportunities, and threats faced by shrimp aquaculture in the study area.

Issues: Five main problems affecting shrimp aquaculture development in this region were emphasized by shrimp producers:

1. Lack of links with research centers.
2. Insufficient capacity of the cold chain.
3. High cost of feed and of high quality larvae.
4. Dissemination of viral diseases.
5. Silting of the estuaries and of water channels.

3.2.4 Spatial Analysis

One of the main objectives of Geographical Information Systems is to facilitate the decision making. The systems incorporate algorithms to assess simple,

TABLE 3. SWOT matrix designed at the participative workshop/meeting.

Strengths	**Opportunities**
1. Environmental attributes to undertake aquaculture.	1. Possibility of diversification with other aquatic species.
2. High market demand for shrimp.	2. Extractive fishing stability or decline.
3. Experience in shrimp farming.	3. Job creation within the state of Nayarit.
4. Willingness to regularize the UPAs.	4. Access to technology.
5. Job creation within the state of Nayarit.	5. Access to new international markets.
Weaknesses	**Threats**
1. Severity of viral diseases.	1. Unfair market competition.
2. High operating costs.	2. Insecurity due to organized crime.
3. Lack of financial resources from banking institutions for operation of UPAs.	3. High operating costs.
4. Lack of entrepreneural culture.	4. The siltation of water channels and estuaries.
5. Control and carrying capacity.	5. Shrimp imports.

multiple, and multi-criteria objectives interacting with the criteria and knowledge of the group of experts involved in the project of aquaculture management (CONAPESCA—CESANAY).

The spatial analysis in this case study aims to determine the portion or portions of the total surface area that meet a set of weighed criteria. Heuristics is used to solve conflicts with massive sets of data.

Each criterion to be met is addressed through the classification of thematic information layers to create abstract territorial models; these layers were obtained through a bibliographical survey at the diagnosis stage. Each layer is assessed and reclassified at different points of the methodology stated for each aptitude model, verifying for possible conflicts, and looking for the best solution using a minimum distance rule with weighed values.

When building each model, criteria for definition of aptitude for shrimp aquaculture were established as factors and restrictions. Later, they were spatially represented by subject matters according to each factor or restriction.

Multi-criteria evaluation (Eastman *et al.*, 1993; Aguilar-Manjarrez, 1996; Malczewski, 1999) allowed the interaction of all factors simultaneously, without having to perform several overlay map operations, nor modifying attribute values by a constant value, nor a final reclassification of the end map resulting from a combination of all layers of the information process. The maps resulting from the multi-criteria evaluation showed the importance that the factors with the highest assigned weights had, which exerted the greatest influence in determining the areas with the greatest potential.

ArcGIS 10 software was used for this case study. The sets of data were expressed in a vectorial format which may be integrated into any commercial or free geographic information software. The output data sets were:

- Georeferencing of UPAs.
- Aptitude for aquaculture by species (shrimp).

Both UPAs and the study area P-P, Nayarit, were geo-referenced using information generated by the project executor (CESANAY) from the survey Census of Aquaculture Production Units (UPAs) and their conditions. Moreover, for determining the aquaculture aptitude areas, environmental information from the National Institute of Statistics and Geography (INEGI) was used for the following variables: soil types, hydrology, geomorphology, topography and slope, localities and population, roads, electricity, and Natural Protected Areas. Later, thresholds were determined to state the aptitude for shrimp aquaculture and the priority of each variable through a multi-criteria analysis based on consultation with experts, bibliography, and the results of the participatory workshop/meeting (environmental attributes). The other variables (Table 1) were used for the integral diagnosis report.

3.2.4.1 UPAs Geo-referencing of UPAs

The Census of Aquaculture Production Units (UPAs), and their conditions, were established based on the information generated from the diagnosis stage; then the 163 UPAs identified were delimited along with their table of attributes (Figure 3).

3.2.4.2 Aquaculture Aptitude (Shrimp)

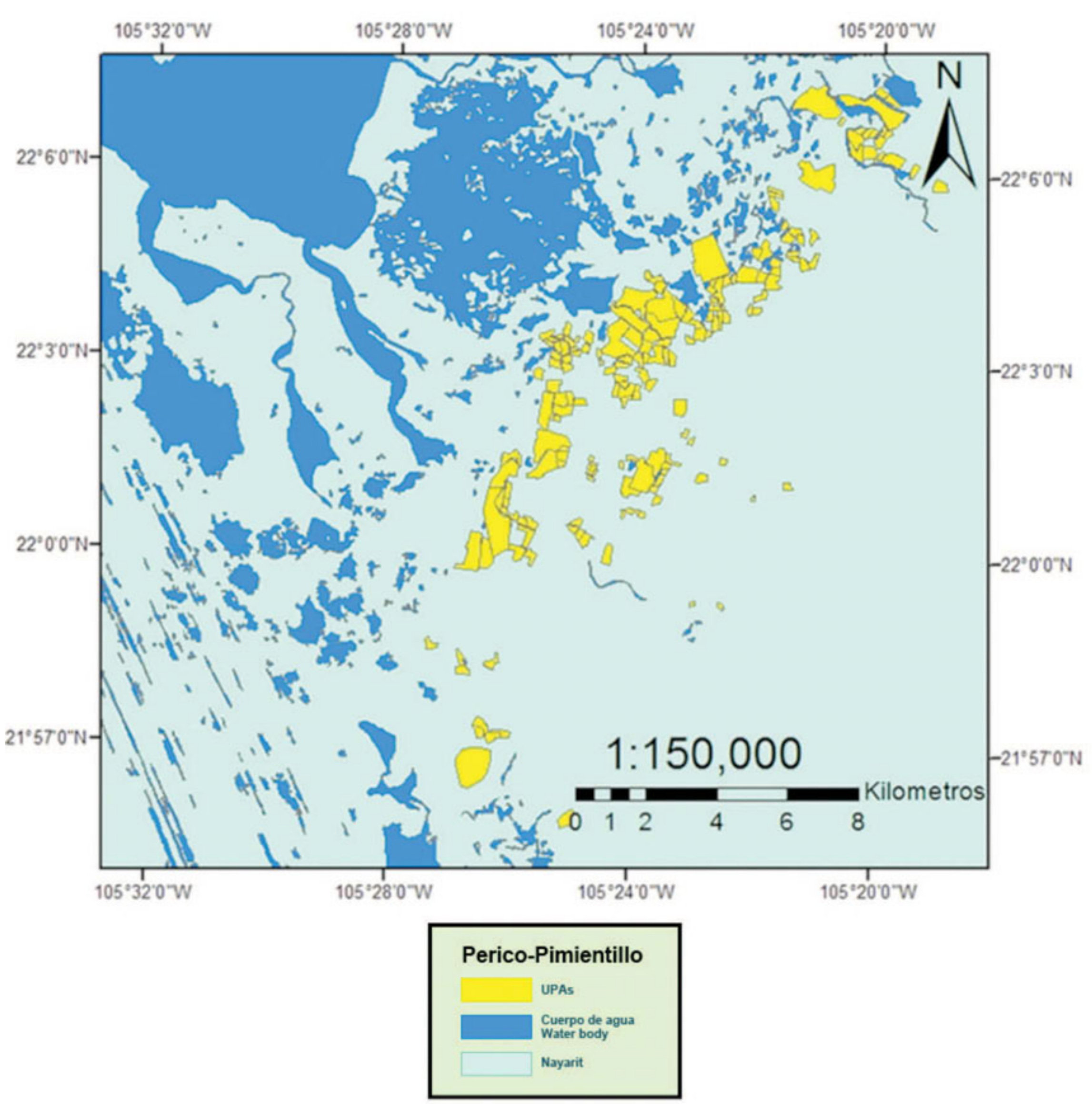
Geographic Information Systems were used for the determination of shrimp aquaculture aptitude in the study area based on the results of the spatial analysis (Figure 4) and the coverage area was determined for each aptitude (Table 4).

Once the suitability of shrimp aquaculture in the study area was determined, it became clear that new UPAs may be developed in a surface of 3,741.59 hectares. However, this growth must comply with current legislation for an orderly growth of aquaculture.

4. PROPOSAL FOR THE COMPLIANCE OF UPAs WITHIN THE P-P NAYARIT STUDY AREA

For optimal performance in the P-P Nayarit study area, it is essential that UPAs fully comply with all current

FIGURE 3. Limits of the 163 UPAs in the study area.



regulations regarding aquaculture. As mentioned above, the sprawl of shrimp aquaculture in the study area has been irregular, and, according to the diagnosis, most UPAs operate under inappropriate conditions.

It is necessary that every UPA undertakes actions to comply with all technical specifications established in aquaculture regulations, such as being duly registered in the National Registry of Fisheries and Aquaculture under CONAPESCA, complying with regulation terms for use and discharge of surface water, and obtaining an environmental impact assessment resolution and the federal maritime land lease from SEMARNAT.

The following actions were identified for the compliance of UPAs based on the findings of the diagnosis of the current project as well as upon the recommendations of the aquaculture sector:

- Register in the National Registry of Fisheries and Aquaculture under CONAPESCA.
- Host an inspection visit by each aquaculture production unit by federal inspectors of the Federal Attorney for Environmental Protection.
- Environmental impact resolution granted by PROFEPA.

FIGURE 4. Limits of shrimp aquaculture aptitude areas and of the UPAs.

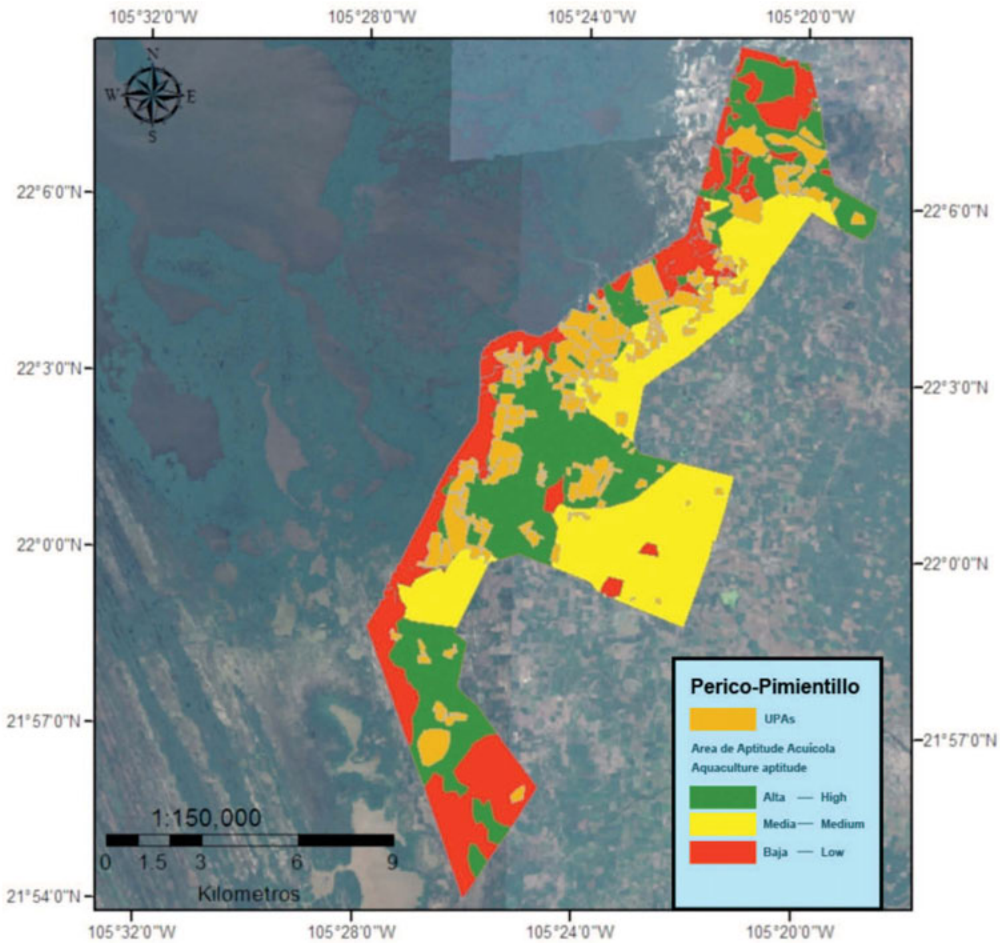


TABLE 4. Surface area and percentage for shrimp aquaculture aptitude in the study area.

Aptitude Surface Areas		
Aptitude	**Hectares**	**Percentage**
High	5,368.00	45%
Medium	3,661.00	31%
Low	2,817.00	24%
Total	11,845.00	100%

- Permit granted by the National Water Commission (CONAGUA) for use of surface water and wastewater disposal.
- Preparation of the Environmental Impact Assessment—Regional Modality—of the P-P Nayarit study area, including impact mitigation measures during both the operation stage and the site abandonment.
- Submission of the Environmental Impact Assessment—Regional Modality to SEMARNAT.
- Environmental Impact Assessment Resolution granted by SEMARNAT.
- All other permits, as needed for each UPA (federal maritime land lease by SEMARNAT, changes in land use, etc.).

Social and economic benefits will result from the compliance process, such as:

- Legal certainty for UPAs located in the P-P, Nayarit study area.
- Access to financial resources granted by federal, state and municipal authorities to support aquaculture activities.
- Increased productivity and competitiveness of shrimp aquaculture farms.

- Increase of direct and indirect jobs.
- Aquaculture activity consolidation in this region.

5. RESULTS ASSESSMENT BY CONAPESCA

CONAPESCA specialists performed a detailed analysis and evaluation of the expressed results, in compliance with the Terms of Reference set for the three stages of the proposed aquaculture management project: (i) characterization of the study area, (ii) comprehensive assessment of the aquaculture sector in the study area, and (iii) proposal for the compliance of UPAs. CESANAY was the executor of the case study.

Once the results were validated, a deed settlement was issued stating that the use of public resources for the present aquaculture management project was properly applied. Thereafter, the spatial analysis was published in the website "Acuasesor" (http://acuasesor.conapesca.gob.mx/) containing: (i) Geo-referencing of UPAs, and (ii) shrimp aquaculture aptitude. The website aims to offer public technical and administrative elements as a contribution to the development of the national aquaculture sector. This website is recognized by FAO within the Country Initiatives Collection of NASO aquaculture maps (www.fao.org/fishery/naso-maps/country-initiatives/es/).

6. CONCLUSIONS

In the study area P-P, Nayarit, 163 UPAs are devoted to shrimp farming using only semi-intensive culture systems in earthen ponds with minimal technological levels due to their limited financial resources and the scarce support received by the producers.

Most production units face water availability problems for their aquaculture operation, largely due to siltation of estuaries and channels used for the supply of water. 70 percent of the UPAs performs only one productive cycle per year while 30 percent perform 2 cycles per year.

100 percent of the production units in the study area do not comply with the current applicable legal framework for shrimp farming.

Low competitiveness of UPAs is due to high input costs for the operation of aquaculture farms, especially the costs of balanced feeds, which represent 50 percent of total production costs.

Sanitary conditions are part of the main problems that shrimp aquaculture faces, since the site has been affected by diseases such as White Spot Viral Disease, Taura virus, and IHHNV virus, and more recently, atypical mortalities have been reported related to acute hepatopancreatic necrosis syndrome.

The P-P, Nayarit study area offers a significant potential for the growth of aquaculture, having a surface area of 3,741.59 ha (31.33 percent) of high aptitude if shrimp farming projects are developed in compliance with the current legal framework.

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ANNEX 1. CASE STUDY EFFECTIVENESS MATRIX

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	The boundaries were defined after expert and stakeholders consultation, location of shrimp farms, geographical and hydrographical boundaries (maritime zones, mangrove, human settlements, roads, etc.).		• Background documents; • Participatory meeting; • Specialist meeting; • Topographic maps.	5	6,000
1.2 Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	Compilation of relevant federal legislations, inter-secretarial cooperation and agreements were consulted.		• Review of national legal framework for aquaculture; • Institutional analysis; • Consultations with federal institutions; • Consultation with aquaculture specialists.	5	6,000
1.3 Setting the broad development objectives and identifying the main issues	Regularization of shrimp farms operating in the zone of the case study. Identifying the aptitude areas for shrimp farming.		• Consultation; • Census; • Workshops; • Topographic maps; • Background documents; • Specialist meeting.	5	40,000

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.4 Zone boundary definition based on relevant criteria	Environmental and governance criteria were identified for the zone of the case study.		• Mapping and analysis using GIS and remote sensing data; • Multicriterial analysis.	5	4,000
1.5 Gross estimation of potential production/ area	Based in the national aquaculture production data base, average density of shrimp culture developed in the zone and the environmental variables.		• Institutional data consulting; • Census.	5	4,000
1.6 Formal allocation of the zone for aquaculture purposes	Based in the environmental criteria to indicate the shrimp farming aptitude zones.		• Mapping and analysis using GIS and remote sensing data; • Preparation of federal Web site "Acuasesor"(maps, tables and charts).	5	5,000
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	Location of farm sites were estimated by shrimp farming aptitude zones (based in environmental criteria).		• Mapping and analysis using GIS and remote sensing data.	5	10,000
2.2 Carrying capacity estimation	Not calculated at this first phase.	Not done		0	25,000

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.3 Set license production limits within zone or water body carrying capacity	The results of the study are aimed to establish production limits and base line to carrying capacity in future projects.	Not done		0	10,000
2.4 Allocation of licenses and permits	The results of the study are aimed to establish an inter-institutional effort to regularize all the shrimp farms of the zone through licences and permits.	Not achieved		0	20,000
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant waterbody or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries	The common water body identified is an estuary and in the other hand are the rural roads to access the shrimp farms.		• Participatory consultations; • Current maps; • GIS and remote sensing data and tools.	5	10,000
3.2 Estimate total carrying capacity if appropriate based on the different risks	Not calculated at this first phase.	Not done		0	25,000
3.3 Organize a formal association of all farmers in that area	Most of the local farmers are voluntarily registered in a local Aquaculture Health Committee funded by federal government and farmers to minimize the propagation of diseases in aquaculture species.		• Periodical meetings; • Laboratory analysis of organisms in case of massive mortality to prevent propagation of diseases.	5	—

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant waterbody or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.4 Setting the broad development objectives and identifying the main issues and agree on common management,[3] monitoring and control measures	Not calculated at this first phase.	Not Done		0	25,000
3.5 Monitoring of relevant variables and enforce management measures	The local Aquaculture Health Committee in association with the local farmers monitored periodically environmental and cultured species health conditions.		• Monitoring by stakeholders; • Enforcement discussed and endorsed by local communities.	4	—
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.1 Regular monitoring and evaluation	Not calculated at this first phase.	Not Done		0	30,000
4.2 Periodic review and adjustment	Not calculated at this first phase.	Not Done		0	30,000

3 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**	**Approximate production from each aquaculture zone or AMA**			
Number of zones and range of implementation	1	740 tonne of shrimp			
Other notes	**Positive issues**	**Negative issues**			
(especially social issues)	The local farmers with the support of the local Aquaculture Health Committee want to regularize their shrimp farms; however none of the farms are operating with any legal authorization. Once they regularize their farms they can access to federal funds to improve their facilities. The farmers have the support of the local Aquaculture Health Committee to manage aquaculture species diseases.	The lack of funding blocked local farmers to access new culture technology (water treatment, water recirculation systems, aeration, biofloc, etc.). The lack of interest on reporting the total aquaculture production, to the federal authorities.			

Aquaculture Site Selection and Zoning in Oman

Dawood Suleiman Al-Yahyai[1]

ABSTRACT

The vision of the Ministry of Agriculture and Fisheries (MAFW) is to develop aquaculture in sustainable, competitive and environment-friendly basis in Oman which meets the needs of customers for high quality aqua products. Several features making Oman attractive to local and foreign investors include long coastlines with their diversified natural marine resources, world-class infrastructure, close proximity and easy access to key export markets, attractive financial incentives, support commitment from government authorities and well organized institutional and legislation frameworks. Determination of suitable sites for aquaculture is very important for the success of the commercial aquaculture projects. Therefore, Ministry of Agriculture & Fisheries conducted a detailed survey of the Omani coast at the beginning of the last decade. An atlas for suitable sites along the coast was prepared which include general oceanographic and environmental description about the coast of Oman. It also contains general information about the suitable methods for aquaculture and major constraints. In Oman, the sites for aquaculture projects were allocated in cooperation with the concerned authority in Oman such as Ministry of Housing and Ministry of Environment & Climate Affairs. A recent project was started by the Ministry of Agriculture & Fisheries to select suitable sites for marine cages in Musandam Governorate using GIS and remote sensing tools which determines the carrying capacity for each site. The main objective of this project is to build up a model for sustainable aquaculture development applicable to other regions of the Sultanate of Oman.

1. GENERAL OVERVIEW

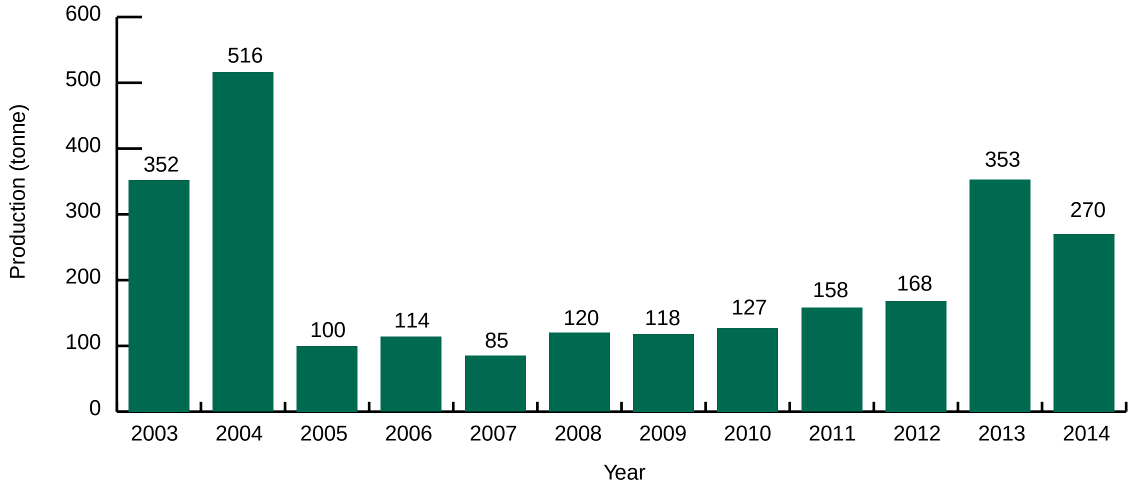
The aquaculture development in Oman started in 1992 with the research activities as trials for different local species. Ministry of Agriculture & Fisheries aims from these researches to test local species under local conditions. These researches include local Indian white shrimp (*Penaeus indicus*) culture (Gindy *et al.*, 2000a,b), cage culture of European sea bream, *Saprus aurata* (Al-Qasmi *et al.*, 1998), local abalone culture (*Haliotis mariae*), hatchery techniques for local silvery black sea bream (*Acanthopagrus cuveiri*), biology and hatchery techniques for local sea cucumber (MAF, 2011). For aquaculture site selection, two surveys were conducted (Gindy, 1999 and Al-Yahyai, *et al.*, 2004). The aim of these two surveys was to define and select the suitable sites for aquaculture. The second survey, which was conducted in 2004, was more comprehensive and includes the whole coast of Oman.

After the success of these researches and their proven applicability of different aquaculture projects in Oman

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

Al-Yahyai Dawood, S. 2017. Aquaculture Site Selection and Zoning in Oman. In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document*, pp. 271–286. Report ACS18071. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

FIGURE 1. Total aquaculture production in Oman, 2003–2014.



with local species, the private sector started to invest in aquaculture with marine cage culture of European sea bream; the first project started in 2002. This project was in the Bandar Khyran area in Musact Governorate. The first commercial production in Oman was in 2003 which reached 253 tonne. This production was from the marine cage project. The majority of this production was European sea bream. Figure 1 shows the aquaculture production since 2003 until 2013. The highest production was in 2004 which was 516. From 2007, all the production consists of shrimp produced from shrimp farms in the Mahout region in the middle of Oman. Freshwater integrated aquaculture in Oman is very limited currently, but it represents good opportunities for development. In 2013, the production of tilapia was 3 tonne only which increased to reach 20 tonne by the year 2015.

The Ministry of Agriculture & Fisheries realizes the importance of sustainable development of aquaculture and to put a clear plan to achieve this sustainability. Therefore, and in coordination with FAO, it prepared the master plan for aquaculture development in 2007 which was considered as the main turning point in the aquaculture development process in Oman. Based on this plan, the Ministry of Agriculture & Fisheries takes several initiatives which include but is not limited to the following:

1. Atlas for suitable sites for aquaculture;
2. Establishment of aquaculture committee;
3. Establishment of aquaculture centre for researches and directorate of aquaculture development for investment opportunities and monitoring;
4. Issuing aquaculture by-laws; and
5. Preparation of investment guidelines.

In 2011, the Ministry of Agriculture & Fisheries (MAF) developed the strategy for aquaculture development 2011–2030. This strategy was based on several studies conducted by the MAF in cooperation with FAO, such as an aquaculture master plan conducted in 2007 (FAO, 2007), food safety and environment in aquaculture (FAO, 2008) and consultation with different experts. The main objectives of this strategy include:

1. Developing aquaculture in a sustainable manner using modern technology such as GIS and ecosystem based management;
2. Developing the local communities and increasing their participation in the projects;
3. Encouraging the small and medium enterprise;
4. Increasing the fisheries production through the increase of aquaculture production. Annual growth 20 percent;
5. Attracting and encouraging the foreign investment through incentives.

Through the implementation of this strategy, the Ministry of Agriculture & Fisheries expects to achieve the following:

1. Increase the aquaculture production to reach 20,000 by year 2040;
2. Increase the contribution of aquaculture to GDP and diversification of the economy;
3. Provide job opportunities for Omanis;
4. Enhance the supporting sector such as feed mills, processing, etc.; and
5. Preparation of BAP booklets.

2. AQUACULTURE ZONING

According to aquaculture by-laws, a site should not be installed near any sensitive environmental areas or in sites that contradict with fishermen activities or a navigational route in the sea (MAF, 2012). However, there is no detailed specification in the by-laws regarding the site selection, size or criteria of the site required for each type of aquaculture. The land will be rented for the company and renewed annually.

2.1 Site Selection Project

Determination of suitable sites for aquaculture is very important for the success of the commercial aquaculture projects. This selection is based on many criteria and factors that should be considered before selecting the site. Therefore, the Ministry of Agriculture & Fisheries conducted a detailed survey of the Omani coast at the beginning of the last decade (Al-Yahyai *et al.*, 2004). This survey was concentrated mainly on the land to select the suitable sites for land aquaculture. Oman is located in the southeast corner of the Arabian Peninsula. It has more than 3165 km of coast from Musandam in the north to Salalah in the south which faces three seas: Arabian Gulf, Gulf of Oman and Arabian Sea (Figure 2). Oman has 11 Governorates with 8 coastal ones. These coastal regions include Musandam, North and South Al-Batinah, Muscat, South Al-Sharqiuah, Al-Wusta and Dhofar. Each of these regions has its special morphological characteristics.

The total area of Oman is about 309,500 km^2 that contains the mainland and some islands such as Masirah and Al-Halaniyat islands. Oman has about 11 topographical areas such as (Anonymous, 1990):

1. Mountain.
2. Mountain and plateaus affected by monsoons.
3. Dissected rocky plateau.
4. Accumulation plain.
5. Accumulation/denudation plains.
6. Coastal alluvial plain.
7. Sabkha and dunes.
8. Nearly level pediplains.
9. Gently undulating pediplain.
10. Umm As-Samim sabkha.
11. Sand dune areas.

There are two coastal alluvial plains in Oman, one in the Al-Batinah region and the other in Salalah. These plains were formed from the deposition of wadis, mainly fine sand and granules. Sabkha areas appear dominantly in the Al-Wusta region and Eastern coastal plain in the Sharquiah region.

Each coastal governorate was visited twice to collect the necessary information. This information included location, water quality, soil type, topography, accessibility, soil and infrastructure, etc. Maps, description and photographs for each area were produced. On the basis of this information, site identification and evaluation were made. In addition to the field data, available information from different governmental authorities was also collected.

Each region in Oman has its special features that allow some types of aquaculture and not the others. Musandam Governorate in the North of Oman is more suitable for cage culture projects or other marine aquaculture projects such as shellfish or seaweed

FIGURE 2. General map of Oman.

FIGURE 3. One of the protected lagoons (fjord-like) in Musandam suitable for marine cage aquaculture.

culture (Figure 3). This is due to the availability of the deeper khawrs (fjord-like). On the other hand, this area is not suitable for land-based aquaculture due to the lack of the suitable large site along the coast. Al-Batinah Governorate is a heavily dense population area along the coast. For this reason and also due to the major infrastructure projects along this coast such as water desalination plants, harbors and the major coastal road, there are no available sites for land aquaculture. For marine projects, there are possibilities for cage culture, but they should be located more inside the sea due to the low depth of the coastal area which extends for a big distance inside the sea, and also for the major fishermen activities. This area is more suitable also for integrated tilapia aquaculture as it is one of the best agriculture lands in Oman.

Muscat Governorate is the capital of the country in which most of the development is concentrated. Therefore, availability of the free land for land aquaculture is very low or absent compared to other regions. There are few places suitable for cage culture in Muscat and one site was already utilized before for European sea bream cage culture. Al-Sharqiuah and Al-Wusta Governorates which face the Arabian Sea are among the best places for land aquaculture in Oman, especially for shrimp culture. These two regions include many large sites with suitable soil types that are not suitable for any other commercial projects (Figure 4). Cage culture may not be suitable due to the very rough sea during the summer. In the south of Oman (Dhofar region), there are many suitable sites for abalone indoor culture. Cage culture in this region is difficult due to the monsoon effects and very high seas during the summer.

Marine sites in other regions rather than Musandam were not included in this survey as time and resources were limited.

2.2 Atlas for Suitable Site for Aquaculture and Zoning Process

This atlas is considered as a most comprehensive publication for suitable sites in Oman for aquaculture (MAF, 2010). Preparation of this atlas was based on the result of a previous survey and also more studies from the consultant company which prepared the atlas. The consultant company used satellite images, physical data and environmental data (soil and water parameters) for preparations of this atlas. The atlas contains general oceanographic and environmental descriptions about the coast of Oman. It also contains

FIGURE 4. Large subkha area suitable for shrimp aquaculture.

general information about the suitable methods for aquaculture and major constraints. The main part of the atlas discusses the physical and environmental characteristics of different regions in Oman. The atlas divides the coast into 7 regions, region I: Rakhyut to Sawqrah; region II: Sawqrah to Madrakah; region III: Gulf of Masirah; region IV: Masirah to Ras Al Hadd; region V: Ras Al Hadd to Muscat; region VI: Muscat to Shinas and region VII: Musandam.

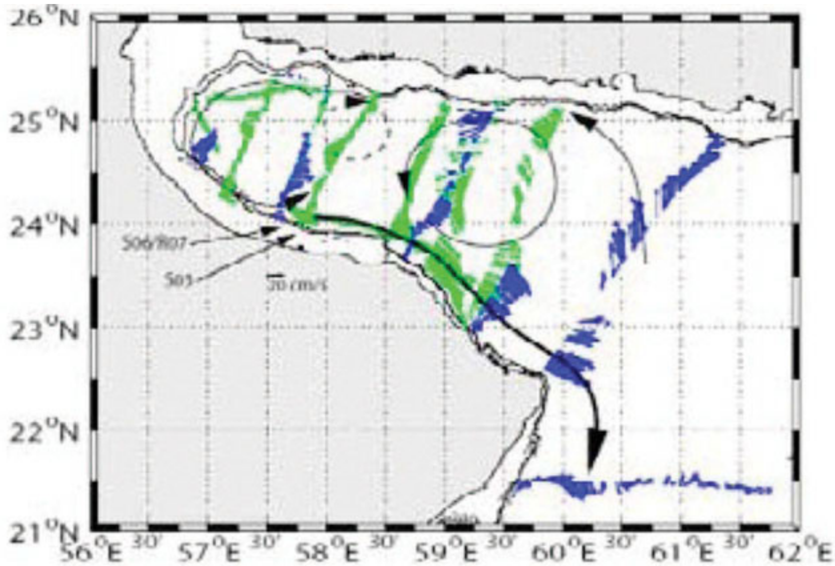
For each region, there is a detailed description about oceanographic characteristics such as weather, wind conditions, bathymetry, regional circulation of currents (Figure 5), tides, sea surface temperature, phytoplankton, sea surface salinity, and waves. It also includes descriptions about environment of the region and environmental constraints that may affect the aquaculture projects such as seagrass and algae, mangrove, marine turtle, coastal birds, and coastal protected areas. Samples of seawater were also taken from determined sites in each region and a description of the results was included in the atlas. Soil samples were also taken from some of the sites and analysis was presented with advice for suitability for shrimp pond culture or not. General information about ports available in the regions was also presented with the facilities available in these ports that can be used for aquaculture. In each region, there is also a description about the aquaculture potential and the suitable type of aquaculture that can be conducted in the region. Finally, there is also a cartographic illustration for each region.

Despite the wide information about the whole coast of Oman and suitability of each region for different types of aquaculture, there is no detailed information about suitable sites for aquaculture such as size, cultured species and carrying capacity for the site for both land and sea areas. In general, this atlas is a good initial step in aquaculture zoning in Oman and it can be the base for more detailed study about each region.

2.3 Site Allocation Process for Aquaculture

As a result of the survey and the atlas study, suitable sites for aquaculture were determined by the Ministry of Agriculture & Fisheries and sent to the Ministry of Housing to allocate the sites for aquaculture. Ministry of Housing is the competent authority in Oman for sites allocations for all purposes. The information about the sites including name, coordinates and size required is sent to the Ministry of Housing which reviews the information, and if the site is not allocated

FIGURE 5. General circulation in the Sea of Oman (MAF, 2010).



for any other purpose, the subject will be forwarded to the local administration branch of the Ministry of Housing where the site is located. The reason behind this is to review the issue with the local people to eliminate any contradictions in the interests of local people. After that, the approval is given for the site. Then, the issue is sent to the Ministry of Environment & Climate affairs for the environmental approval for the site. This is to assure that the site is not in any natural protected areas or there are no natural sensitive areas such as coral reefs, seagrass, mangrove, etc. If the environmental approval is given, the site is allocated for the Ministry of Agriculture & Fisheries for aquaculture purposes. For sea sites, the same process is also applied. The Ministry of Transport & Communication is also involved in sea sites as it is responsible for navigation routes. Local people are consulted for the sea sites through a local committee which includes representatives of fishermen. This committee ensures that the cage structures or any other types of marine aquaculture don't affect their fishing activities.

The site will be opened for investors through a public advertisement. All the applications are evaluated technically and financially by an aquaculture technical committee. The recommendations of this committee are raised to the main aquaculture committee for a final decision.

2.4 Selecting Suitable Site for Marine Cage Aquaculture in Musandam Governorate–GIS-Based Approach

The importance of GIS in aquaculture is increasing and it is used widely in several countries in the process of aquaculture management and development (Aguilar-Manjarrez *et al.*, 2010). Spatial planning is an important element in the process of applying ecosystem based management in aquaculture. In Oman, most of the use of remote sensing and mapping was in fisheries. These tools have been used to monitor the movement of commercial fishing vessels as these vessels have predefined areas in which to catch. A survey for fish stocks assessment in the Arabian sea coasts of Oman used also these tools to provide spatial information that can be used in the management of the important commercial marine species in these areas. In aquaculture, the previously mentioned book *"Atlas of Suitable Sites for Aquaculture Projects in the Sultanate of Oman"* used maps and spatial data for mapping of aquaculture sites and to select of suitable site for aquaculture.

Using GIS models is being recognized as a tool for aquaculture, but this use was faced by many obstacles such as lack of appreciation of the benefits of GIS, inadequate administrative support, limited understanding of GIS principles and associated methodologies

(Nath *et al.*, 2000). Realizing the importance of GIS and spatial tools in aquaculture management, the Aquaculture Development Directorate initiated in September 2014 a project entitled "Sustainable Development of Fisheries & Aquaculture in Musandam Governorate—A GIS-Based Approached" with the financial support from Agriculture & Fisheries Development Fund (AFDF). The main aim of this project which will be for 2.5 years was to evaluate all the factors that affected the selection of suitable sites for aquaculture and also to determine the carrying capacity of each site using GIS tools. The study area which is located at the North of Oman is considered as the main area in Oman for cage culture due to the availability of large deep protected lagoons (fjord-like). This project will also take into consideration some fisheries aspects such as fish landing places and fisheries activities in the study area. The objectives of this project include:

1. Identify suitable generic areas for aquaculture development in Musandam Governorate.
2. Identify and assess the key biophysical and socio-economical industry related factors affecting the development of commercial aquaculture in the Governorate.
3. Identify suitable species for culture according to local conditions and requirements.
4. Define carrying capacities of khawrs (fjords) according to local conditions.
5. Determine efficient strategies through resource assessment and management for suitable site selection decision making.
6. Identify all fishing landing sites and beach purse seining sites in addition to the sites of supporting activities such as fish drying and fish processing plants using GIS models.
7. Build up a model for sustainable aquaculture development applicable to other regions of the Sultanate of Oman.

In general, we expect a better understanding of the dynamic of marine environment in the study area and information that helps decision makers to better determine and allocate sites for aquaculture, taking into consideration all the environmental, socioeconomical and biological factors. The main expected outcomes from this project are:

- To advance the knowledge and understanding of key biophysical and socioeconomic factors affecting the development of the aquaculture industry.
- To define effective strategies through resource assessment and management for efficient decision making on suitable site selection for development.
- To identify suitable species and technologies for culture according to the conditions defined.
- To develop an integrative methodology for site selection of aquaculture opportunities within the Musandam Governorate that combines spatial factors and criteria (water quality, currents, depth, sediment quality and ecological quality) to identify suitable areas using GIS tools, and explores production, socioeconomic outputs and environmental impacts by applying farm-scale carrying capacity modelling specie-specific.
- To define the suitable fish landing sites and beach purse seining places.
- To make management recommendations, in order to exemplify the use of this approach to assist the decision making process and reduce socioeconomic and environmental problems associated with aquaculture expansion.

This study includes three stages of works. The first stage is for a literature review which includes collecting all the available information about the study area and also about using GIS in aquaculture and spatial planning. In this stage also, biophysical and socioeconomic criteria to be considered in the model will be also determined. The second stage, which is the important stage in this project, will be for primary data gathering on required criteria and also for generation of basic mapping. It will be for two years. The mapping will include:

- Biophysical parameters of the Governorate and subregions.
- Active agro-industry operations and infrastructure available of the region.

- Land ownership, usage and future planning of the region.
- Local, Governorate and export markets for seafood products.
- Suitable areas for aquaculture development.

This stage will also include:

- Verification (ground-truthing) of data sources by field sampling prior to the modelling stage.
- Quality control and testing of inferred or modelled data sets.
- Development of integrative methodologies and models for site selection for aquaculture development within the Musandam Governorate and subregions that combines spatial factors and criteria established (carrying capacity).
- Assessment of the general applicability of the final models.

Satellite imagery, digital maps of the study area and aerial photos will be collected and used in the GIS models. The third stage will be for finalizing the reports and recommendations and setting the strategies and options for aquaculture development in Musandam Goveronrate.

Supreme Council for Planning, which is the highest authority in Oman for land planning, conducted a project to develop Comprehensive Economic Development Strategy & Spatial Master Plan for Musandam Governorate. This is the same area for the previous project. This broader project encompasses all activities, not only fisheries, and its aim was to put the master plan for development of Musandam Governorate for the next 25 years (2040). The final results and reports are not yet finalized as these results will be discussed among different authorities and stakeholders. GIS tools were used in this project for availability of land that can be used for urban functions. In this project, maps that illustrate all possible uses for different areas in the Governorate were developed including uses for fisheries purposes. Specific areas for aquaculture purposes were also defined in different parts of the region. This determination was general determination of an area with no specific site size or carrying capacity of this site.

3. INSTITUTIONAL AND REGULATORY FRAMEWORKS

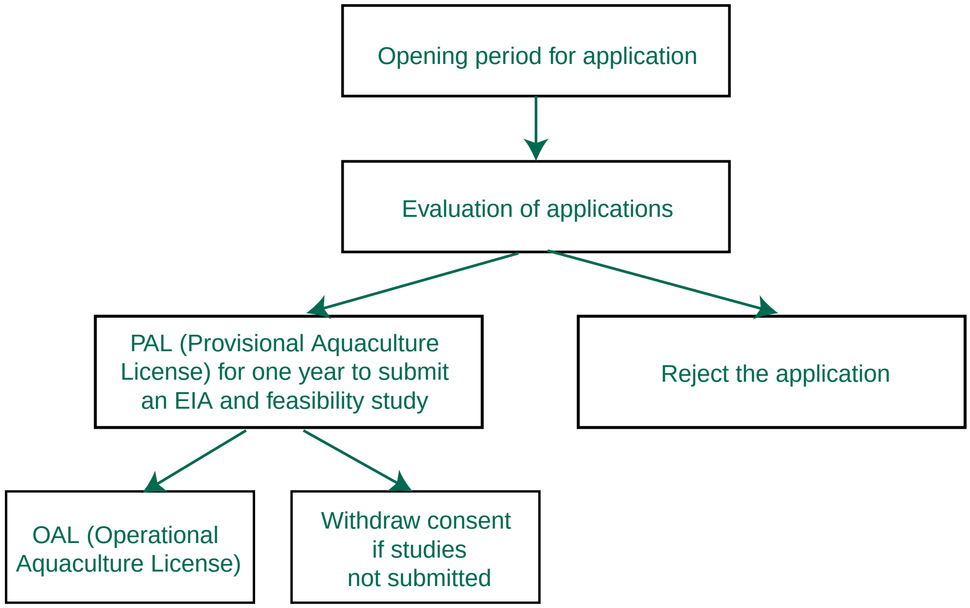
3.1 Institutional Framework

Availability of one governmental organization responsible for management and development of aquaculture is one of the important keys in the successfulness of the aquaculture sector. In Oman, the Ministry of Agriculture & Fisheries is the main governmental authority responsible for aquaculture development. The Directorate of Aquaculture Development in the Ministry is the main department responsible for aquaculture development and management. This Directorate is also responsible for authorization, licensing and monitoring of aquaculture projects. The aquaculture centre conducts scientific and experimental researches and disease control of aquaculture projects. The Fish Quality Control Centre is responsible for issuing quality permits for aquaculture products and residue planning. The Directorate of Aquaculture Development coordinates the works regarding the aquaculture between the different departments.

Aquaculture License Procedures

All the applications for aquaculture projects are submitted to the Directorate of Aquaculture Development which compiles all the necessary documents for the application. The applications are evaluated by the technical committee which is headed by the Director General of Fisheries Development and contains members from the Directorate of Aquaculture Development, Aquaculture Center, Water Resources Management Centre and Legal Department. The recommendations from the technical committee will be raised to the main aquaculture committee for final approval. This committee is headed by the Minister of Agriculture & Fisheries. It contains members from different ministries at the levels of Undersecretaries

FIGURE 6. Application process for aquaculture projects in Oman.



and Director Generals. These ministries are Ministry of Agriculture & Fisheries, Ministry of Environment & Climate Affairs, Ministry of Trade & Commerce, Ministry of Transport & Telecommunication, Ministry of Housing, and Ministry of Finance.

If the company gets the approval from the Committee, it will be given a Provisional Aquaculture License (PAL) for one year to complete the feasibility study and EIA study. These studies are reviewed by the Ministry of Agriculture & Fisheries with EIA and are also reviewed by the Ministry of Environment & Climate Affairs for environmental approval. If the studies are approved, the company will sign a contract with the Ministry of Housing for usufruct right of the land. After that, the company will be given an Operational Aquaculture License (OAL) from the Ministry of Agriculture & Fisheries. The contract is for 20 years with annual renewal. Figure 6 illustrates the procedures and routes of the applications for aquaculture projects.

3.2 Legal Framework

In Oman, there is a special regulation for aquaculture which is the by-law of aquaculture and quality control of its product (MAF, 2012). This by-law was first issued in 2004 and amended in 2012. It contains about 80 articles in different aspects such as licensing and its requirements, quarantine procedures and quality issues. According to this regulation, a company can't start any aquaculture project without permission from the competent authority (Ministry of Agriculture & Fisheries). The regulation also states the requirements for quarantine and prevents the culture of exotic species without permission from a competent authority. The rules state the works of the aquaculture committee and the flow of the applications from the private sector. For licensing issue, the laws describe the requirements for the license and the information needed by the Ministry to process this license, such as regular information about the company, site for the project, and species to be cultured. Table 1 shows some of the main laws and regulations that control aquaculture activities in Oman.

TABLE 1. Main laws and legislations related to Aquaculture in Oman.

Law	Purpose
Law of Sea Fishing and the Protection of Marine Biological Wealth issued in 1982 and amended in 1993	All fisheries activities in Oman including aquaculture are regulated by this law
Law for the conservation of the environment and prevention of pollution (RD 114/2001 superseding RD 10/82)	This law is the main frame for the environment protection in Oman and it controls all the activities that affect the environment
Regulation	
By-law of aquaculture and related Quality Control Regulations. (MD 177/ 2012)	Regulate the aquaculture activities and operations
By-law of discharging liquid waste in the marine environment (MD 159/2005)	Controls the discharge of any liquid substances in marine environment. It applies also to aquaculture currently
By-law for organizing the Issuance of Environmental Approvals and the Final Environmental Permit (MD 68/2004)	Regulates and controls the process of issuance of environmental approval and EIA process. It applies also to aquaculture currently

4. ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

Protecting the environment is one of the main priorities in Oman. Therefore, the Ministry of Environment & Climate Affairs was established as the main governmental authority responsible for the protection of the environment in Oman. There are many laws for environment protections in Oman of which the law on Conservation of Environment and Prevention of Pollution is the main one. This law was issued in 1982 and amended in 2001 (MECA, 2001a). According to this law, no establishment of any source or area of work shall be started before obtaining an environmental permit confirming its environmental soundness. This also includes the aquaculture projects.

There are many executive by-laws from the main environmental law. One of them is specialized for organizing the Issuance of Environmental Approvals and the Final Environmental Permit (MECA, 2001b). This regulation covers all the industrial projects including the aquaculture projects. It detailed the necessary requirements and the approval system for an Environmental Impact Study (EIA). According to these regulations, the industrial establishments have been classified into three categories according to the materials used in production, production capacity and the degree of their impact on the adjacent environment. Each category has its own environmental conditions according to the level of environmental impact arising from its construction and operation. Aquaculture projects are classified in the third category, which requires more detailed study of EIA.

The owner of the any establishment (including an aquaculture establishment) shall apply to the Ministry of Environment & Climate Affairs (MECA) for Environmental approval. An Environmental Impact Assessment (EIA) study should be submitted with the application and the ministry official shall inspect the proposed site to determine the environmental conditions that must be fulfilled. The preliminary approval is given to the establishment to commence the construction process. The approval shall include specifications about environmental conditions to be fulfilled prior to starting operations and shall be valid for one year, renewable for a similar period. The final environmental permit is given to the establishment after fulfillment of the conditions stated in the preliminary environmental approval and shall be valid for two years and renewable for a same period or other specified period.

A guideline for the EIA study for aquaculture projects is detailed in the investment guideline for aquaculture in Oman (MAF, 2015). The study should include a full baseline survey for the site and areas that may be impacted by the project's operation. Impacts of the projects will be detailed in the study with the corrective measures. A complete monitoring plan, which can be undertaken internally and be monitored by an external agency, should be detailed also in the study. A complete list of all chemicals, pharmaceuticals, and other substances for use on the project will be submitted with details of risks of use. The investor will also submit a risk assessment analysis for the operation of the project with a "what if" scenario developed for a worst case position.

There are fees against the issuance of the environmental approval and the final environmental permit. Depending on its nature of activities, as evaluated by the Competent Authority, the establishment shall be bound to conduct an Environmental Audit (EA) by specialized companies approved by the Sultanate according to the requirement of the ISO 14000 series for the environmental management system, every two years from the date of receiving their final environmental permits.

For aquaculture projects, there is an agreement between the Ministry of Agriculture & Fisheries and the Ministry of Environment & Climate Affairs (MECA) that the EIA study submits first to the Directorate of Aquaculture Development which will evaluate the study and after that, the applicant gives the study to MECA.

5. AQUACULTURE MONITORING

Monitoring is defined in the EU Regulation 882/2004 as conducting "*a planned sequence of observations or measurements with a view to obtaining an overview of the state of compliance* ***with feed or food law, animal health and animal welfare rules.***" Aquaculture monitoring in Oman is at the initial development stage, as only one commercial project exists in Oman. Three departments in the Ministry of Agriculture & Fisheries are responsible for aquaculture monitoring—the Directorate of Aquaculture Development, Aquaculture Centre and Fish Quality Centre. The involvement of each department depends on the type of monitoring. The Directorate of Aquaculture Development monitors the production process and environment, the Aquaculture Centre monitors the fish health and the Fish Quality Centre monitors quality of the fish during the cultivation and quality of the final product and residue plans. Therefore, efforts have been made to harmonize and coordinate the work of these departments. One team was established for monitoring which included members from the three departments with the lead of the Directorate of Aquaculture Development as the focal point for aquaculture monitoring. The team will have the competences for all the steps of an aquaculture project development:

- farm construction,
- preharvesting production process,
- best aquaculture practices,
- environmental follow-up,
- disease control,
- postharvesting production process,
- consumers health.

Guidelines for aquaculture monitoring have been prepared by the three departments. This guideline contains the detailed mechanisms for the work of a monitoring team before, during and after any inspection visit. It contains also the necessary tests required during the inspection visit. The guideline also specifies the type of monitoring, such as full inspection for renewal of the license, inspection for first approval, inspection during construction (new farm or farm modification), periodic programmed inspections and random spot checks. Different inspection forms have also been prepared in this guideline depending on the type of aquaculture facilities such as hatchery, shrimp farms, fish farms—tanks onshore, fish farms—cages offshore, abalone farms—RAS, shellfish farms, and seaweed farms. There are also forms for feed mills and fish processing plants if they exist on the farm.

6. CONCLUSION

Despite that the aquaculture industry is at an early stage in Oman, the Government takes all efforts for development and management of the sector in a sustainable manner. Among these efforts are the selection of suitable sites for aquaculture projects, as selection is one of the main criteria for the success and sustainability of any aquaculture project. Different projects were conducted for site selections but these projects were generally in terms of selection and no carrying capacity was determined or size of the site.

A recent initiative was conducted by the Ministry of Agriculture and Fisheries to use GIS tools for site selection for marine cage aquaculture, which will enhance and develop the process of selection and produce more detailed data and criteria for the site including the carrying capacity and environmental standards.

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ANNEX 1. CASE STUDY EFFECTIVENESS MATRIX

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	Scoping is done with spatial, political and social aspects.	Physical parameters for site not defined yet.	• Regulations for aquaculture and quality control of its product (MD 177/2012).	4	US$500 000 (only for one area in Oman).
1.2 Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	Land and sea rights are defined by law.	Ecosystem quality standards not defined.	• Regulations for aquaculture and quality control of its product (MD 177/2012).	3	Included in the previous cost and only for one area.
1.3 Setting the broad development objectives and identifying the main issues	Done		• Aquaculture master development plan.	5	
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.4 Zone boundary definition based on relevant criteria	Selection based on general criteria without predefined criteria.	Preselection standards not defined.	• Regulations for aquaculture and quality control of its product (MD 177/2012).		2.5 million US$. Estimation for the other 5 coastal areas in Oman.
1.5 Gross estimation of potential production/ area	In the atlas for suitable site, general production was estimated but not per site. It was per general area.	Not done specifically per each site.	• MAF, 2010. Atlas of suitable Sites for Aquaculture Projects in the Sultanate of Oman.	2	Included in the previous cost and only for one area.
1.6 Formal allocation of the zone for aquaculture purposes	Aquaculture committee take the responsibility for site allocation.	Standard criteria for selection and carrying capacity for each site not done.	• Regulations for aquaculture and quality control of its product (MD 177/2012).	3	Included in the previous cost and only for one area.

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	Determination of land based site depends on the size of the available site and many criteria. This process between Ministry of Agriculture & Fisheries and other ministries.	For sea sites no standard done or carrying capacity.	• Regulations for aquaculture and quality control of its product (MD 177/2012); • Consultation with local people.	3	
2.2 Carrying capacity estimation		Not done		0	Included in 1.4.
2.3 Set license production limits within zone or water body carrying capacity		Not done			Included in 1.4.
2.4 Allocation of licenses and permits	Done through Aquaculture Committee.		• Meetings of aquaculture committee, • Consultation with local people.	4	
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant waterbody or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries		Not done	• No aquaculture park or cluster currently in Oman.	0	
3.2 Estimate total carrying capacity if appropriate based on the different risks		Not done		0	
3.3 Organize a formal association of all farmers in that area		Not done (only one farm in Oman).		0	

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant waterbody or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.4 Setting the broad development objectives and identifying the main issues agree on common management,[1] monitoring and control measures		Not done			
3.5 Monitoring of relevant variables and enforce management measures		Not done			
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.1 Regular monitoring and evaluation	Monitoring plan done recently and start to implement, but only one farm exists.		• Regulations for aquaculture and quality control of its product (MD 177/2012).	4	
4.2 Periodic review and adjustment	To be done after implementation.				
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**	**Approximate production from each aquaculture zone or AMA**			
Number of zones and range of implementation	NA				
Other notes (especially social issues)	**Positive issues**	**Negative issues**			

1 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Mariculture Parks in the Philippines

Patrick White and Nelson A. Lopez[1]

ABSTRACT

The Government of the Philippines through the Bureau of Fisheries & Aquatic Resources has promoted the development of mariculture zones and parks as a way of responsible and sustainable development of coastal cage aquaculture to provide livelihood to local communities and contribute to food security. At the present time there are over 60 mariculture parks in operation throughout the Philippines. The concept of the Mariculture Park (MP) is patterned upon the development of an industrial estate in a selected zone designated for aquaculture within municipal waters, wherein aquaculture plots are leased to small to medium sized aquaculture farms, and infrastructure (mooring systems, navigation lanes and docking areas), utilities (support facilities) and technical services are provided by the government. The development process for setting up and operating a mariculture park follows a well-defined set of steps. The main features of the mariculture park development include: (i) Shared infrastructure—multiproduct onshore warehouse, cold storage and ice plants facility, service as well as ferry boats, communal mooring system; (ii) Shared services—availability of seeds and feeds supplier, cage fabricator and manpower services; (iii) Shared security—internal and external security; and (iv) Sustainability—well-selected sites for small, medium and large scale investor. Controlled maximum production. Environmental monitoring.

1. INTRODUCTION

The Mariculture Park (MP) in the Philippines is an integrated business approach in aquaculture which has been adopted as an integral program of the Comprehensive National Fisheries Industry Development Plan (CNFIDP) and promoted by the Bureau of Fisheries and Aquatic Resources (BFAR) in partnership with the private and public sectors. The major goals are to ensure food security and create livelihood opportunities for coastal communities. The concept of the mariculture park is patterned upon the development of an industrial estate in the sea, wherein aquaculture plots are leased to investors/aquaculture farmers and infrastructure (mooring systems, navigation lanes and docking areas), utilities (support facilities) and technical services are provided by the government.

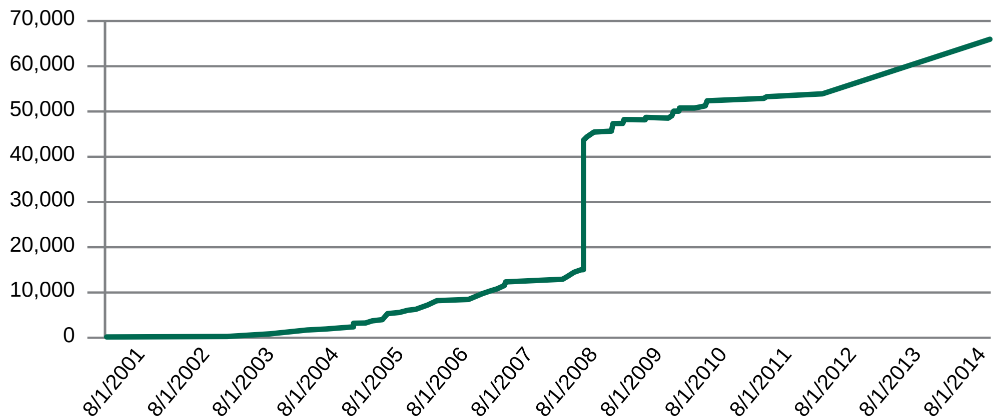
The idea of the mariculture park evolved as a solution to address some of the pressing problems besetting the aquaculture industry in the Philippines, such as fish kills caused by environmental degradation in densely farmed areas, unregulated utilization of the coastal waters for aquaculture, low productivity, inaccessibility to suppliers and markets, slow adoption of technologies and limited capital for investments.

Mariculture park development follows an ecosystem-based management approach and is also a valuable

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

White, P. & Lopez, N. A. 2017. Mariculture Parks in the Philippines. In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document*, pp. 287–313. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

FIGURE 1. Mariculture park development in cumulative number of hectares.

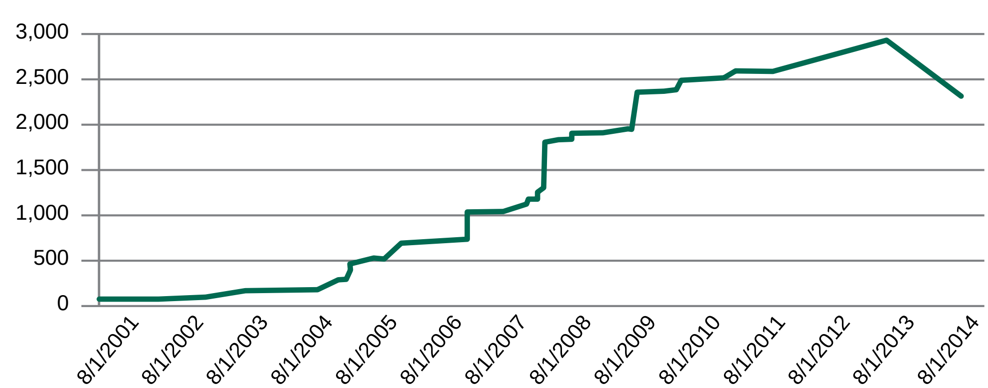


tool for coastal resources management. In the mariculture park, the government manages the activities sustainably by regulating the number and sizes of cages and other structures. The management of mariculture parks takes into consideration the ecological, social, economic and institutional aspects of development. Like any development strategy that involves utilization of natural resources, mariculture has both positive and negative impacts. The development of mariculture, as experienced in commercial scale MPs, has evidently brought about economic benefits such as increased production, job opportunities and to a certain extent reduced illegal fishing activities.

Over a decade, ever since the mariculture parks and zones program was implemented by BFAR, there were observed less reported fish kills and disease occurrence virtually in almost all areas established. This compares to the early stage before the implementation of mariculture parks and zones along municipal waters, where records of mass mortalities due to fish kills were prevailing almost annually resulting in big losses in the sea farming industry, particularly on the milkfish cage operations in the Province of Pangasinan known as an established milkfish producing province in the country. Hence, with the proper planning of establishing mariculture parks, the perennial incidence was abated.

The first mariculture park was established at the Island Garden City of Samal, Davao in 2001. From 2003 onwards, BFAR expanded the program in other regions of the country which have replicated the project. In July 2012, there were 66 mariculture parks nationwide at different stages of development and 5 MPs to be rehabilitated. As of June 2014 there were 67 MPs established throughout the country with 3 more sites scheduled for launching in Mindanao. The total area covered by mariculture parks was 53,469.33 ha. The 67 mariculture parks have approximately 73 percent of the fish cages, growing milkfish, while the remaining 27 percent are growing groupers, siganids (rabbitfish) and seaweeds. An average mariculture park covers

FIGURE 2. Mariculture park development in cumulative number of cages.



810 hectares (range 60–27,000 ha) and has 45 cages (range 1–500). Figures 1 and 2 illustrate the cumulative number of hectares and cages for the period 2001–2014. In 2013, however, there was a noted decreased in the farming operations, particularly in the East Visayan region of Leyte and Samar provinces as more than a thousand cages were wiped out by Typhoon Haian. Rehabilitation of the zoned areas and reinstallations of cages are currently ongoing to date.

These mariculture parks are strategically located in various points along the East Seaboard and West Seaboard and are designed to connect the Philippine Mariculture Industry to the international market through a live fish trade network.

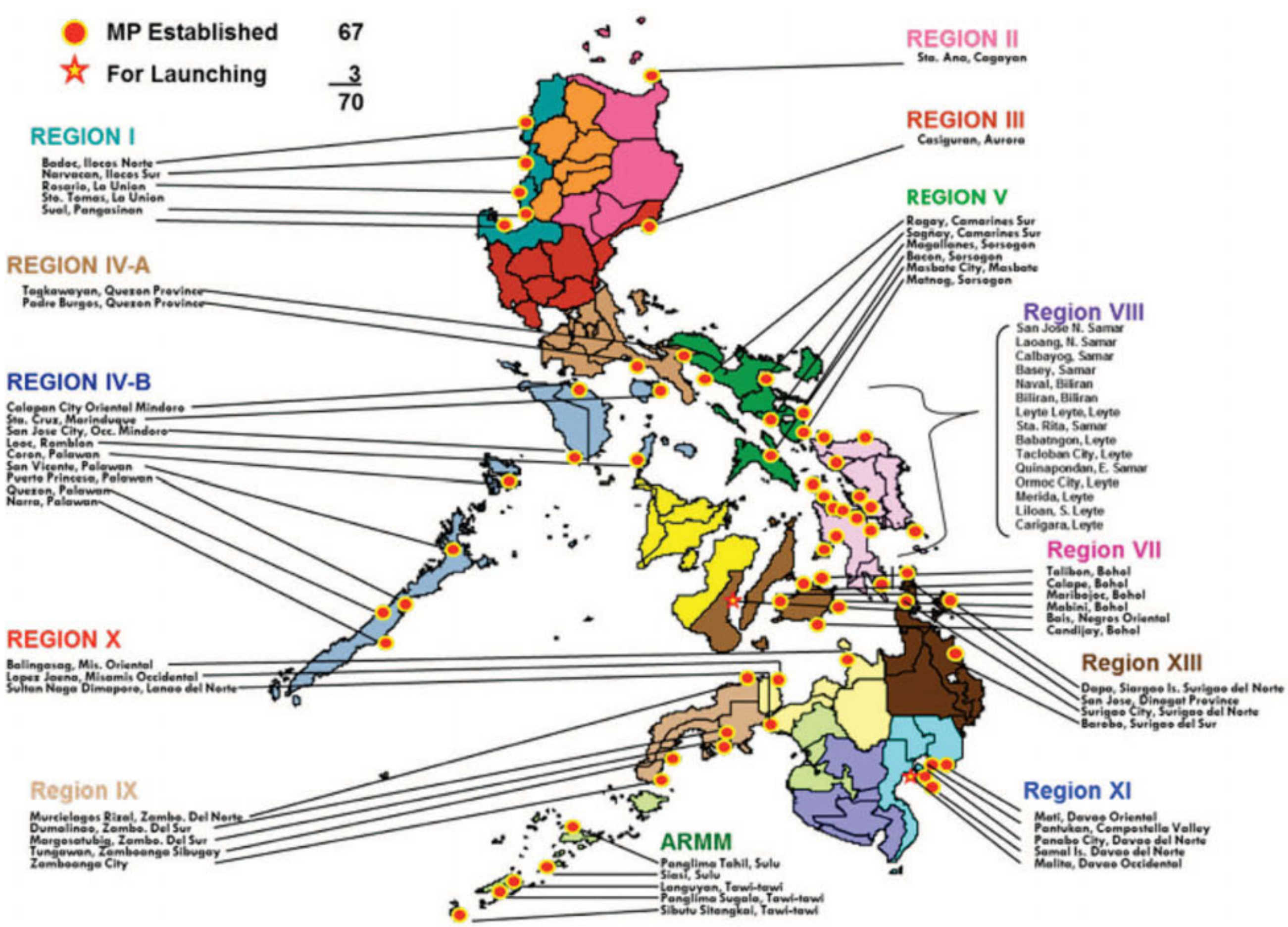
A summary of the mariculture parks operational status is given below:

- 67 Established mariculture parks
- 66 MPs/mariculture Zones Assessed
- 1 MP/Mariculture Zone for Assessment
- MPs for Intensive Promotion and Development
  - Priority for 2013–2014
    - **a.** Balingasag Mariculture Park—Misamis Oriental
    - **b.** Panabo Mariculture Park—Davao del Norte
    - **c.** Pantukan Mariculture Park—Compostella Valley
  - Other Potential Areas
    - **d.** Padre Burgos MP—Quezon
    - **e.** San Jose MP—Northern Samar
    - **f.** Surigao City MP—Surigao del Norte
    - **g.** Lopez Jaena MP—Misamis Occidental

The objectives of the Mariculture Park Development Program in the Philippines include:

- Employment generation and poverty alleviation in the countryside
- Promotion of marine fish culture as an alternative source of livelihood for marginalized and sustenance fishers

FIGURE 3. Location of mariculture parks in the Philippines (as of June 2014).



- Development of an area with appropriate equipment and infrastructure that will allow fishers, fish farmers and investors to operate cost-effectively and securely
- Development of skilled and technically capable fishers to support the mariculture industry
- Promotion of the use of environmentally friendly inputs and farm management practices
- Promotion of Good Aquaculture Practices (GAqP) to address environmental resilience and protection of sensitive habitats.

The main features of a mariculture park are as follows:

- Multiproduct onshore warehouse, cold storage and ice plants facility, service as well as ferry boats
- Sufficient navigational lanes and communal mooring system
- Internal and external security
- Well-defined sites for investment category for small, medium and large scale investor
- Ready available mooring support services for small-scale operators
- Availability of seeds and feeds supplier, cage fabricator and manpower services.

The advantages of being a producer in a mariculture park include:

- Minimal rental cost of a site
- Protection and security provided by Local Government Unit (LGU), BFAR and military assistance from Philippines National Police (PNP)
- Technical assistance from BFAR and LGU
- Financial assistance from private and government lending institutions, rural and commercial banks
- Marketing assistance from BFAR, LGU and private marketing experts
- Availability of feeds, fingerlings, fish cages, manpower pool and other ancillary services.

The legal basis for the establishment of the mariculture park are:

- City/Municipal Ordinance
- Memorandum of Agreement LGU-BFAR
- Section 22 of Republic Act 8550 (R.A. 8550)
- National Rules and Regulations
- Local Lease Agreements
- Environmental Compliance Certificate (ECC).

The development process for setting up a mariculture park occurs in the following sequence:

- Site selection and prioritization
- Pre-assessment of site suitability
- Public hearing/consultations
- Municipal resolution
- Municipal ordinance
- Development plan
- Environmental Impact Assessment (EIA)
- Organization of Executive Management Council (EMC)
- Detailed survey/Environmental Compliance Certificate (ECC)
- Subdivision plan
- Installation layout (mooring/cages)
- Training
- Lease/permit issuance
- Operation and management
- Regular monitoring (physico-chemical).

2. ZONING PROCESS

The development of the mariculture park concept in the Philippines started with the creation of the BFAR National Mariculture Parks Development and Management Committee to provide leadership and direction in the implementation. The committee was composed of BFAR National and Regional Staff. The committee was under the Office of the Assistant Director for Technical Services with its technical staff providing for the Secretariat.

The committee was composed of two committee core groups, based at the BFAR central office that provided technical expertise, assistance and coordinating functions to BFAR Regional Offices focal persons/regional management committees and Executive Management Councils (EMC).

The Environmental and Scientific Studies Core Group functions were:

- Update mariculture parks environmental profiles
- Conduct technical surveys for the establishment of new mariculture parks
- Conduct environmental monitoring in compliance with ECC and other established protocols
- Conduct carrying capacity studies for MPs

- Conduct socioeconomic impact evaluation of MPs
- Conduct training on environmental monitoring for regional staff and LGUs
- Conduct environmental R & D related programs and projects.

The Development, Management and Technological Services Core Group functions were:

- Updating management strategies of mariculture parks
- Strengthening of mariculture parks governance
- Manpower Pool Development
- Development of appropriate technologies (seed production, grow-out and post-harvest) in cooperation with other government institutions, state universities and colleges, nongovernment organizations and the private sector through demonstrations projects/pilot projects/production trials
- Development of business models (seed production, grow-out and post-harvest)
- Coordination, facilitation and assistance on credit and marketing
- Facilitation for the support services of ancillary industries
- Mariculture Parks Enterprise Development
- Conduction of capability building projects
- Locators and fisherfolks organizing
- Information and Education Campaign (IEC).

Operational funds were sourced out from BFAR funds appropriated for mariculture parks development and management programs. Specific operational funds downloaded to regional offices for specific activities were disbursed in accordance with existing accounting and auditing rules and regulations.

The establishment of a mariculture park is based on environmental, socioeconomic and governance (e.g., legal) considerations, therefore following an Ecosystem Approach to Aquaculture (EAA).[2] The development of mariculture parks is consistent with the national fisheries policies of the Philippines, i.e., Fisheries Code of 1998 and other relevant promulgations such as the Agriculture and Fisheries Modernization Act of 1997 and the Local Government Code of 1991.

2 EAA guidelines reference.

The following criteria are considered in the selection of mariculture parks:

- Accessibility
- Peace and order
- Availability of inputs
- Availability of technical guidance and assistance
- Availability of other ancillary industries
- Availability of transport and roads
- Availability of ice plant and cold storage
- Proximity to markets.

Prospective mariculture areas are first subjected to a baseline environmental assessment which includes study of the area's current patterns and physical configuration, the chemical characteristics of the water column and a socioeconomic study.

Travaglia *et al.* (2004) demonstrated the use of satellite imaging radar for mapping existing coastal aquaculture and fisheries structures in the Lingayen Gulf. This method, as well as the interpretation of satellite images, can be used to identify existing activities in the proposed area.

A rapid assessment of the existing habitats is also included in the study to map out location of critical habitats and so that appropriate buffer zones are provided for protection for these valuable habitats. The baseline data generated from the study becomes the basis for zoning and development planning to ensure sustainable mariculture activities. Only recently has GIS been used by BFAR to support the zone selection process with the use of a particle tracking model (TROPOMOD) and on the bases of the existing Department of Environment and Natural Resources (DENR) Environmental Impact Assessment-Environmental Compliance Certificate (EIA-ECC) requirements.

Once the proposed area is found suitable for mariculture, it is recommended that a Municipal Ordinance be enacted by the proponent Sangguniang Bayan/Panglungsod (Municipal/City Council) to declare the area as a mariculture park. Should the LGU and BFAR agree on the establishment of the project, a Memorandum of Agreement is forged between the LGU and the BFAR to develop and co-manage the mariculture park.

This process follows a number of well-defined steps:

1. **Rapid Area Assessment.** The process for preparation and undertaking of the Rapid Area Assessment is as follows:
    - Organize Rapid Area Assessment Team
    - Preparation of maps for mariculture development
    - Tentative demarcation of proposed area
    - Preparation of location profile
    - Retrieval of secondary data (such existing maps of mangrove, seagrass areas, etc.)
    - Habitat assessment such as mangroves, coral reef and sea grasses reports
    - Water quality assessments reports (temperature, pH, salinity, DO, turbidity, transparency, coliform levels, nitrogen, nitrites, phosphorous, phosphates, total suspended solid, heavy metals, etc.)
    - Previous socioeconomic studies and community consultation activities in the area.

2. **Area Assessment.** If the zone is found to be potentially suitable then a more detailed area assessment is undertaken. This comprises of:
    - Consultation with stakeholders; i.e., information and educational campaign to fishers, LGUs, NGOs, academes and local fisheries institutions on the formation of cooperatives/association, LGUs on governance and resource management and project operations
    - Conduction of environmental habitat and water quality assessment
    - Participatory resource assessment whereby stakeholders are jointly encouraged to engage in the site assessment process.

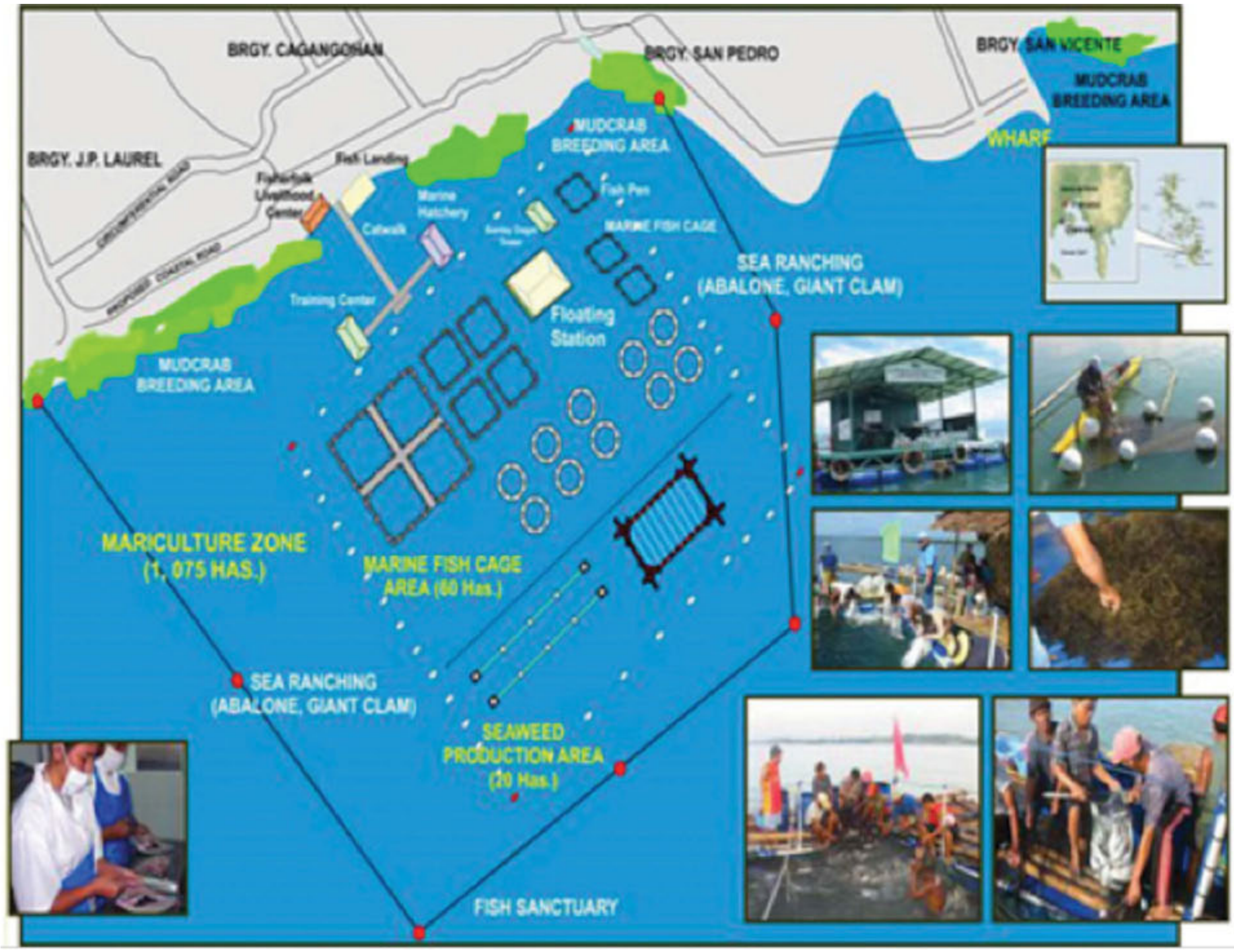
3. **Hydrographic Study.** A hydrographic investigation is undertaken starting with the orientation/briefing of LGU and Survey Team. The team then undertakes the following:
    - Conduction of Bathymetric Survey (tide levels, current patterns, depth, elevation, slope, shape, bottom topography)
    - Preparation of Bathymetric Maps of the area based on the data collected during the survey.

4. **Zonation.** The zoning of the mariculture area is defined as:
    - Preparation of Mariculture Park Spatial Development Plan (maps and work plans)
    - Establishment of navigational lanes
    - Establishment of general boundaries of the proposed area based on the rapid assessment conducted with the TROPOMOD application predicting potential impact to the environment consistent with the environmental impact assessment studies of the DENR
    - Zoning of the mariculture parks to different projects
    - Establishment of markers for farm plots
    - Conduction of Local Government Unit orientation for public awareness and as reference for legislation. This orientation covers:
        - Mariculture Parks/Zone (MP/Z) concept
        - MP/Z overview
        - Survey results
        - MP/Z development plan.

Establishment of boundaries for mariculture parks and the zonation plan is presented in Figures 4 and 5.

5. **Public Consultation.** Public consultation is undertaken in two phases, Pre-public hearings and Public hearings:
    - **Pre-public hearings.** Initially there are pre-public hearings conducted with the attendance of the Mayor, Vice Mayor, Sangguniang Panlungsod (SB) Members, Non-Governmental Organisations (NGOs), and Chairmen of Coastal Barangays. Then a second pre-public hearing is conducted with the attendance of farmers and fishers, fishpond operators, hatchery operators, and input suppliers. Topics that are presented include:
    - Overview of mariculture zone proposed development plan
    - Business livelihood
    - Opportunities to fishers
    - Fishers/farmers obligations and benefits.

FIGURE 4. Initial mariculture plan and boundaries.



Following the pre-public meeting, the municipal ordinance or resolution is drafted, which reserves the identified area for the mariculture park.

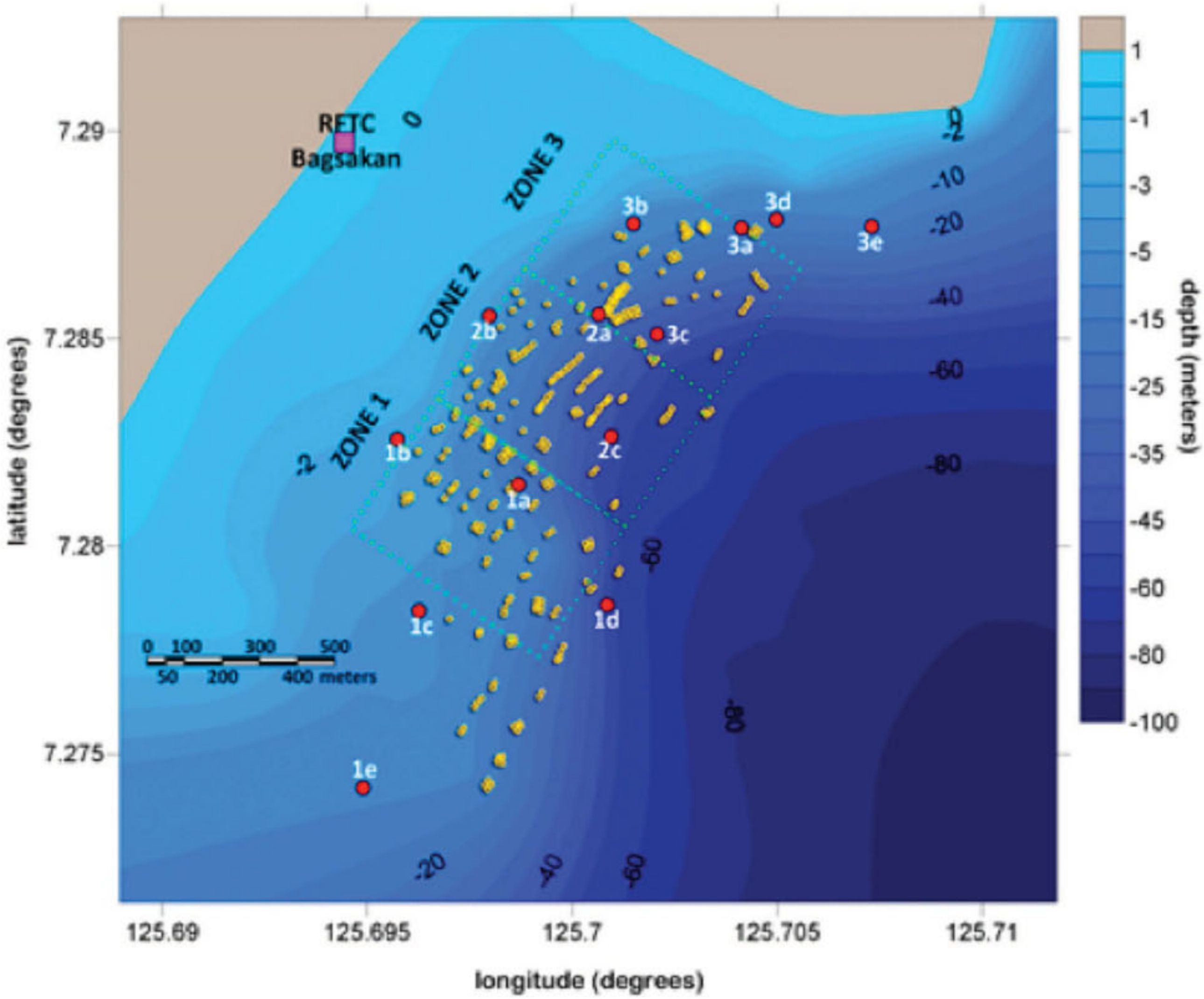
- **Full public hearing.** This is followed by consultation comprising of a full public hearing.

6. **Mariculture Park Operations Manual.** Following the public hearing the Mariculture Park Operations Manual is prepared and adopted followed by drafting and approving a resolution authorizing the mayor to sign a Memorandum of Agreement (MoA). This MOA is between BFAR and LGU and states the function and obligations of BFAR as well as the function and obligations of LGU.
7. **Environmental Compliance Certificate.** An environmental compliance certificate (ECC) secured from the Environmental Management Bureau (EMB) of the Department of Environment and Natural Resources (DENR) is likewise required before the area is developed on a commercial scale. The TROPOMOD model is a tool that can support the Environmental Impact Assessment prior to ECC issuance

The process for fulfilling the environmental requirements is as follows:

- Survey and data gathering for the preparation of the EIA
- Compliance of ECC requirements
- Filing of ECC.

FIGURE 5. Panabo Mariculture Park with depth profile and spatial distribution of fish cages.



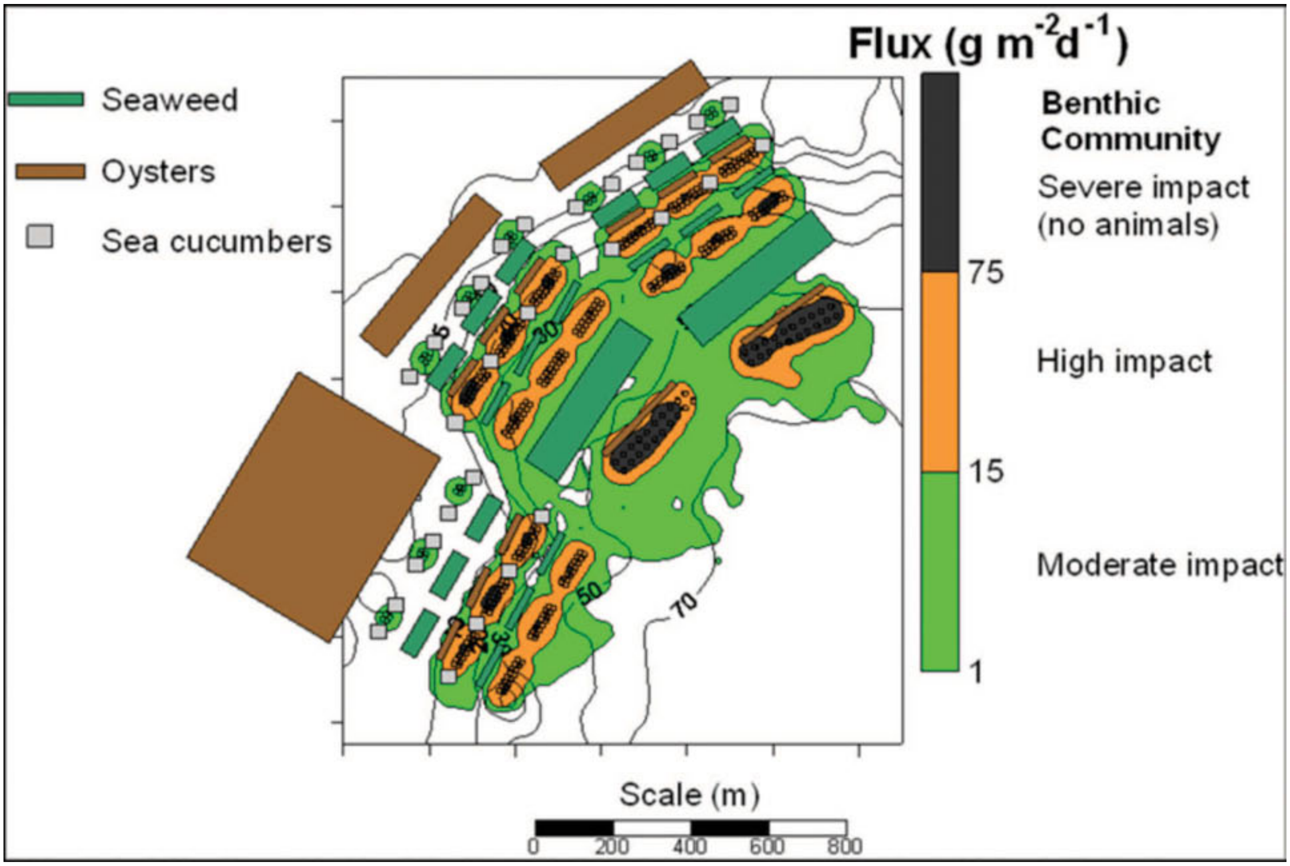
Note: Depth profiles are in shades of blue with indicated depth in meters at low tide, June 2011, and spatial distribution of 320 fish cages (yellow boxes), as of September 2010. Also indicated are 3 zones (delineated by dotted lines) used as reference divisions for the survey. Red dots indicate stations for water/substrate quality monitoring. Individual farm plot boundaries are distinguished by poles with coloured coded flags in all areas.

The conduction of an Environmental Impact Assessment (EIA) determines which area of the coastal municipality is to be declared as MP zones. White (2009) described the process for EIA and environmental monitoring of clusters of small-scale farms in Bolinao.

3. CARRYING CAPACITY ANALYSIS

Establishment of any aquaculture structures and development of any coastal areas or municipal waters in the Philippines for production purposes strictly follows the environmental regulations imposed by the Department of Environment and Natural Resources and existing rules of the Bureau of Fisheries and Aquatic Resources. Typically physicochemical parameters are also included in the carrying capacity analysis. During the Norwegian Agency for Development Cooperation (NORAD) funded project entitled "Planning and management of aquaculture parks for sustainable development of cage farms in the Philippines" (AquaPark, 2006), the project adapted the modelling environmental impact

FIGURE 6. Output from TROPOMOD for Panabo Mariculture Park.



of cages (TROPOMOD) model to assess sustainable carrying capacity for mariculture parks. TROPOMOD is a particle tracking model which simulates the dispersion of waste feed and waste faecal particles from fish cages. Using depth and current velocity data from environmental surveys and husbandry data such as cage layouts and feed ration from production surveys, TROPOMOD predicts flux of waste solids to the seabed (grams waste feed and faeces m^2 seabed per day). This waste flux is related to a level of impact on the sediment benthos.

TROPOMOD was also used to predict flux and nutrient plume from the fish culture to various Integrated Multi-Trophic Aquaculture (IMTA) units. These predictions were used to locate IMTA units in optimum locations relative to the finfish culture and some estimations of IMTA production were made.

Output from TROPOMOD modelling indicating the optimal size and position of the recommended secondary IMTA production areas for Panabo Mariculture Park together with predicted benthic impact from the cage culture are shown in Figure 6 above.

4. SITING AND LICENSING

Authorizations to engage in and set up an aquaculture facility are granted by Local Government Units (LGUs) that have jurisdiction over the location and licensing of the aquaculture operation in municipal waters defined as to include streams, lakes, inland bodies of water and tidal waters within the municipality (and which are not included within protected areas) as well as the marine waters as delineated in the Fisheries code of 1998 (basically limited to the territorial waters 15 km from its baseline).

Mariculture operations require a lease approved by the LGU, specifically to address the following:

- Extent (area) of mariculture site
- Type of operation to be carried out (species to be cultured, technology and system to be used)
- Time frame of the permit or lease
- Performance
- Fees
- Termination.

Grant of mariculture zone areas is based on mooring spaces to ensure that usage of area-space for sea cage farming is solely based on the granted space as provided. Granted mooring spaces not developed/installed with cages within 6 months will be lost and awarded to other applicants. The BFAR prescribes the guidelines for the installation of sea cages.

The Fisheries Code of 1998 requires all LGUs to enact regulations on aquaculture licensing and permits. The Code spells out the need to control stocking density and feeding rates in such aquaculture facilities.

Granting of culture areas shall be prioritized as follows:

a. First Priority: Local fishers/residents and Filipino companies operating within the municipality where the mariculture zone is located
b. Second Priority: Residents or Filipino companies operating within the province or region where the mariculture zone is located
c. Third Priority: All other Filipinos or Filipino companies in the Philippines
d. Fourth Priority: Foreign nationals or companies allowed to engage in natural resource development following existing legal framework.

For larger investors:

a. First Priority: Enterprises engaged in fishing
b. Second Priority: Enterprises engaged in food production
c. Third Priority: All other small enterprises that would like to venture into mariculture.

For small investors:

a. First Priority: Entrepreneurs engaged in the fisheries industry
b. Second Priority: Entrepreneurs engaged in the agricultural sector
c. Third Priority: All other small entrepreneurs who would like to engage in mariculture.

For the marginalized sector that is eligible to operate within the fully developed area, the prioritization shall be as follows:

a. First Priority: Fishers displaced from their usual fishing practice due to restrictions on type of fishing gear allowable within municipal waters
b. Second Priority: All other municipal fishers operating within the area where the mariculture zone is located who may want to shift to mariculture.

Duly registered fisher folk organizations/cooperatives have preference in the grant of fishery rights by the LGUs. The SEAFDEC, through its Aquaculture Department and BFAR can provide technical assistance for the establishment, training and marketing support to local government units, coastal fishers, cooperatives/associations, and nongovernment organizations with respect to the establishment.

The applicant for the mariculture zone locator need to submit the following documents:

a. Operational Plan (to be provided by the mariculture zone if necessary)
b. List of machinery and equipment to be used by the applicant with the statement of their capacity, ownership and/or mode of payment.

Additional documents required include:

c. Copies of articles of incorporation and bylaws
d. Resolution of applicant's board of directors authorizing the filing of application; list of each director, principal officers and major stockholders including their bio-data
e. Company brochures and/or photographs of product
f. Other supporting documents, papers, clearances as may be required by the EMC depending upon the nature of the business and the type of business organization of the applicant.

A certificate of lease is issued only upon the execution of the lease agreement by the EMC and when the applicant has:

a. Complied with all the pre-registration requirements
b. Submitted within 20 calendar days from the receipt of the notice of approval of the application, a formal acceptance of the proposed terms and conditions of registration for good cause shown; said period maybe extended if the request therefore is filed before the expiration of the period sought to be extended
c. Paid the registration fee—however, in appropriate cases as may be determined by the board, the mariculture zone management or the duly authorized officers of the EMC shall be empowered to issue business permits and licenses to mariculture zone locators in lieu of the certificate of registration after the proper evaluation of their application in accordance with the set of criteria duly approved by the board and upon payment of the corresponding fees.

The Land Bank of the Philippines (LBP) can provide financial or loan assistance to registered fisher organizations/cooperatives for the construction of the fish cage and to finance the initial stocks and feeds.

5. OPERATION AND MANAGEMENT

The operation of a mariculture park is basically a public-private sector partnership, and since a large percentage of the investments come from the private sector, its success is dependent on private sector investments and the efficient governance by the public sector.

The mariculture park is established with the fabrication of concrete blocks for permanent mooring systems ready for investors in designated areas based on the development plan. A two (2) hectares progressive technology demonstration area is allocated as a showcase to interested prospective locators and for training purposes.

Training is undertaken for mariculture investors:

- Caretakers Trainings
- Maintenance Crew Trainings
- Harvesters Trainings
- Livelihood Training (seaweeds, oysters, mussels, grouper)
- Trainings on CRM, environmental monitoring
- Entrepreneurial Trainings/business opportunities for fishers
- Training on Post-harvest/processing (value-added products development).

A one-stop shop is established for investors for fast approval of applications using standardized application forms for the issuance of lease/permits.

The organisational structure of the mariculture park and their functions are as follows:

- Department of Agriculture as the Executing Agency
- BFAR-Southeast Asian Fisheries Development Center (SEAFDEC)-LGU Signatories of the MOA
- EMC—Executive Management Committee takes charge for the over-all administration of the Marine Park Project
- BFAR-Regional Director (BFAR-RD) coordinates with the EMC on day-to-day operations
- BFAR-RD as Project Manager of Mariculture Park Management Unit (MPMU).

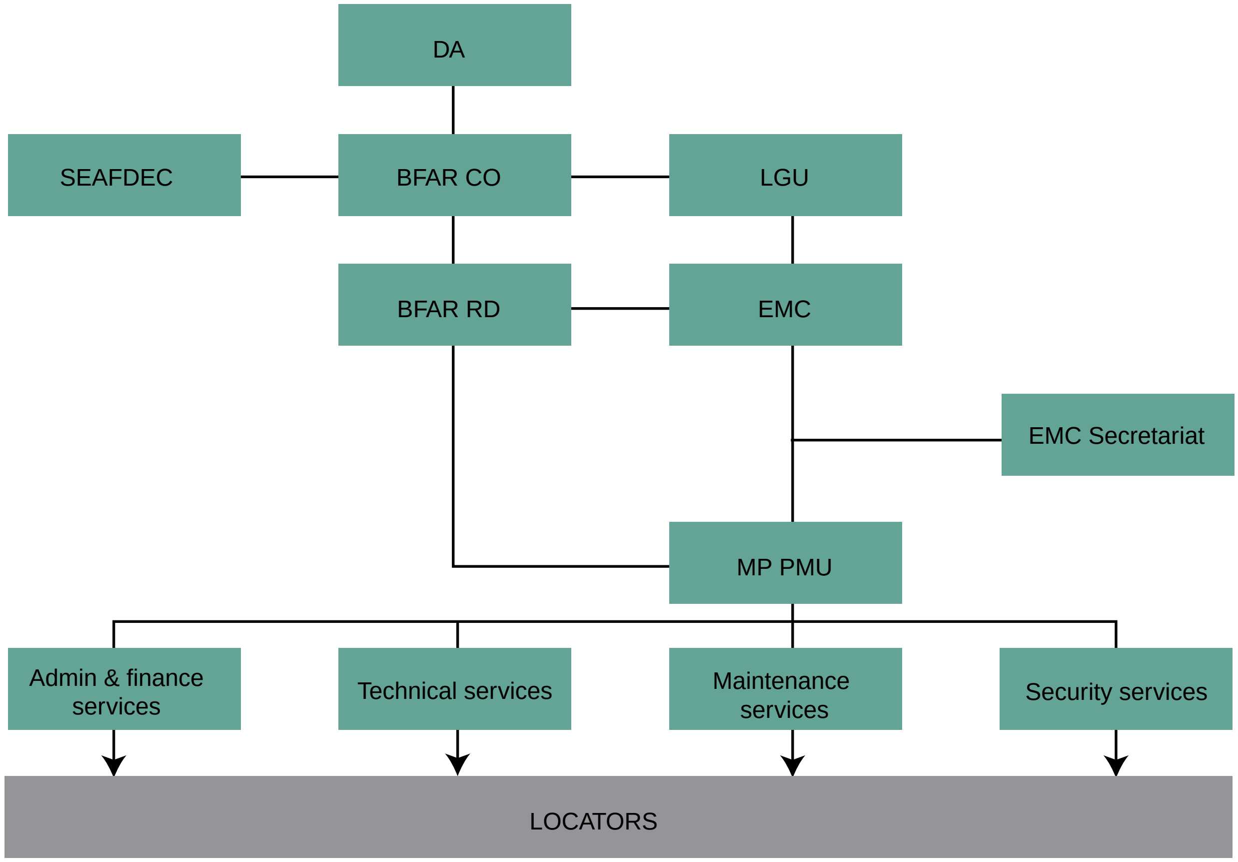
The management of the mariculture park is undertaken by an Executive Management Council, comprising of public, private and NGO members.

The Executive Management Council is chaired by the Local Government Executive or the Municipal Mayor and co-chaired by the BFAR Regional Director. It is composed of:

a. Municipal Agricultural Officer
b. SB Chairman—Committee on Agriculture
c. Barangay—Chairmen of Concerned Barangays
d. Representative from Department of Environment and Natural Resources Office (DENRO), e) Representative from Municipal Fisheries and Aquatic Resources Management Council (MFARMC)
e. BFAR Staff
f. Representative from the Locators Association (LA). The Secretariat is from BFAR or LGU.

The responsibilities of the EMC are to provide the General Direction, set appropriate policies and standard operating

FIGURE 7. Organisational structure and functions for a mariculture park.



procedure, assumes the general functions of planning, directing/implementing, evaluation and monitoring and approval of action for execution of the Mariculture Park Management Unit (MPMU). The Chairman presides over all meetings, signs approval of resolutions, all official communications of the EMC, approved plans, budget and other permits associated with the conduction of mariculture and other ancillary industries of the mariculture park and approves disbursements of funds generated from the operation of the mariculture zone.

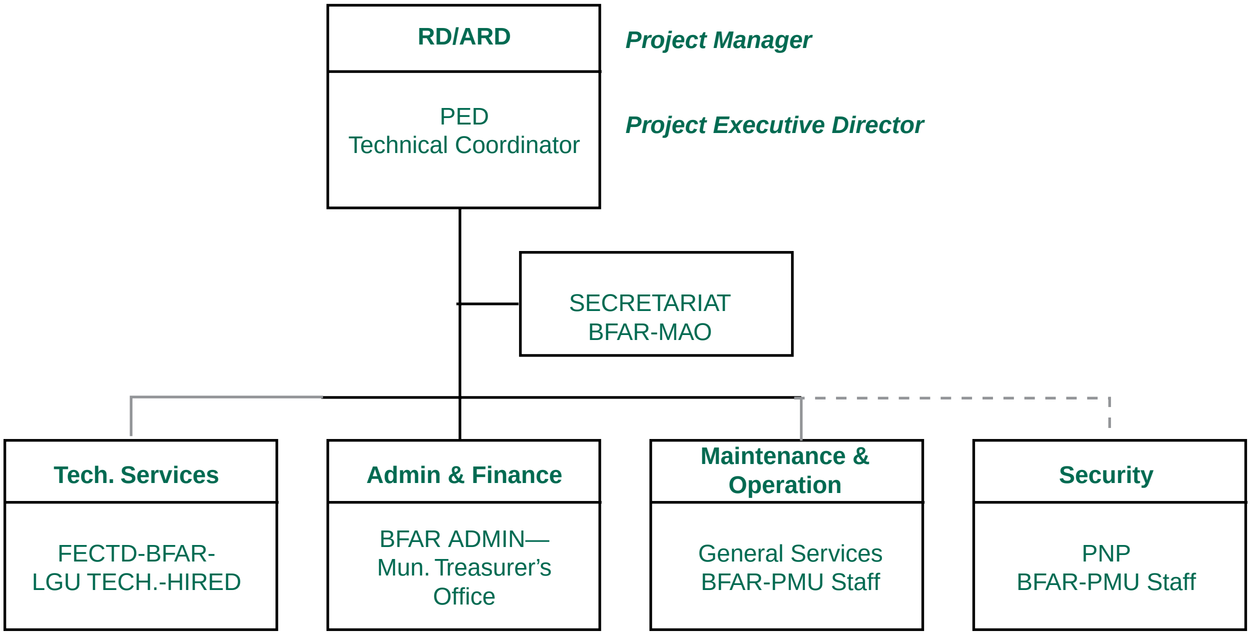
The Mariculture Park Management Unit (MPMU) implements the day-to-day operations of the MP ideally composed of the technical, maintenance, security and administrative services personnel. An MP Operations Manual containing all critical policies and regulations consistent to the principles of Good Aquaculture Practices (GAqP) standards is the main document that serves as the guide for all activities within the parks.

BFAR plays a major role in the management of MPs under a comanagement scheme with the LGUs as stipulated in the standard Municipal Ordinance and Memorandum of Agreement where, specifically BFAR shall provide for the technical assistance and financial support in the development of the MP.

BFAR Director/Regional Director is the cochairman of the EMC, which is the governing council of the MP and the Project Management Unite which implements the daily operational activities of the MP, it is composed of the BFAR-LGU staff, assigned or detailed to the Project Management Unit.

The initial cost of the development is shouldered by BFAR with cost sharing from the LGUs such as, technical study of the MP site, orientations and consultation activities, provision for demarcation of boundaries, (based on resource assessment conducted, TROPOMOD applications and EIA requirements), provision of the one (1) hectare mooring systems, launching expenditures, provision for two (2) units with at least three (3) clusters of cages as demonstration facilities including inputs, preparation in the application for ECC, conduction of

FIGURE 8. Suggested organisational structure of the Project Management Unit.



investment forum and production of IEC materials. Demonstration cages are maintained by BFAR for new investors and to encourage other locators outside the locality to invest. Demonstration facilities (demo-cages have no specified time period to serve as show-case/ show-window to prospective investors/locators as they come. The same facilities are also used for practical hands-on training for new investors.

BFAR provide sustained assistance in the establishment of one-stop shopping to serve the investors, provide assistance in planning, project implementation, training for the necessary skills of caretakers and other maintenance staff, assists post-harvest activities, and assists investors access to financing and marketing of the product.

BFAR also in the early stage provides for a multi-purpose motorboat, mobile technical and security staff, provides for a floating office which serves as the BFAR-LGU research and development headquarters and makes available the Regional Fish Health Laboratory to support the MPs.

FIGURE 9. Support from BFAR and local feed suppliers.

Monitoring boat provided by BFAR

Associated feed shops

Source: BFAR-RFTC Panabo City, 2010.

FIGURE 10. Communal facilities for fish landing and marketing.

Community fish landing jetty

Source: BFAR-RFTC Panabo City, 2010.

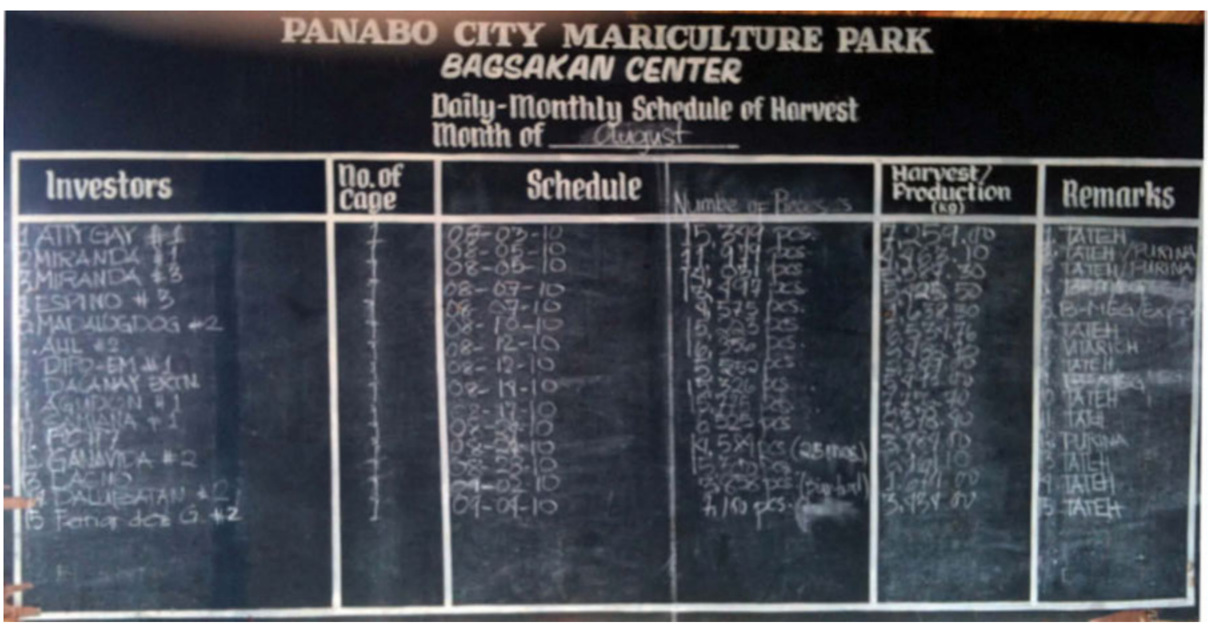
Communal fish marketing area

BFAR in coordination with the Municipal Agriculture Office (MAO), provides extension services such as technical assistance and technical training and is channelled through the municipal LGU. It is the duty of the duly formed municipal *Bantay Dagat* Task force (seawatch) in coordination with the MAO and the municipal-based PNP to do the regular fisheries law enforcement activities.

The mariculture park provides communal facilities for all members including landing jetty, fish marketing area, and ice supply.

The stocking of fry and harvesting of fish is coordinated so that there is a continuous supply of fish to the market. Batches of harvested produce are labelled as to source, date of harvest, and other details following the GAqP guidelines for traceability requirements.

FIGURE 11. Coordination of the harvesting of fish from the different mariculture park producers and feed traceability.



Source: BFAR-RFTC Panabo City, 2010.

6. ENVIRONMENTAL MONITORING AT THE MARICULTURE PARK ZONE SCALE

An output of the EU funded project PHILMINAQ "Mitigating impact from aquaculture in the Philippines," was the development of 3 categories of environmental survey:

1. Simple survey for clusters of small farmers or medium sized farmers
2. Intermediate survey for large farms for aquaculture zones
3. Detailed survey for research purposes.

Regular Category 1 surveys are sufficient for monitoring physical and chemical parameters for mariculture parks (see below).

Category 1. Simple cheap, cost-effective survey aimed at LGU monitoring mariculture parks and medium sized farmer.

This survey measures the following parameters:

- **Cage layout and sizes.** Cage layouts and dimensions give crucial information for interpretation of survey results and also for modelling of the area.
- **Hydrographic.** Depth recordings provide information to assist the sampling of the water column and seabed during the survey. Accurate depth measurements are also important for management of the site so that mooring ropes and nets can be set at the correct depth. Water depth below the net should be at least double the net cage net. Also, computer modelling of cages requires accurate depth measurements on the basis of the TROPOMOD supported with the physiochemical parameters and bathymetric data taken from the site assessment study.
- **Condition of the seabed sediments.** The condition of the seabed sediments is important as too much organic input to the seabed causes oxygen to be absent resulting in no fauna living there. If no fauna are living in the sediment, waste from the cages above is not eaten and it builds up on the seabed. This results in chemical reactions where gas bubbles from the sediments rise to the cages above and cause stress to the fish. It is important to monitor the biological and chemical condition of the seabed using sediment grabs or sediment cores to take samples for biological and chemical analysis.
- **Oxygen levels in the water column.** Oxygen levels in the water column (surface, mid-level column and bottom levels of the cage structure) are important as very low levels result in fish kills. Also, low levels of oxygen stress the fish and cause poor growth. Oxygen levels in the water column are affected by many things, including water temperature, concentration of phytoplankton (algae), current and condition of the seabed as described above.
- **Turbidity of the water column.** Water turbidity is measured and monitored in two ways either using a secchi disk or depth transparency light emission instrument. The turbidity of the water column relates to how much algae and suspended solid material is in the water column. High turbidity may be linked to high levels of nutrients which cause excess algal growth or seasonal effects such as high suspended material from runoff caused by rain. This is important as high concentrations of algae and suspended material (high turbidity) can lead to reduced oxygen in the water column if this material starts to decay.

7. PERFORMANCE MONITORING AND REVIEW

The development of the mariculture parks is regularly monitored and the data recorded and made publically available on the BFAR web portal http://mariculture.bfar.da.gov.ph/

The data that is monitored and recorded includes:

- State of MP development—planning, launching, operational
  - Launch date
  - Mariculture park surface area
  - LGU resolution number
  - Date enacted
  - ECC no. and date

- Infrastructure in place
  - Cages
  - Moorings
  - Boundary markers
  - Floating guard house
  - Wharf
  - Boats (service boats, patrol boats, supply boats, bancas)
  - Security lighting
- Production data (annually for each species cultured)
  - Stocking density
  - Stocking size
  - Culture period
  - Annual production
  - Average price/kg (farm gate, retail)
  - Value of production
  - Product destination
  - Number of fish traders
- Ancillary support service monitoring name, number, type
  - Hatchery and fingerling suppliers
  - Feed suppliers
  - Cage fabricators
  - Aquaculture supplier dealers
  - Harvesters

Mariculture parks that are not operating optimally are evaluated and those found with significant problems enter a program for rehabilitation.

- Boats
- Engines
- Moorings
- Cages

8. COST-BENEFIT SUMMARY

Economic/Financial Analyses of Mariculture Park Operations

Presented below is an economic evaluation of the mariculture park in Panabo City, Davao (PCMP) with an aggregate area of 1,075 hectares, 153 units of cages built in 2006 (marginalized groups, 17 cages and private investor group, 136 cages). The average number of cages operated by the marginalized group was 2 to 3 units; while the private investor group averages 34 cages per unit. Financial analyses are shown in Table 1.

Based on the above, the PCMP operations are economically viable. The cost structures differ as well but the proportion of the costs are much lower in PCMP. Operations with 1–3 cages are the most affected. Operating with more than 20 cages, this time, is very profitable in PCMP. Total expenses stand at 49 percent of sales leaving a very comfortable net profit margin of 51 percent, valued at Philippine Peso (PHP) 287,776 per cage, corresponding to an ROI of 112 percent per cycle. On an annual basis, an operator in PCMP can expect a return of 224 percent per annum.

The best results, however, is still operating between 10–20 cages or an average of 15 cages. Total expenses stand at 57 percent of sales resulting to an average net profit return of 46 percent of sales after depreciation has been adjusted. The corresponding average net profit per cage stands at PHP 230,507 but the return on investment stands at 117 percent, 5 percent higher

TABLE 1. Results of financial analysis in PCMP for milkfish culture.

Criteria	Less than 10 Cages	10–20 Cages	More than 20 Cages
Average fixed expenses (% of sales)	24%	17%	17%
Average variable expenses (% of sales)	50%	26%	29%
Average other operating expenses (% sales)	6%	14%	5%
Recovery from depreciation	(4%)	(3%)	(2%)
Average net profit (% of sales)	24%	46%	51%
Average net profit per cage (PHP)	185,741	230,507	287,776
Average return on investment	72%	117%	112%

TABLE 2. Results of financial analysis of grouper culture in PCMP.

Criteria	Less than 10 Cages
Average fixed expenses (% of sales)	16%
Average variable expenses (% of sales)	35%
Average other operating expenses (% sales)	17%
Recovery from depreciation	(5%)
Average net profit (% of sales)	37%
Average net profit per cage (PHP)	286,363
Average return on investment	47%

than investments in more than 20 cages. On an annual basis, the ROI for an investor stands at 234 percent.

In the case of grouper, two cases were noted in PCMP using 1 cage per operation. Compared to the other mariculture projects, returns in grouper culture are favorable considering the cost structure given in Table 2 above.

The increased share of other operating expenses is noticeable, particularly with the additional floaters and nets, as well as transportation costs, but the selling price at PHP 350 per kilo more than compensates for the increased costs. Overall, average net profit per cage is PHP 286,363 (37 percent) with an average return on investment of 47 percent. On an annual basis this corresponds to 94 percent per annum.

9. SOCIAL CHALLENGES AND BENEFITS

The mariculture park in Panabo City (PCMP) Davao, has provided a significant increase in employment and has thus benefitted a number of stakeholders.

It is estimated that current total job employment derived from MPs, either part-time or full-time, had already reached over 500 people. Over 235 came from fishers/local residences and portions of their income resulted in having additional local revenues generated by LGUs of Panabo City and the revenues generated by other neighbouring municipalities of the province due partly to increasing purchases of market goods and trading activities. Support services and activities for mariculture parks are created both upstream (for example fish fry producers, nursery operators, feed suppliers/agents) and for downstream (for example processors of fish and other aquatic products, ice sellers and fish traders). Additional beneficiaries come from within the communities' periphery who engaged themselves into small–medium businesses. Survey results show that most of them have economic and social gains from MPs continuing operations in the area. In Barangay Cagangohan alone with a population of 13,162 (NSO, 2010), the beneficiaries of the MP reached to a total of 209 local people.

10. DISCUSSION AND CONCLUSIONS

The mariculture parks are intended to answer the needs of job generation, food security and environmental resiliency. Priority is given to the marginalized sector, but it is open to all other interested investors big and small. The program initiative allows controlled development of aquaculture within designated zones, with limits on production within the local carrying capacity rather than unplanned aquaculture development which is more difficult to manage and control.

TABLE 3. Barangay Cagangohan direct beneficiaries of marine park.

Position/Activity	Number	Age Range	Remarks
Fish cage caretaker	150	25–40	Milkfish cages—PHP 3,000–5,000/month
Fish cage frame maker	12	28–50	Contract PHP 500/day
Fish net maker/repairer	12	32–48	Agreed package cost at PHP 4,000/net done 3–4 days
Fish harvester	15	16–30	PHP 200–250/day
Fish processor	20	30–55	Group of women and mothers involved in milkfish deboning; sardines making (PHP 200/day or 46,000/cropping)
Total	**209**		

Unbalanced resource use and limited capital for investing in cages among small fishers are pressing issues in mariculture park development. While some small-scale fishers are employed in the mariculture parks, some have not been hired, while others lack the capital to invest. To address this concern, the government (BFAR) has recently launched the "rent-to-own" cage project as initial livelihood assistance for displaced sustenance fishers in the areas where mariculture parks are established.

There are problems, however, with trying to bring existing farms inside of the newly established mariculture park as existing producers are resistant to being forced to cooperate with other competing producers and having to conform with the strict management measures and standards of good aquaculture practices. The number of existing farms outside of the established mariculture parks varies according to localities since they were established/operational before the mariculture parks boundaries were allocated by the LGU.

Of the 67 mariculture parks that have been established, few can be considered to be presently operating on a commercial scale; for example, only 10 mariculture parks have more than 50 cages. The other mariculture parks are at various levels of development; some are newly established while others have to be rehabilitated. The establishment and operation of the mariculture parks require significant technical and management input from the Local Government Unit, and BFAR.

Constraints on the success and failures of operations, maintenance, and overall administration of mariculture parks were traced on the following factors:

- Governance and lack of support on the part of the LGU
- Changes in the LGU administration
- Lack of financial assistance and manpower support on the part of the government
- No interested cooperators/investors in the locality
- Product marketability affecting price of the commodity.

The criteria to assess the overall performance of the mariculture parks in terms of their operational status, production and socioeconomic impact are given below:

- Legal Framework
  - Memorandum of Agreement
  - Municipal Ordinance
  - Environmental Compliance Certificate
- Status of MP
  - Management and Operation
  - No. of Production Units installed
  - No. of Investors/Locators
  - Ancillary Services available.

"Risk mapping" is part of the area assessment study. However, the unpredictable climatic changes that have a direct impact to the mariculture parks has been found to be caused by storm surges, typhoons, flooding and water siltation resulting in destruction of facilities, fish escapes and depletion of the resources causing a big loss to investments.

The mariculture parks if properly managed create an enabling environment wherein aquaculture farmers can operate their farms securely, cost-effectively and sustainably with the integration of support systems vital to the success of investments, such as: technically skilled workforce and service providers; accessible and available sources of inputs, markets, financing, facilities and infrastructure (hatcheries, ice plant and cold storage, pier, laboratories, transport facilities); and responsive governance. The industry support system extends throughout the whole supply value chain.

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ANNEX 1. CASE STUDY EFFECTIVENESS MATRIX—PHILIPPINES MARICULTURE PARKS

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$) $ = > US$1,000 $$ = 1,000 to 10,000 $$$ = 10,000 to 100,000
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	The request to set up the mariculture park is by the Municipality. The aquaculture zone boundaries are identified by BFAR based on Aquaculture suitability selection criteria within the Municipal waters. All areas for mariculture zones are selected based on technical, social, economic viability and sustainability. Environmental preservation is the management's paramount concern.	Scoping is undertaken less for social aspects.	• Hydrographic study participatory meetings; • Topographic maps and nautical charts; • Maps of mangrove and sensitive habitats.	4	$$ per Park
1.2 Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	Policy and regulations are well defined at the central Government level for the development of mariculture parks as a framework for sustainable development of new areas for aquaculture. Water quality standards exist for different categories of water bodies.	Policy and regulations are less easily implemented at the local government level.	• The Fisheries Code of 1998 requires that aquaculture areas be designated by local governments within municipal waters; • Fisheries Office Order No. 317, 2006 contains all the implementing guidelines and procedures for the establishment and management of mariculture parks.	4	$$ undertaken once

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$) $ = > US$1,000 $$ = 1,000 to 10,000 $$$ = 10,000 to 100,000
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.3 Setting the broad development objectives and identifying the main issues	The development context favours employment generation, poverty alleviation and alternative livelihoods for marginalised and sustenance fishers.		• Undertaken generically within Fisheries Office Order No. 317, s. 2006.	4	$$ undertaken once
	Identifying and prioritizing the main issues undertaken generically.	Not undertaken systematically.			
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.4 Zone boundary definition based on relevant criteria	• Mariculture park zone selection is based on defined zone selection criteria including physical configuration, the chemical characteristics of the water column and a socioeconomic study. It is undertaken with public consultation. • Suitability thresholds for species and culture systems for the zone defined and consulted. • Use of buffers away from mangroves, coral reefs, river mouth and navigational channels.	Mariculture park zone selection can be influenced by politics resulting in parks located in less suitable areas.	• Rapid suitability survey for zone selection and establishing buffers from sources of pollution, river outlets, etc. • GIS now being used in zone selection (various software).	3	$$ per Park

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$) $ = > US$1,000 $$ = 1,000 to 10,000 $$$ = 10,000 to 100,000
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.5 Gross estimation of potential production/ area	Gross estimation of potential aquaculture production is estimated using benchmarks or TROPOMOD.	TROPOMOD modelling not always used.	• Simple productivity per ha benchmark. • Sometimes sophisticated particle tracking model TROPOMODs.	3	$ per Park
1.6 Formal allocation of the zone for aquaculture purposes	Allocated by the Local Government Unit for aquaculture as per Fisheries Office Order No. 317. Municipal/City Ordinance reserving the identified marine area as mariculture zone and enacted by the Sangguniang Bayan/ Panglungsod.		• Participatory allocation process. Prepublic hearing. Public hearings. • Mariculture Park Operations Manual. • Environmental Compliance Certificate.	5	$$ per Park
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	• Individual farm site selection is undertaken with moorings installed to define the exact position for the cages. • Cages locations allocated in rows with set space between rows. • Farm sites are positioned in a grid format to allow easy navigation and not to impede currents.		• Field data collection and field measurements (i.e., bathymetry). • Simple mapping.	5	$ per Park

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$) $ = > US$1,000 $$ = 1,000 to 10,000 $$$ = 10,000 to 100,000
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.2 Carrying capacity estimation	Carrying capacity estimation undertaken by modelling (TROPOMOD).	TROPOMOD modelling not always used.	• The carrying capacity of cages in the lake is based on the physicochemical and biological productivity measured in terms of biomass (g/m^3). and nutrient uptake (gm/C/m^3).	4	$ per Park
2.3 Set license production limits within zone or water body carrying capacity	Production limits are set by limiting the number of licenses for cages and limiting the stoking density of fish in cages to within the estimated overall sustainable carrying capacity.		• Environmental Compliance Certificate (ECC) secured from the Environmental Management Bureau (EMB) of the Department of Environment and Natural Resources (DENR).	4	$ per Park
2.4 Allocation of licenses and permits	Allocation of licences is undertaken by the LGU. Allocation of sites favouring small-scale fishers or fisher organisations. Granted sites not developed/installed with cage within 6 months will be forfeited and awarded to other applicants.	Issuing of licences to potential farmers can be subject to political influence.	• LGU license issuing procedures. • The Fisheries Code of 1998. • There is one-stop shop center established in the mariculture zone to facilitate the registration, licensing and issuance of permits to mariculture zone locators.	4	$ per Park

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$) $ = > US$1,000 $$ = 1,000 to 10,000 $$$ = 10,000 to 100,000
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant waterbody or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries	There is good boundary identification. Area management is undertaken within the whole defined mariculture zone. Allocation of zones within park for fish sanctuaries.	There can be problems in arranging area management where farmers are already established in an area, compared to establishing area management in new aquaculture areas.	• Participatory consultations; • Hydrodynamic models; • Depth and current maps; • GIS and remote sensing data and tools; • Risk maps (e.g., for algal blooms, surge, etc.).	5	$$ per Park
3.2 Estimate total carrying capacity if appropriate based on the different risks	Carrying capacity estimated mainly on environmental risk and some social.		• The carrying capacity of the Park is determined through the conduct of physicochemical and biological studies to determine plankton/ algae density, nutrients and transparency and fish biomass and composition; • Carrying capacity estimation using the TROPOMOD model.	3	$$ per Park

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$) $ = > US$1,000 $$ = 1,000 to 10,000 $$$ = 10,000 to 100,000
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant waterbody or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.3 Organize a formal association of all farmers in that area	Strong area management of all the farmers by the Executive Management Council and strong technical assistance for stocking and harvesting management by BFAR.	Organisation of the EMC can be overly complex.	• Procedures detailed in Fisheries Office Order No. 317, s. 2006.	5	$$ per Park
3.4 Setting the broad development objectives and identifying the main issues agree on common management,[3] monitoring and control measures	Common management measures are agreed and written into a mariculture park operation manual which follows Code of Good Aquaculture Practices.	There is less area management for biosecurity measures.	• Fisheries Office Order No. 317, s. 2006 contains guidelines on management of mariculture parks.	4	$ per Park
3.5 Monitoring of relevant variables and enforce management measures	There is good enforcement of management measures by the EMC and MPMU supported by BFAR.	Depends on the effectiveness of the Executive Management Council.	• BFAR undertake regular environmental monitoring and assist with the collection of production data.	4	$ per Park per year

3 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$) $ = > US$1,000 $$ = 1,000 to 10,000 $$$ = 10,000 to 100,000
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.1 Regular monitoring and evaluation	The EMC, thru its representatives, conduct specific periodic inspection of sea cages, building, facility or structure within the mariculture zone to check on the state of environment, aquaculture practices, health, medical, occupational and safety standards of the building structure and the general condition and maintenance of the plant.	Regular environmental monitoring could be strengthened.	• Category 1 Environmental monitoring survey.	3	$ per Park per year
4.2 Periodic review and adjustment	The mariculture zone locator should correct any deficiency or violations of pertinent regulations noted in the regular inspection within a reasonable period of time to be determined by the EMC. Remedial measures are implemented where parks are less successful.	Solutions not always found.	• Assessment of management plan according to new threats or emergencies. • EAA tool box.	5	$$ per Park

Phase/Step	Well Done/Achieved (examples are provided below on well done steps and main achievements)	Not Done/Not Achieved	Associated Activities and Tools (examples provided as bullet points)	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$) $ = > US$1,000 $$ = 1,000 to 10,000 $$$ = 10,000 to 100,000
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**		**Approximate production from each aquaculture zone or AMA**		
Number of zones and range of implementation	66 mariculture parks 61 operational 5 to be rehabilitated		Average park has 45 cages (range 1 to 500) Estimated total production from all mariculture parks 1997—321 MT 2007—62,097 MT 2012—90,425 MT 2014 (1st half)—91,797.379 MT		
Other notes (especially social issues)	**Positive issues**		**Negative issues**		
	• Assistance is given for the development of secondary associated businesses (net making, net mending, cage making, etc.). • Strong coordination of seed stocking and harvesting to provide continuous fish production. • Acts as a SME business incubator. • Assistance to Public Private Developments such as feed and seed supplies. • Integrated Multi-trophic Aquaculture (IMTA) is starting to be included in mariculture park design and operation.		• Not all Aquaculture parks are productive, successful or profitable for the farmers. • There is still some local environmental impact due to overproduction. • It is difficult to create mariculture parks in areas with existing aquaculture production.		

Mariculture Parks in Turkey

Güzel Yücel-Gier[1]

ABSTRACT

Turkish marine aquaculture has seen rapid growth along the Aegean coastline since 2000. This case study focuses on Mariculture Parks in Gulluk Bay where 55 percent of total marine aquaculture production occurs. Conflict with other coastal zone stakeholders prompted new regulation from the Ministry of Environment and Urbanization (MEU). In 2007 new regulations for Gulluk Bay lead to the definition of two mariculture zones. These cover 20.8 percent and 0.45 percent of the area licensed for the cages of the Bay. This was done by a Turkish Inter-Ministerial Consortium, in conjunction with the Mugla Fish Farmers Association. Site selection and zoning addressed basic issues through a participatory process involving stakeholders, scientists and central government. This has subsequently proved to be a weak point in the whole process. The two mariculture zones were evaluated separately in Gulluk Bay. Two total zoning EIA reports were separately produced for the Bodrum zone and for the Milas zone. Monitoring is done by government officers. Aquaculture zoning, spatial planning, aquaculture management, and risk mapping are among the most important issues for the success of aquaculture. They need to be carried out in accordance with sustainability and best practice guidelines. Turkey has recently focused on such issues and is trying to set guidelines which will enable true sustainability to take place. When we look at the whole EIA process it needs the estimation of carrying capacity for a new aquaculture potential area and harmonisation with the monitoring and management system to be used.

1. BACKGROUND

Inland aquaculture started in Turkey in the 1970s. But aquaculture expanded rapidly with the contribution of marine fish farms in the 1980s. It was dominated by cage farming of sea bass (*Dicentrarchus labrax*), sea bream (*Sparus aurata*), and trout (*Oncorhyncus mykiss*). In the Turkish marine finfish sector sea bass and sea bream are dominant. Turkish marine aquaculture production has increased from 35,000 tonnes in 2000 to around 109,000 tonnes in 2013 (TUIK, 2013). It has been going through a period of unprecedented growth over the past 13 years (Figure 1).

It is the rapid growth of the aquaculture sector which makes it remarkable.

Development opportunities for aquaculture in the coastal zone of Turkey are limited because of the difficulties in obtaining access to suitable sites. Its expansion in coastal waters has not only added more pressure to marine and coastal ecosystems, but has also created conflicts among existing users of coastal resources. Consequently, there was a need for expansion space and this growth has led to the drafting and implementation of new planning and management policies by the Turkish government. Coastal planning was realized by the inter-ministry committee in 2007. However there was no broad-based "Integrated Coastal Management Board" with minimal inputs by the mayor, nongovernmental organizations and so on. It was a process that increased

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

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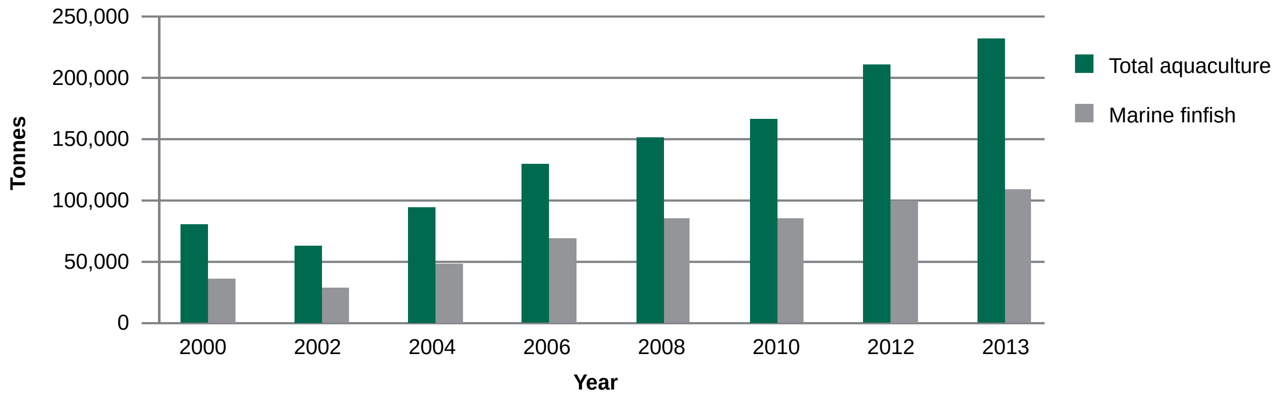
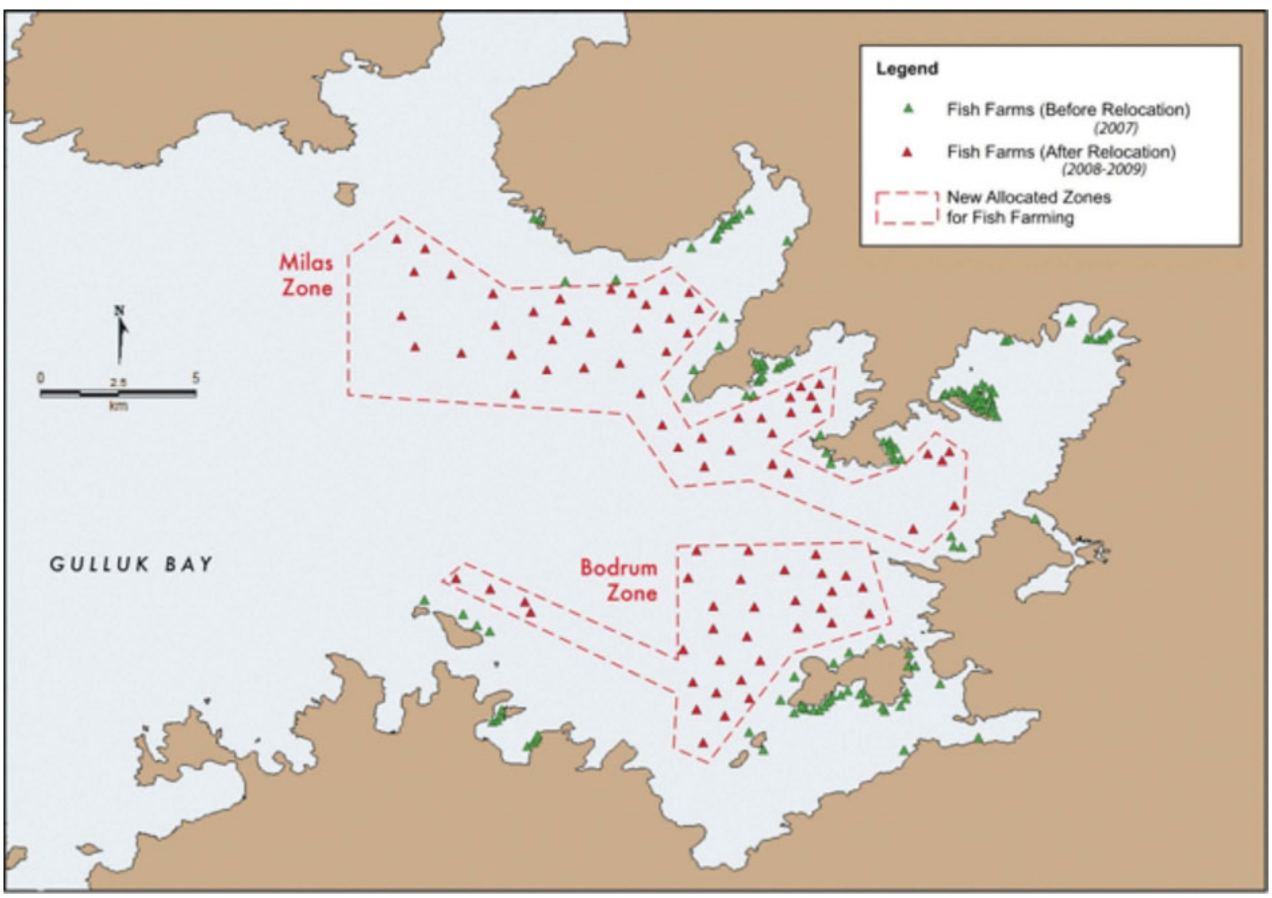
FIGURE 1. Overall aquaculture production and marine finfish production in Turkey.



the pressure on fish farming in the coastal zone. Priority and legitimacy over the maritime space was supported by the legal framework and given to the aquaculture industry through the establishment of a mariculture zone. This was a basic move to avoid conflicts and to assure the sustainable development of the sector.

The Ministry of the Environment amended existing environmental legislation. It was then obligatory for the farms to be moved from the shallow shoreline waters to the deeper areas, particularly in gulfs and bays. Two mariculture zones were defined in Gulluk Bay, Mugla (Figure 2), which has a surface area of about 670 km²

FIGURE 2. Shows the position of licensed farming facilities before and after relocation according to the provisions of the Environmental Law (MEF, 2007).



and a coastline of around 262 km. Accordingly in 2007 new parameters and criteria (Table 1 and Table 2), were established in Gulluk Bay comprising two large mariculture zones. There was a Milas Zone and a Bodrum Zone as defined by a Turkish Inter-Ministerial Consortium, together with Mugla Fish Farmers Association. The mariculture zone covers 20.8 percent (139.8 km^2), of the Bay. Licensing for the cage areas was only taken up for 0.45 percent (3.03 km^2), of this area (Yucel-Gier, *et al.*, 2013). Gulluk Bay contributes about 70 percent of the total Turkish marine aquaculture production of sea bass and sea bream. Major uses of the Bay were defined as aquaculture, trawling, natural areas and marine transport. The movement of farms to these mariculture zones took place in 2009. Before relocation, 127 fish farms had been working close in-shore. These had a reported 52,000 tonnes production capacity in 2007. As an economic consequence the small-scale fish farm has now disappeared. After relocation a total number of 81 new, larger, fish farms began to operate in Gulluk Bay and planned production capacity was increased to 88,000 tonnes. Forty-eight of these fish farms have a capacity of between 500 and 1,000 tonnes (EIA, 2008). The production capacity in 2013 was estimated at 60,000 tonnes (www.muglakulturbalikcilari.com). There is still 28,000 tonnes available capacity.

TABLE 1. Physical parameters and criteria for sensitive areas where cage fish farms can be set up (MEF, 2007).

Parameters	Criteria
Water depth	≥30 m
Distance from the coast	≥0.6 mile
Current speed	≥ 0.1 m sec^{-1}

TABLE 2. Scale for risk of eutrophication (MEF, 2007).

TRIX Index	Characteristics
TRIX < 4	No eutrophication risk
4 ≤ TRIX ≤ 6	High eutrophication risk
6 < TRIX	Eutrophic

Note: Trophic Status Index.

2. AQUACULTURE ZONING

2.1 Definition of Ecosystem Boundaries (Spatial, Social and Political Scales)

Mariculture zoning was carried out in terms of a 2006 Environmental Law. In this mariculture zone aquaculture has precedence over other uses. It is recognized by physical and spatial planning authorities that a system aimed at integrating aquaculture activities into coastal zone areas should avoid conflicts with other users. According to this law "Marine aquaculture facilities should not be constructed in sensitive areas such as enclosed bays and gulfs or in natural and archeologically protected areas." In connection with this law, a Notification which describes criteria for aquaculture site selection (Table 1 and Table 2), in enclosed bays and gulfs was published in 2007 (MEF, 2007). According to a further amendment of this law, farms unable to fulfil these new criteria were compelled to relocate in the years between 2008–2009 (Figure 2). Fish farms found to be in contravention of this notice were under threat of closure. Since this Turkish legislation was enacted, the majority of fish cages have been moved further from the near-shore coast as required. The law further indicates that monitoring is necessary in fish farms, which already exist in enclosed bays and gulfs, if these sensitive areas have an eutrophication risk. Ecological boundaries based on *Posidonia oceanica* (Table 1) and eutrophication (Table 2) are outlined in the tables.

An accurate definition of social boundaries is considered a key issue to ensure the sustainable development of aquaculture in Turkey. Pressures of coastline occupancy and use are increasing. The image of aquaculture has often had a negative reputation regarding the quality of product and impact of this activity on the environment. This boundary needs to be identified, analysed and integrated in the selection and management of aquaculture sites.

2.2 Consultation with Stakeholders

Coastal aquaculture along the Eastern Aegean coast has been going through a period of unprecedented growth over the past 15 years, especially along the Izmir and Mugla coasts. The rapid growth of fish farming and tourism has been paralleled by the very rapid urbanization of the coastal zone. Coastal planning was realized by the inter-ministry committee. This activity is vital for both aquaculture facilities and other stakeholders. The development of Turkish Marine Aquaculture site selection and zoning should address all the issues through a participatory process involving stakeholders, scientists and government. It is necessary to find acceptable solutions for site selection and zoning. Agreements must be negotiated on the most cost-effective and socially acceptable mechanism for mariculture development. This is a frequently a weak point in the whole process.

Legal, Regulatory and Institutional Frameworks

Finfish farmers must obtain permits from the Ministry of Food, Agriculture and Livestock (MFAL*). Finfish farming activities are controlled by a number of specific laws and regulations administered mainly through the MFAL and the Ministry of Environment and Urbanization (MEU**).

Table 3 shows Turkish laws and regulations about aquaculture.

*MARA changed to MFAL in 2011.
**MEF changed to MEU in 2001.

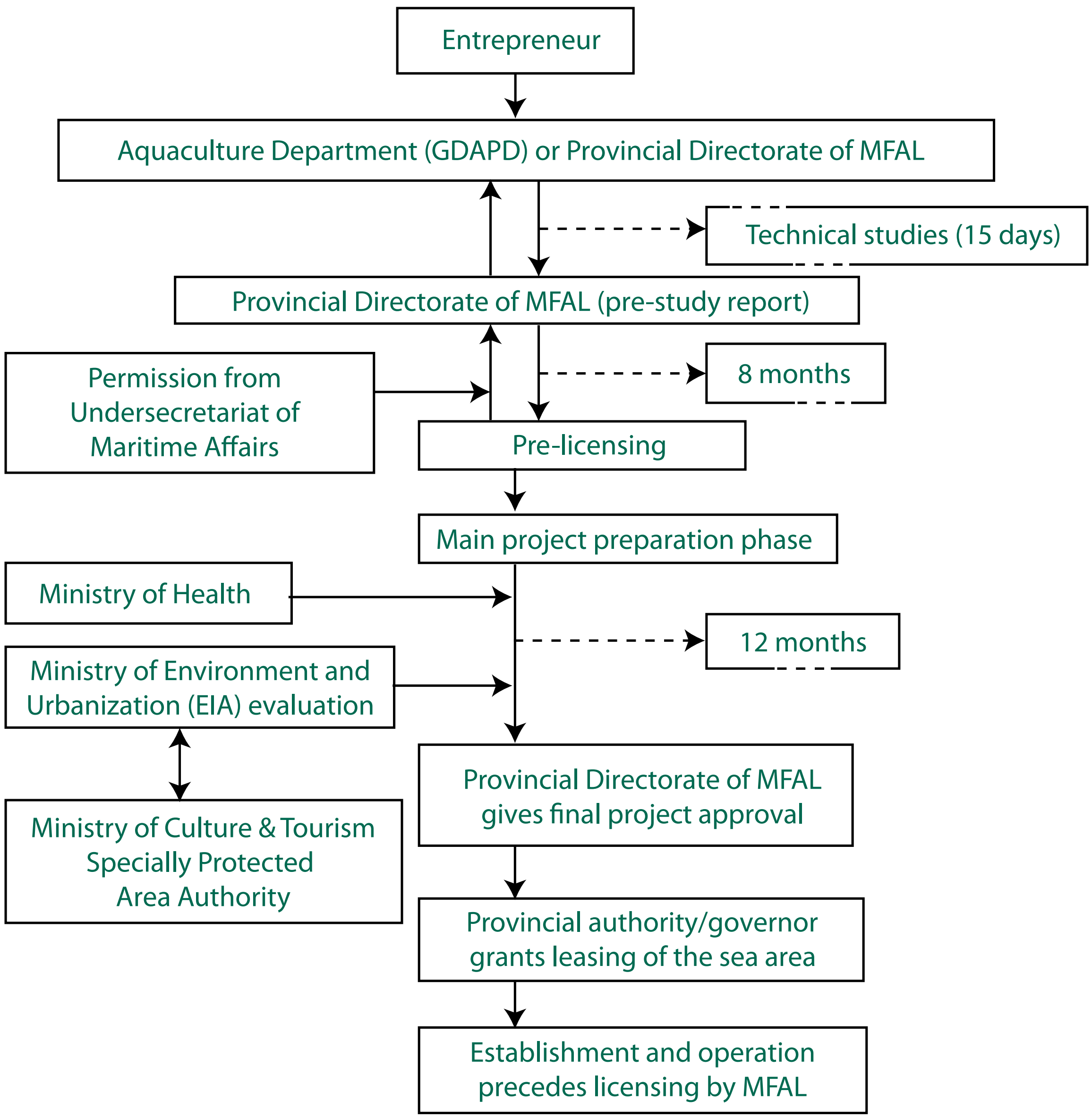
TABLE 3. Legal, regulatory and institutional frameworks.

Law	Content
Fishery Law (Fishery Law No. 1380, 1971) and its amendment (Fishery Law No. 3288, 1986; Fishery Law No. 4950, 2003).	All fisheries and aquaculture activities are regulated by the Fishery Law. With the last revision (2003) important legislative principles and standards were provided for the establishment and management of aquaculture facilities.
Environmental Law (Environmental Law No. 2872, 1983) and its amendment (Environmental Law No. 5491 in 2006).	Its associated regulations laid the general legal basis and framework for environmental protection similar to many other European countries. The last Turkish Environmental Law (2006) forced marine aquaculture facilities to move offshore within one year.
Regulation	**Content**
Regulation on Aquaculture (No. 25507) in 2004 (MARA, 2004), as amended in 2005 (MARA, 2005 and 2006).	It addressed major issues related to aquaculture like license renewal and development in terms of management, technology and related matters. A minimum capacity of 250 tonnes/year and water quality criteria were fundamental considerations in these proposed licensing requirements for marine aquaculture.
In 1993, detailed EIA regulations were enacted; these regulations were again extended and revised in 1997, 2002, 2003, 2008 and finally in 2013. They accommodated adaptations in accordance with the European Union EIA Directives 85 /337/EC and 97/11/EC.	A major component of this regulation regarding aquaculture activities is the need for the Environmental Impact Assessment (EIA). This is a process to define the environmental alterations that any developmental projects may have and, subsequently, to determine whether a project can be approved, or needs to be amended before approval, or rejection. EIA only applies to 1,000 tonne/year capacity farms.
Regulation for Water Pollution Control (MEF, 2004) were revised in 2008 (MEF, 2008)	Also, according to the Regulation for Water Pollution Control, Article 15 gives the general criteria of quality required for marine environments.
In 2007 a regulation (MEF, 2007) was made to identify the criteria for closed bays and gulfs qualifying as sensitive areas where fish farms are not allowed.	Fish farms already established in enclosed bays and sensitive areas were to be reevaluated in accordance with physical and chemical criteria.
Monitoring regulations for fish farms were introduced (MEF, 2009).	This includes sampling techniques and frequencies for sediment and water quality.

Licensing Requirements for Cage Farms and EIA Procedures

MFAL is the main authority responsible for licensing sea cage farms with a minimum capacity of 250 t per year (MARA, 2006). Figure 3 shows stages and durations associated with the steps of the licensing procedure. Besides MFAL, a number of other public authorities are also involved in the licensing process. These include the Ministry of Health, the Ministry of the Environment and Urbanization, and Undersecretariat of Maritime Affairs which takes the responsibility of contacting the Ministry of Culture and Tourism. This procedure is only covering sea level, whereas land logistic activities are more challenging. Currently in Gulluk Bay, Mugla Fish Farmer's Association is negotiating communal land access, facilities and piers.

FIGURE 3. Site licensing and leasing procedures for marine fish farms.



According to the Aquaculture Regulation (MARA, 2004) the following requirements for marine cage fish farms should be given:

1. Space/area available on a license should be large enough to allow for site rotation and should be no less than twice the actual area occupied by the cages.
2. Distance between cage farms is determined by the central Aquaculture Department according to criteria such as projected annual production capacity, water depth and current speed.

In Environmental Law No.5491, 2006 amendments, finfish farming in sensitive areas such as enclosed bays and natural or archaeological sites were prohibited. Details of this ban were substantiated by a notification in 2007. Fish farms already established in enclosed bays and sensitive areas were to be reevaluated in accordance with the physical and chemical criteria indicated in the Tables 1 and 2.

EIA Procedures

A major component of this law (Table 3) regarding aquaculture activities is the need to execute an Environmental Impact Assessment (EIA), which is a process to define the environmental alterations that any developmental projects may have and, subsequently, to determine whether a project can be approved, or needs amending before approval, or must be rejected. MEU issues a special format for the EIA of a marine aquaculture farm, which defines the scope of the necessary investigations; a summary of this is given in Table 4.

In the context of the EIA regulations, it has also been pointed out that the international conventions for environmental protection ratified by the Turkish government should also be respected and considered within the EIA procedure. Those farms producing over 1,000 tonnes yearly have to prepare a full EIA report and those smaller than 1,000 tonnes per year are eligible for a preliminary EIA investigation.

Zone Management of Gulluk Bay

Two mariculture zones were defined in Gulluk Bay, Mugla. There was a Milas Zone and a Bodrum Zone as defined by a Turkish Inter-Ministerial Consortium, together with the Mugla Fish Farmers Association. We had Regional Environmental Impact Assessment studies for these two zones from the Ministry of Environment.

TABLE 4. The special format used in an application for an EIA report in connection with the establishment of an aquaculture project (MEF, 2008).

Chapter I: Detailed description of the project, including its feasibility.
Chapter II: Detailed description of the environmental characteristics of the area in which the farm will be located. Given that the project will have an impact on both the immediate area and its surroundings, such a report is required of applicants.
Chapter III: Identification of impacts of the project on the environment and the necessary precautions to be taken to mitigate any effects.

The following points are specified in the EIA in order to assist the management process:

- The cage-net can only occupy a maximum of ⅓ of the water column.
- Eighty-one fish farms are to be established in 50 parcels with a capacity between 300 tonnes to 3,000 tonnes. In each parcel there can be 2 to 4 fish farms.
- Distance between the parcels should be a minimum of 400 m to a maximum 5.6 km.
- The area of parcels should be between 8,400 m^2 to 92,500 m^2. A maximum of four farms can share the same parcel.
- Fish farms in the same parcel will share the common responsibility of business agreements, according to which they have to take necessary precautions to avoid pollution. If pollution is detected and the source is not defined, all fish farms in the parcel will be held responsible.
- The fish farms within the common area (each parcel), should operate in harmony and within the assigned area. Thus the cages cannot be moved or expanded in an area without the permission of the ministries.
- The mooring systems to be established, together with their maintenance and checks, within the common area should be done in collaboration.
- Warning signalization to limit and identify the positioning of cages must be constructed. This is for

FIGURE 4. A barge near a fish farm in Gulluk Bay, Mugla.

labelling and providing a guard for safety of life and property. Marine traffic operators should be involved in this.
- Within this EIA there was no allowance for land logistics. All activities including social needs of personnel, food storages and automatic feeding machines should be constructed on barges (Figure 4).

These points are important for the management of the zone. But, unfortunately, the boundaries of each parcel within the zone and farms within each parcel are not properly defined for the purposes of management. Therefore the cumulative effect of individual elements cannot be identified and rectified.

The Monitoring

Mugla Fish Farmers Association uses accredited laboratories to analyse the TRIX index twice a year, for all fish farms in the two allocated zones. All data is sent to the Ministry of Food, Agriculture and Livestock and to the Ministry of the Environment. According to monitoring regulations, labs must sample the water at surface level, in the water column and in the benthic zone including sediment for analysis. But there is no holistic thinking on environmental management at the Bay level. Our project called "Project for the Establishment and Development of Environmentally Sustainable Eco-Friendly Fish Farming Systems in the Aegean Sea 2014–2015" is piloting this process. But it needs to be upgraded and formalized.

Health monitoring is done by the MFAL for each farm. But the requirements at parcel and zoning levels need more precise definition. Whereas some big companies use a very effective monitoring system along the lines of certificates like GLOBAL GAP, BRC, ISO 22000, ISO 14001, ISO 9001, HACCP, and IFS, unfortunately small farmers often fail to do this. Some farmers follow certification schemes but there is currently no generally used compulsory Code of Practice.

The two mariculture zones were evaluated separately in Gulluk Bay (Figure 2). An appropriate Environmental Impact Assessment (EIA) was performed at the time of the establishment of these aquaculture zones (EIA, 2008).

2.3 Zoning Process

2.3.1 Choosing the Tools for Spatial Planning

The general ICZM (Integrated Coastal Zone Management) rules propose that all required monitoring and analysis procedures must be implemented to identify the natural and human-induced stresses on the marine environment, and to resolve potential conflicts of interest. In order to realize this goal, before executing any action, suitable, practical and reliable indicators should be determined. In terms of environmental analysis and evaluation, Geographic Information Systems (GIS) is a very useful tool, not only for capturing, storing, organizing, displaying and reporting of information but also for analyzing and modeling of spatial data (Kapetsky and Aguilar-Manjarrez, 2007). Some difficulties in data sharing among the related disciplines or institutions to develop the full potential of GIS have been challenging. The spatial analysis of the mariculture zone Gulluk Bay has been completed (Yucel-Gier *et al.*, 2013) and sent to the corresponding ministries.

2.3.2 Estimation of Aquaculture Potential

There have been several studies of the selection of areas for suitable fish farming in Turkey. Legislation has put a stop to fish farming activities in the gulfs and bays of Izmir and Mugla. Potential area studies for fish farm location were conducted at the administrative level and in coordination with other ministries in 2008. First, a subdepartment of the Ministry of Food, Agriculture and Livestock (MFAL), the Aquaculture Department of the Directorate General for Fisheries and Aquaculture, identifies drafts of potential aquaculture zones. It uses its own experts and researchers, paying attention to concerns of all other coastal sectors and users. It is the main authority for all aquaculture activities.

The Ministry has to map all identified zones and send the results to all related ministries and institutions, in order to obtain their opinions. These ministries reply to MFAL giving their opinions. MFAL then organizes some field trips and invites the related ministries to participate. A commission of experts and administrators representing all ministries and including local representatives of ministries and fish farmers visits the identified potential zones. They meet several times to discuss and achieve a consensus to determine the final potential zones for aquaculture. They also prepare a report on the decisions taken. The Undersecretaries of MFAL, the Ministry of Environment and other related ministries then sign a Protocol on the agreed zones. After the field visits, MFAL sends a final version of potential zones to the Ministries to have their final say. The Official Gazette then publishes these zones as "Allocated Zones for Aquaculture" and distributes this information. For example for Gulluk Bay this process took six months. The Ministry then requires that the AZA for Gulluk Bay makes an EIA study. Other stakeholders are to be involved in this process. For example the Karaburun peninsula (Izmir) was originally selected (Figure 5). As long as area A is inside Izmir Bay it is identified based on criteria listed in Tables 1 and 2, and as areas B and C are outside the bay, there are no conflicts in the administrative level. In time the studies about monk seal existence were brought to daylight, so A and B were canceled. However new criteria and formulations for carrying capacity are now being researched IMST-216, 2013.

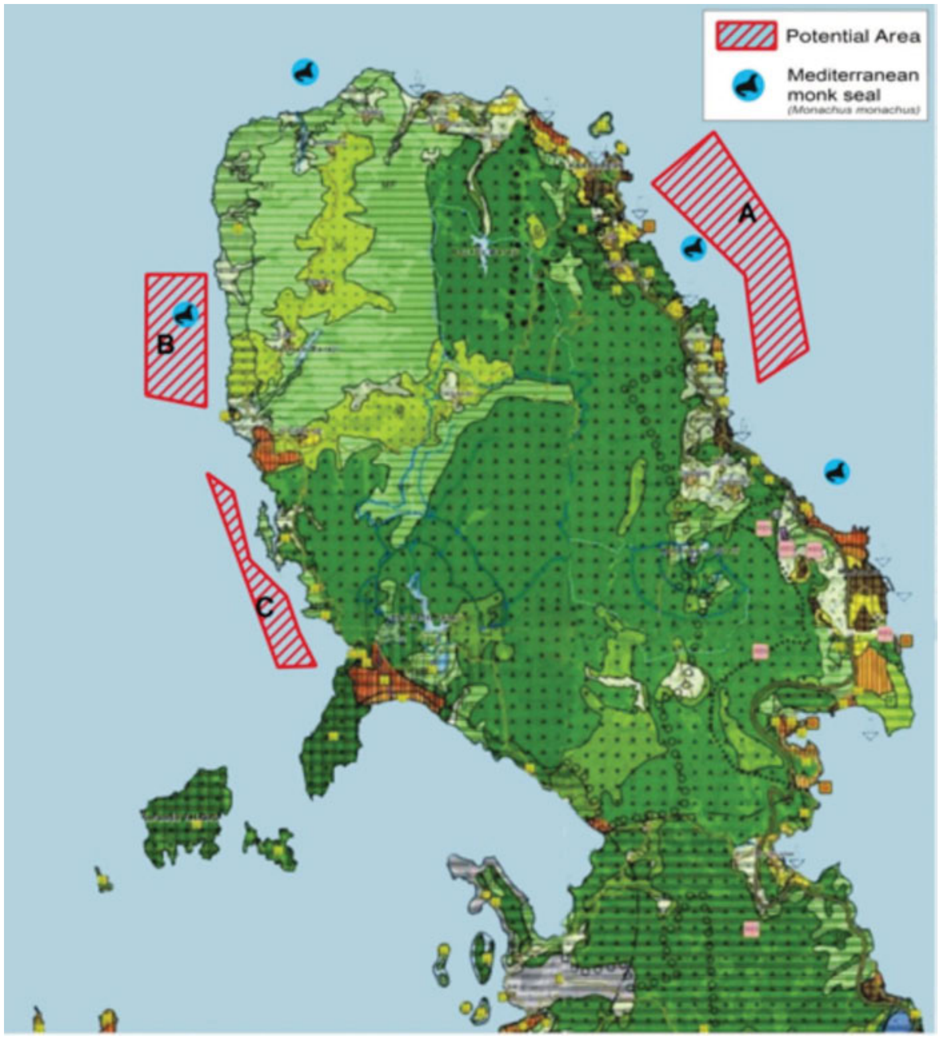
3. MONITORING

3.1 Regulatory and Legal Aspects

The Ministry of Food, Agriculture and Livestock (MFAL) and the Ministry of the Environment and Urbanization (MEU) are authorized to control the water quality, sediment in the aquaculture area, and the food health and quality standard on the farms (Figure 6).

The criteria of water pollution (Table 5) has been updated especially for aquaculture. According to standard monitoring programs, the owners of fish farms were asked to monitor the area in the proximity of the fish farm twice a year in the water column (Table 6). This notification also included the limits for a relevant parameter, defined as the TRIX index. The TRIX index was originally proposed by Vollenweider, *et al.* (1998). In the notification it is defined as: TRIX index = [log (Chl-a $\times$ %O_2 $\times$ TIN $\times$ TP) + 1:5] $\times$ 0:833.

FIGURE 5. An investigative example of the potential field of marine aquaculture on Karaburun Peninsula in Izmir Province (MEF, 2008).



Each of the four components represents a trophic state variable:

Chl-a = chlorophyll-a concentration, as µg L^{-1};

$\%O_2$ = Dissolve Oxygen Deficit percentage;

TIN = Total dissolved inorganic nitrogen ($N–NO_3$ + $N–NO_2$ + $N–NH_4$), as µg L^{-1})1;

TP = total phosphorus, as µg L^{-1}.

Each year in May and August the results of this monitoring programme must be submitted to the MEU. Regarding the benthic sampling one time every 3 years is sufficient. Sampling is done at five locations (one station is at the centre of the fish cages and others at 20 m distance, at all sites cages) in 3 different depths (the surface, mid-water and bottom of the water column) (Table 6). Reference stations change in the dominant current direction between 500–1,000 meters (Figure 7).

The sample analyses are made at private or public laboratories authorized by the MEU. The monitoring programme is to be done for each parcel in the Mariculture zone in Gulluk Bay. The correct coordinates and monitoring of safety signals of the farm area in relation to marine traffic is controlled and supervised by the Coast Guard and by the Undersecretary of Maritime Affairs.

FIGURE 6. Monitoring procedures.

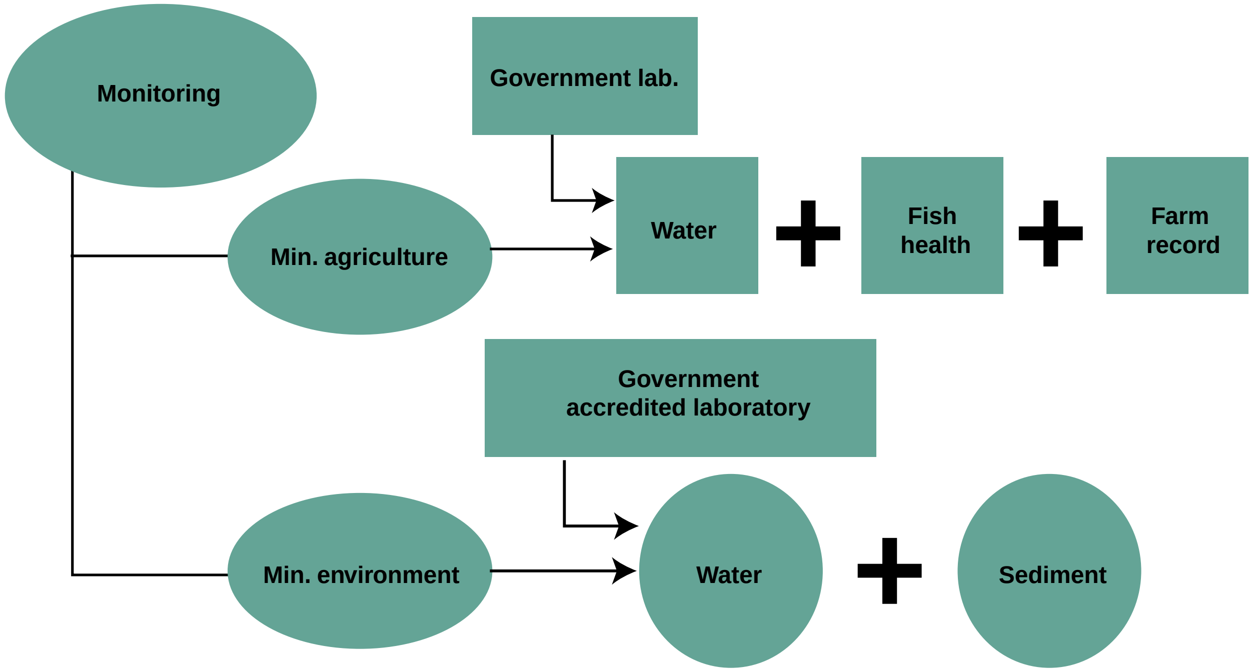


TABLE 5. Water pollution control regulation (MEF, 2004).

Parameter	Criteria
pH	6.0–9.0
Total suspended solids (mg L^{-1})	30
Dissolved oxygen (mg L^{-1})	More than 90% of saturated oxygen
Biochemical oxygen demand, BOİ5, mg/l	
Crude oil and derivatives	0.003
Chl-a, µg/l	Original chl-a levels will be used
Phenol (mg L^{-1})	0.001
Copper, mg/l	0.001
Cadmiyum, mg/l	0.01
Crom, mg/l	0.1
Lead, mg/l	0.1
Nickel, mg/l	0.1
Zinc, mg/l	0.1
Mercury, mg/l	0.004
Arsenic, mg/l	0.01
Total ammonia, mg/l	0.02

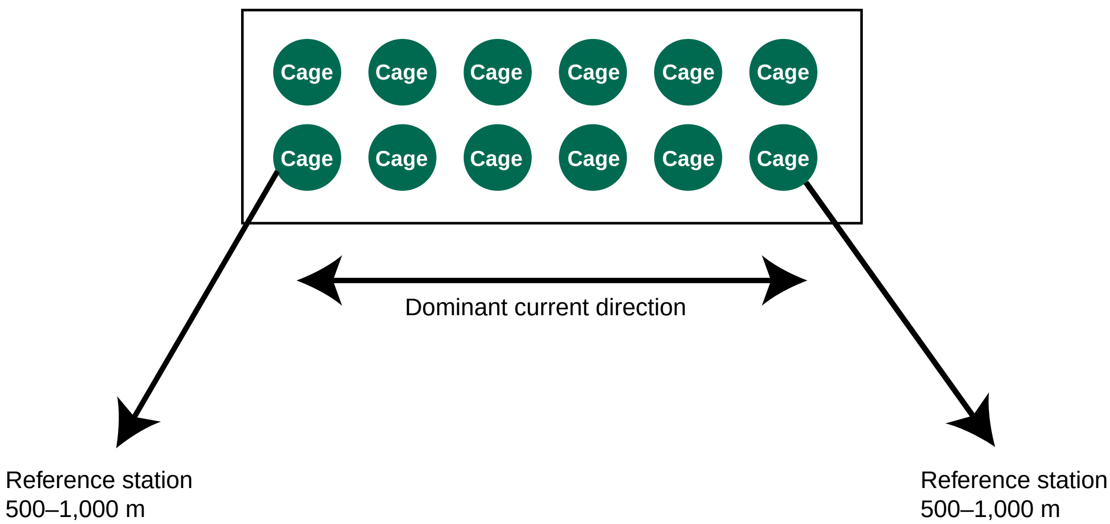
3.2 Evaluation

Several papers have been released about the trophic status index (TRIX) and its relation to water quality concern eutrophication in the coastal waters of the Turkish Mediterranean. They originate from a variety of interested parties (IU, 2006; MEDPOL, 2009). A thematic map based on the trophic index data is commonly used to assess eutrophication status. Figure 6 shows that high TRIX values appear, to a great extent, in shallow waters and in the vicinity of fish cages. The TRIX values that were taken in 2007 were at the bottom only and before any fish farms were moved to

TABLE 6. Monitoring regulations for fish farms (MEF, 2009).

Parameters	Water	Sampling Number/Times	Sediment
Temperature	x	5 sampling stations + 1 reference 3 depth levels Once/year	5 sampling stations + 1 reference point
Sechhi disc	x		
pH	x		
Salinity	x		
DO	x		
TN	x		
TP	x		
Ammonium	x		
Chl-a	x		
TOC			x
Beggiatobacteria			x
Bentic flora and fauna species			x

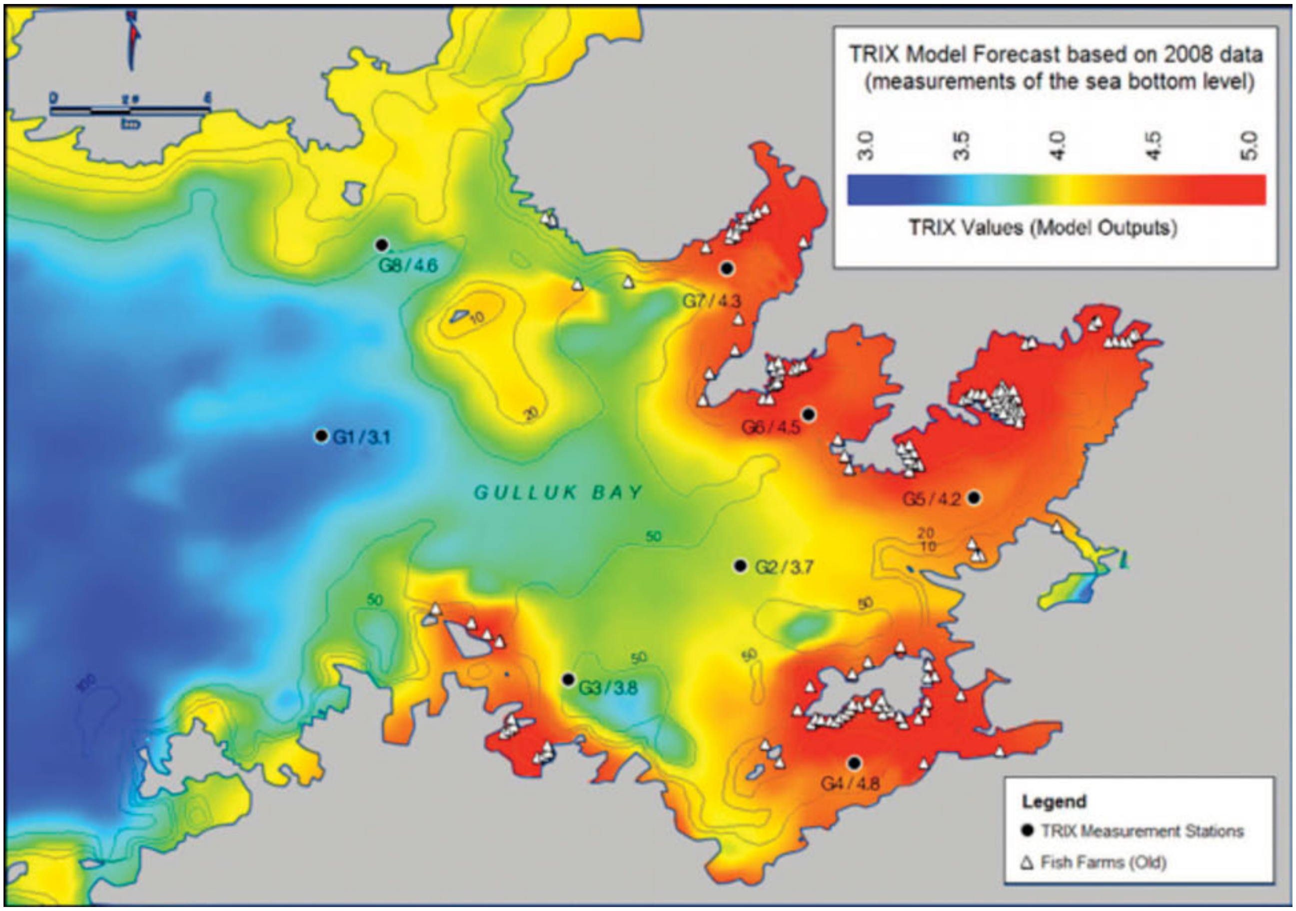
FIGURE 7. Monitoring regulations for fish farms (MEF, 2009).



the new mariculture zone. Water quality monitoring parameters, as TRIX values, ranged from 3 to 5. They were obtained from 8 stations which were represented as G1 to G8. Current pollution originates from remnants of previous fish farming activity, inadequately treated sewage, run-off from agricultural facilities or uncontrolled coastal development. From the TRIX data points, GIS software was used to interpolate TRIX values to create a map (Figure 8). On the basis of this map it is to be hoped that other maps will be constructed over time in order to monitor every sector of economic development along the coastline.

TRIX currently is only applied to an aquaculture area that is placed in a bay such as Gulluk Bay, which is now the preserve of holiday homes. Water is no longer tested. Continued monitoring is necessary so as to show whether or not an improved environmental quality has resulted from the moved fish farms. Gulluk Bay provides a case study with a combination of parameters that have to be carefully identified and precisely monitored. To this end legislation to compel all stakeholders to undertake TRIX examination of their facilities are recommended (Yucel-Gier *et al.*, 2011).

FIGURE 8. TRIX values interpolated from modeled outputs and old fish farming areas in Gulluk Bay (Yucel-Gier, *et al.*, 2013).



4. CARRYING CAPACITY

According to EIA 2008, the effect of impact on the environment by fish farms is calculated in consideration of the amount of food and amount of fish. FCR is 2 for sea bass and 2.2 for sea bream. Food not consumed by automatic feeding is calculated as 0.1 percent. For other feeding processes 12 percent is estimated. The amount of nitrogen (N) and phosphorous (P) are calculated according to these numbers. In the TUBITAK's (2010) report, a project in which the MERAMOD software was used, a map of the distribution of the organic matter from the fish farm was made. Within the IMST-216 2013 project, some modules of this software are in the pipeline, hopefully to be operated on.

5. MANAGEMENT

The management is done according to the following points specified in EIA, 2008. The monitoring programme is based on parcels. In addition to that the big companies are required to use certification systems, for example ISO 9000 and ISO 14000, not because of legislation but as a matter of marketing procedures. Some prestigious certifications are mentioned in Table 7.

TABLE 7. Certificates for fish farm cages.

GLOBAL G.A.P. (Good Agricultural Practices)
ISO 9000—Quality management
ISO 14000—Environmental management
OHSAS 18001 Health and safety management certification
ASC (Aquaculture Stewardship Council)—The ASC uses market forces to transform monitoring compliance with standards at the farm level.

6. COSTS

The overall expense of relocation of the fish farms in Gulluk Bay has been calculated by average production. Taking a farm of 1,000 tonnes and calculated (Table 8) across 81 fish farms in Euros we reach an average relocation cost of €82,619,514. No support was given during the relocation process. For this reason many fish farmers, especially small farmers, were obliged to sell their licence to big farm owners.

Monitoring cost is €1,071 per farm. This is done twice a year and paid by the farmer. (Source: Mugla Fish Farmers Association.)

TABLE 8. The fixed investment for a 1,000 tonnes sea bass and sea bream facility (EIA, 2008).

Project Study	€2,777
Construction	€888,790
Equipment	€108,433
Unforeseen costs	€19,992
Total	€1,019,994

7. DISCUSSION

Advantages

Water quality and depth improved after relocation. This has benefited production. Fish farms have increased their capacities. Regarding the social aspects, the improved quality of the inshore water has lead to a decrease of conflicts. Monitoring was able to be done in a more organized way.

Disadvantages

Due to the financial overload many small fish farms have gone out of business. Although there has been no specific study, it seems that more people used to work on farms in this bay before relocation. During the relocation process the coordinates of fish farms were not marked on the navigation map. This has caused marine transport accidents. Another disadvantage is in the case of a disease. It is more difficult to control infections when fish farms are located all together.

Weakness

Social Challenges and Benefits

As fishery production declines, aquaculture production increases in importance for public consumption. Moreover, the fishing close season lasts about 4.5 months. With mariculture there is access to fish at all seasons. Moreover, it provides job opportunities in the local area so it is also an economic support. However negative publicity about aquaculture products still goes on. Therefore, the result of monitoring must be shared with both the local authority and the consumers in order to increase transparency.

8. CONCLUSION

Aquaculture zoning, site selection and aquaculture management are among the most important issues for the success of aquaculture and need to be carried out in accordance with sustainability and best practice guidelines. Turkey has also focused recently on such issues and tried to set guidelines which will enable true sustainability to take place. When we look at the whole EIA process it needs the estimation of carrying capacity and harmonisation with monitoring and a management system to be used.

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ANNEX 1. CASE STUDY EFFECTIVENESS MATRIX

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	Inter-Ministerial Consortium with Muğla Fish Farmer Association defined the area.	GIS map of whole bays not made by the Ministry.	• Background documents; • Participatory meetings; • Participatory map at Google level/ sketch maps; • Nautical charts.	4	
1.2 Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	Aquaculture rights defined very well by law. Ecosystem—water quality is defined very well.	Land logistics is not defined. All logistics projected to take place on the barges. In the map, shipping lanes had not been marked. Poor benthic model.	• Review of relevant policy and legal framework of 5 Mediterranean countries; • Consultations with relevant institutions.	3	
1.3 Setting the broad development objectives and identifying the main issues	Ministry with AZA gave aquaculture economic parity with other stakeholders.	Only main objective assets. No details for socioeconomic study.	• Communication, consultation participation.	3	
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.4 Zone boundary definition based on relevant criteria	Mariculture zone selection is based on defined zone selection criteria. Creation of buffers to protect *Posidonia* beds, TRIX levels.	Essential environmental socioeconomic and governance criteria were identified for zone, as well as risk (e.g., climate change).	• Participatory meetings; • Literature review and Internet searches; • Identify and prioritize data needs and data sources according to species and culture systems; • Mapping and analysis using GIS and remote sensing data (e.g., water supply, water quality, climate, hydrological characteristics, soil characteristics, topography, sensitive habitats, protected areas, population settlements, etc.). • Use of TRIX index, etc; • Depth 30 meters.	3	

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.5 Gross estimation of potential production/ area	Consumed and unconsumed food was calculated according to the planned capacity of fish production. N and P ratios that were released are defined.	It was not united and related with other parameters (for example: current).	• Modelling not extensively used.	3	
1.6 Formal allocation of the zone for aquaculture purposes	Zones were allocated at national level (by ministry) giving aquaculture priority use of AZA.	No local level participation.	• Official Gazette published and EIA process starts and stakeholders are informed.	3	
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	Suitability thresholds for species and culture systems for the site defined and consulted.		• A very wide ranging project is under way at IMST to be published in 2015.*	4	
2.2 Carrying capacity estimation	TRIX index is basic to Turkish aquaculture legislation. MERAMOD toolbox was used in this project.*	Extensive GIS work done by Gier previously was not built on.**	• Use of TRIX index.	3	
2.3 Set license production limits within zone or water body carrying capacity	Consumed and unconsumed food was calculated according to the planned capacity of fish production. N and P ratios that were released are defined.	The importance of benchmarks was not exploited. Risk assessment studies need developing.	• EIA	3	
2.4 Allocation of licenses and permits	Allocation of licences was done through equal user access rights, under adequate regulation and minimum distance between sites.	Licensing practise needs "one window" consolidation. Regular meetings of stakeholders need establishing.	• Ministries of Environment and Agriculture need to negotiate single window license agreement.	3	

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant water body or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries	Big companies management is good. They use self certification system.	Boundaries and hydrodynamic features within the AZA need better definition to improve management potential of small farms.	• Participatory consultations; • Hydrodynamic models; • Depth and current maps; • GIS and remote sensing data and tools; • Risk maps (e.g., for algal blooms, surge, etc.); • Use of all these tools needs to be improved.	3	
3.2 Estimate total carrying capacity if appropriate based on the different risks	Generally a full economic and environmental risk analyses programme is needed.		• Risk assessment for health, financial and climate change.	2	
3.3 Organize a formal association of all farmers in that area	There is an area management structure with identified leaders and supporting technical groups/ services.**	Farm association needs to be stronger.	• Facilitated participatory tools; • To investigated future global problems; • Guidelines for management on which all fish farmers agree.	3	
3.4 Setting the broad development objectives and identifying the main issues. Agree on common management,[1] monitoring and control measures	A rudimentary framework exists.	EAA toolbox not used.	• EAA toolbox.	3	
3.5 Monitoring of relevant variables and enforcing management measures	There is an integrated monitoring system of the environmental and fish health conditions (only for individual farms).	Management is done by farmers themselves and there is an area certification scheme.	• Monitoring systems developed by stakeholders; • Enforcement discussed and endorsed by local communities; • EAA toolbox.	3	

1 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.1 Regular monitoring and evaluation	There is a regular monitoring programme.	Analyses of parameters could be sharpened. The absence of detailed GIS mapping does not provide clear distribution patterns.	• Assessment of management plan; • Consultation with relevant institutions and with the local communities; • EAA toolbox.	3	
4.2 Periodic review and adjustment	IMST project called "Project for the Establishment and Development of Environmentally Sustainable Eco-Friendly Fish Farming Systems in the Aegean Sea 2014–2015" facilities this.	The Ministry must make this a regular process.	• Modifications to the management plan are considered every two years. New threats or emergencies are tackled as appropriate; • EAA toolbox.	3	
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**		**Approximate production from each aquaculture zone or AMA**		
Number of zones and range of implementation	2 zones		88 farms/total production; 60,000 tonnes in 2013.		
Other notes	**Positive issues**		**Negative issues**		
(especially social issues)	Muğla Fish Farmers Association signed an agreement with EIA level for some management points.		Monitoring results are not accessible to the public. People still have negative image.		

*Project for the Establishment and Development of Environmentally Sustainable Eco-Friendly Fish Farming Systems in the Aegean Sea. 2014–2015.
**Yucel-Gier, G., I. Pazi, F. Kucuksezgin, 2013. Spatial Analysis of Fish Farming the Gulluk Bay (Eastern Aegean) Turkish Journal of Fisheries and Aquatic Sciences 13: 737–744.

Aquaculture Parks in Uganda

Nelly Isyagi[1]

ABSTRACT

Fisheries are Uganda's third most important source of foreign exchange contributing to the livelihoods of about 5.3 million people. To sustain economic growth arising from the sector, an additional 300,000 tonnes/year of fish is required. However, Uganda's natural waters have reached their maximum sustainable yield. Large scale commercial aquaculture offers the only feasible option through which the additional production needs can be achieved within the medium term. Currently, aquaculture production is from isolated small farms that make it difficult to establish production and marketing value chains. Increasing the number of such units shall pose challenges for environmental management.

The Government of Uganda decided to investigate the facilitation of small/medium scale aquaculture development through the development of "Aquaculture parks" (or clusters of farms) located within designated high aquaculture potential areas. This case study describes the government of Uganda steps to identify potential aquaculture areas/zones, and undertake feasibility and economic studies for land based and lake based aquaculture parks. It is an example how a country that has a relatively low level of aquaculture production can identify potential zones and plan area management of those aquaculture zones as a way forward towards responsible and sustainable aquaculture development.

Considering the level of investment and production objectives of Aquaculture Parks, for success and sustainability, it is critical that they be established within appropriate zones. Environmental, social and economic characteristics will determine the location, number, size and appropriate operating systems of the parks. This approach will increase likelihood of success and sustainability.

1. BACKGROUND

Fish is among Uganda's third most important sources of foreign exchange (UBoS, 2013).The fisheries sector employs about 1,000,000–1,500,000 people directly and indirectly through fishing, processing and marketing. Overall, it contributes to the livelihood of about 5.3 million people (MAAIF, 2012).

The sustainability of the fisheries sector has become vulnerable because sustainable fishing yields cannot meet the country's ever increasing demand for fish. Catches have averaged 350,000 tonnes/year over the last ten years while the country's population growth rate is about 3.6 percent per annum (UBoS, 2013). It is also estimated that 75 percent of the major commercial species of export grade[2] caught from Lake Victoria are exported, and only 25 percent is left available for the local market (Kabahenda and Husken, 2009). National annual per capita fish consumption rates have

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

2 Export grade refers to fish caught within the legal size limits and handled as recommended where major emphasis is placed on hygiene and cold storage.

Isyagi, N. 2017. Aquaculture Parks in Uganda. In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document*, pp. 332–357. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

consequently fallen from about 14 kg before 1990 to between 4 kg to 8 kg after 1990 (Ssegane, Tollner and Veverica, 2012).

Levels of fish supply have raised socioeconomic and food security concerns. To sustain the benefits from the fisheries sector, it is estimated that an additional 300,000 tonnes of fish should be produced from aquaculture (MAAIF, 2012). The likelihood of this being achieved under the current aquaculture setting is low. The current aquaculture setup is characterized by isolated and widely dispersed smallholder operations.

There are about 10,000 ponds averaging 200 m across Uganda (FAO, 2005). Despite high levels of public investment to uplift the sector, aquaculture has failed to register a significant contribution to the national catch. Among the major bottlenecks that have continued to affect production are high investment costs, feed, seed, appropriate production systems and markets. Levels of pond production are consequently often low. The fact that fish farms are small, isolated and widely dispersed has further hampered the establishment of appropriate value chains.

Consequently, the Government of Uganda has shifted its development focus and it is now geared towards producing large volumes of fish from designated zones. The purpose of this approach is to stimulate sectoral development rather than just farm development. The establishment of appropriate commercial production and marketing chains will help address the major bottlenecks currently affecting the expansion of aquaculture in the country. These are supplies of commercial feed and seed, development of appropriate production systems, marketing channels and access to technical services.

The government of Uganda is investigating the possibility of promoting small/medium scale aquaculture clustered in "Aquaculture parks" that shall be located within designated high aquaculture potential areas. The location of these zones within areas of high aquaculture potential is to prevent haphazard development with a high likelihood of negative environmental consequences and subsequent failure. Essentially, the Aquaculture Parks will be concentrated areas of production that shall function as commercial industrial parks of fish production (Wathum and Rutaisire, 2008 and MAAIF, 2012).

This case study describes the governments steps to identify potential aquaculture areas/zones, and undertake feasibility and economic studies for land based and lake based aquaculture parks.

2. SCOPING

2.1 Setting Broad Development and Management Objectives

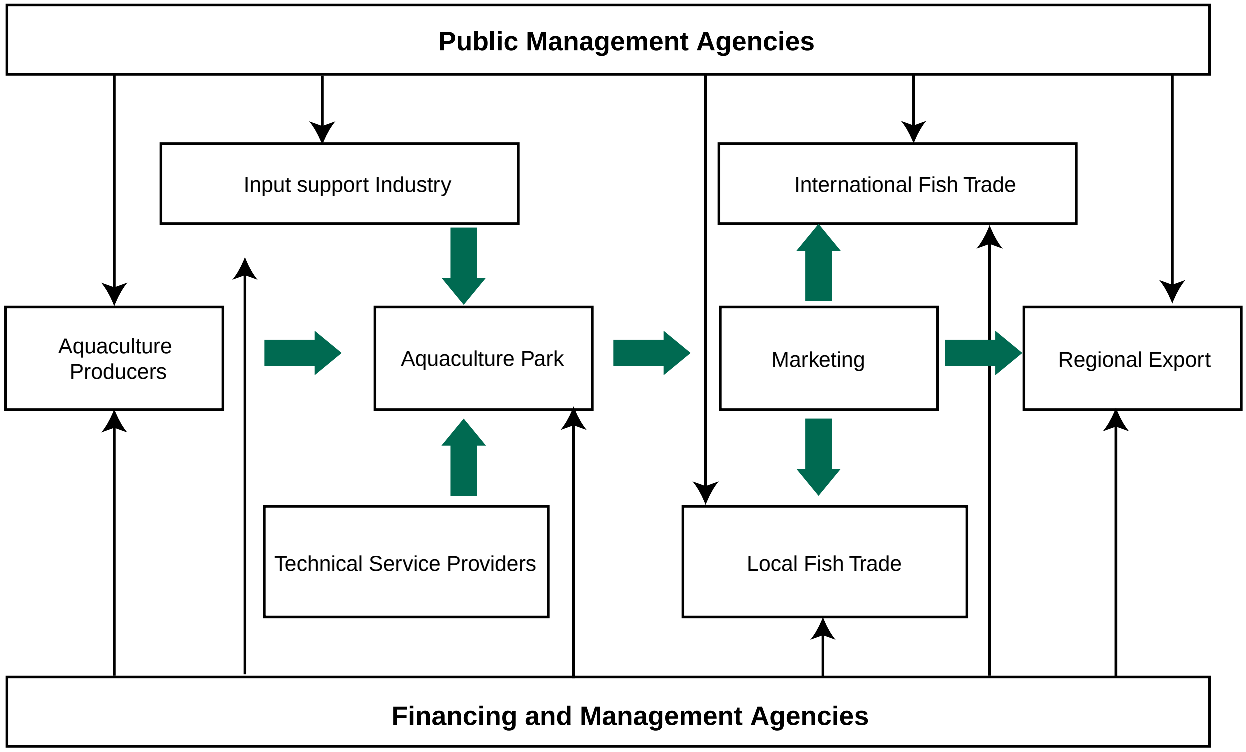
Broad Development Objectives

The broad development and management objectives for Aquaculture Parks are stipulated in the Aquaculture Park Investment Policy (MAAIF, 2012). According to this policy, Aquaculture Parks shall be avenues through which commercial producers are clustered within a specified area out of which viable levels of production that attract desired market segments and stimulate the development of 'Aquaculture Park value chains' can be achieved. This concept is illustrated in Figure 1.

The specific development objectives for Aquaculture Parks in Uganda are (Mugabira *et al.*, 2013):

1. To increase the value of aquaculture production from the present average of US $180 million annually to at least US $600 million.
2. To increase the volume of aquaculture production from 90,000 tonnes to 300,000 tonnes annually.
3. To identify, assess and support the development of infrastructure and utility services for potential sites on land and water, each promoting at least 5,000 tonnes annually.
4. To identify and attract potential investors for aquaculture production and associated inputs.
5. To organise rural smallholder fish farmers into producer groups that can compete for the operation and management of aquaculture parks.
6. To promote sustainable management and operational systems through associations of Aquaculture Parks.

FIGURE 1. Aquaculture Parks value chain process map.



Source: MAAIF (2012).

7. To promote coordination among the respective public and private agencies in the development and management of Aquaculture Parks.
8. To build capacity in the private sector and at central and local government levels.
9. To support, regulate and guide the development of Aquaculture Parks.
10. To develop and adopt environmentally friendly aquaculture technologies and practices.

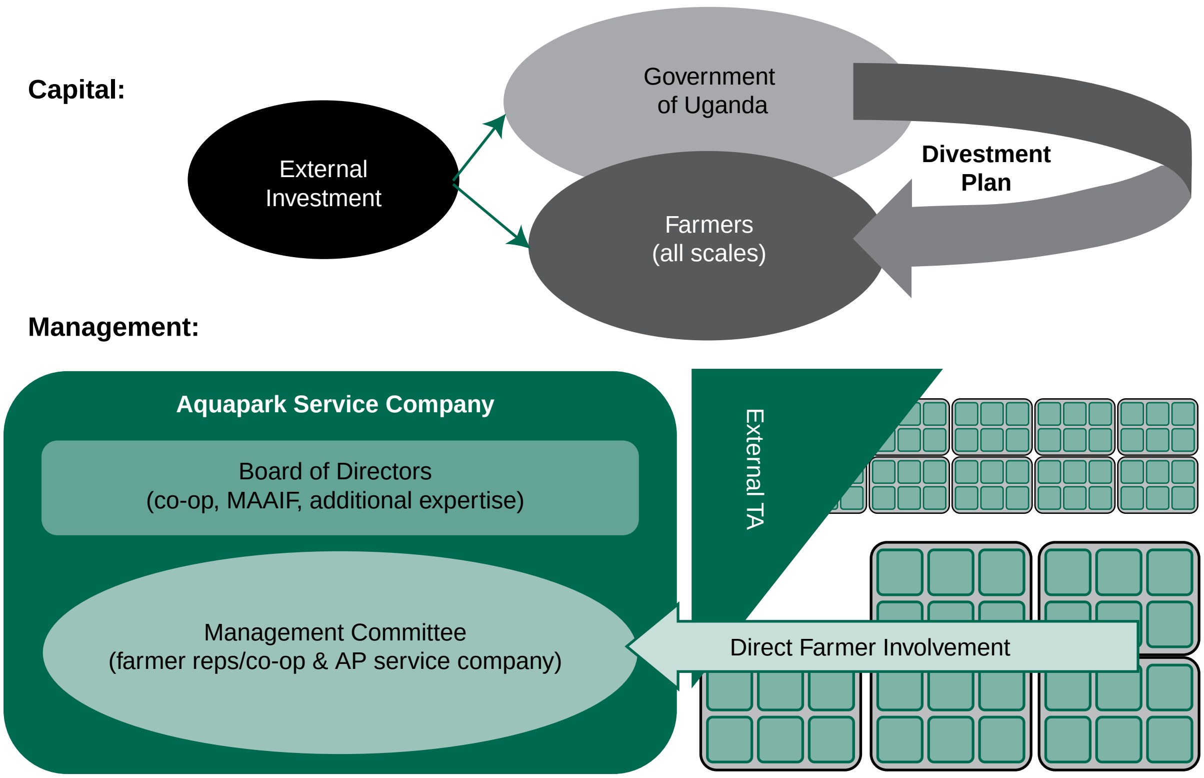
The development of aquaculture parks in Uganda should consider environmental, social, economic and governance aspects. The use of appropriate aquaculture production systems that match the available resources is advocated for. In addition, so is the participation of both the public and private sector in a positive manner whereby both parties contribute equitably depending on their comparative advantage.

Management Objectives

It is proposed that the Aquaculture Parks be run as independent self-sustaining Public-Private-Partnership enterprises that can within the legislated framework sustainably produce and market up to 5,000 tonnes of fish per annum (MAAIF, 2012, Mugabira *et al.*, 2013). This PPP may be in association with a large-scale private sector partner that directly invests in the park or pays a fee to the government to produce within the park (the nucleus estate model). The APs are to be managed based upon sound scientific principles. Thus research and training institutions shall play a key role in ensuring appropriate technology is developed and effectively adopted by appropriately trained personnel, farmers inclusive.

Figure 2 illustrates the Aquaculture Parks conceptual business management model and the roles of the private and public sectors in securing capital and in

FIGURE 2. Proposed Aquaculture Park company structure (MAAIF/EU, 2013).



Aquaculture Parks management. It is proposed that the Aquaculture Parks be managed by an independent service company overseen by a Board of Directors. Farmers would in this case participate in the management through representatives or their cooperative. Initially the Government finances would be used to establish the Aquaculture Parks. A share offer (open to prospective farmers initially) would help recoup a proportion of the capital costs and provide working capital for the farm (purchase of equipment, feed, labour, etc., ahead of revenue from production). The Aquaculture Parks would then become self-supporting.

2.2 Legal, Regulatory and Institutional Frameworks

Aquaculture Park policy activities are coordinated by the National Planning Authority of the Ministry of Finance, Planning and Economic Development. However, the Fisheries Resources Department under the Ministry of Agriculture Animal Industry and Fisheries plays the leading role in implementing these policies with the help of Local Government. Other key lead agencies playing a key role in Aquaculture Parks development are the Directorate of Water Resources in the Ministry of Water and Environment, Ministry of Lands and Urban Development and Ministry of Tourism, Trade and Industry. The key statutory bodies involved are the National Environment Management Authority, Uganda Investment Authority and Uganda Wildlife Authority.

The principle policies that guide the development and management of Aquaculture Parks are the National Fisheries Policy and the National Aquaculture Parks Investment Policy. A summary of these and other key policies is described in Table 1.

The primary regulations governing aquaculture are summarized in Table 2.

TABLE 1. Policies directing Aquaculture Park development in Uganda.

Policy	Overall Goals
The National Fisheries Policy, 2004	To ensure increased and sustainable fish production and utilisation by properly managing capture fisheries, promoting aquaculture and reducing post-harvest losses.
The National Aquaculture Parks Investment Policy, 2012	To create a competitive, market-oriented and environmentally responsible aquaculture industry.
The National Water Policy, 1999	To attain an integrated and sound water resources management regime that balances economic, ecological and health priorities. This includes water for agricultural production, under which water for aquaculture use falls.
The National Policy for Water for Agricultural Production, 2011 (draft)	The provision of water for increased agricultural production and productivity through coordinated interventions targeting water for crops, livestock and aquaculture. The need for this policy was realized based on the fact that the quantity and quality of water resources available to boost and sustain agriculture were receding due to an array of factors that included poor watershed management, inadequate water, harnessing capacity and rational use of water resources.
The National Agricultural Policy, 2013	To promote food, nutrition security and household incomes through coordinated interventions that focus on enhancing productivity and value addition, providing employment opportunities, and promoting domestic and international trade.
The National Environment Management Policy, 1994	This provides the overall policy framework to ensure sustainable social and economic development in the country that maintains or enhances environmental quality and resource productivity without compromising ability of present and future generations to meet their needs.
The National Policy for the Conservation and Management Wetland Resources, 1995	To ensure the protection and sustainable use of wetland resources so as to maintain their ecosystem function to include long-term interests of future generations.
The National Trade Policy, 2007	To develop and nurture private sector competitiveness, to support the productive sectors of the economy to trade at both domestic and international levels, with the ultimate objective of creating wealth, employment, enhancing social welfare and transforming Uganda from a poor peasant society into a modern and prosperous society.
The Uganda National Land Policy, 2013	To ensure efficient, equitable and optimal use as well as management of land resources for poverty reduction, wealth creation and overall socioeconomic development. The sustainable exploitation of land resources while safeguarding environmental sustainability is stressed.
Science and Technology Policy, 2009	To strengthen national capability to generate, transfer and apply scientific knowledge, skills and technologies that ensure sustainable utilization of natural resources for the realization of Uganda's development objectives.
The Uganda Food and Nutrition Policy, 2003	To ensure food security and adequate nutrition for all the people in Uganda.
The Public-Private Partnership Framework Policy, 2010	To enable the public and private sectors to work together to improve public service delivery through private sector access to public infrastructure and related services.

TABLE 2. Legal and regulatory framework.

Law	Content
The Constitution of Uganda, 1995	The main legislative body of the country offers every Ugandan the right to and responsibility for creating a clean and healthy environment.
The Fisheries Act, 1970	Provides the framework for the management and sustainable use of fishery resources so that sustainable benefits are realized for the people of Uganda. It covers fisheries, access to lakes for fishing and aquaculture.
The Water Act, 1997	Provides the framework for the management of water resources in the country, its use and quality control.
The National Environmental Act, 1995	Relates to the protection and preservation of the environment. It provides for various strategies and tools for environment management that include Environmental Impact Assessments.
The Land Act, 2010	Provides the framework with which land, ground water, natural streams, wetlands are held, managed and utilized for the common good of the people of Uganda.
The Local Government Act, 1997	Provides for the decentralization and devolution of Government functions, powers and services from the central to local governments and sets the political and administrative functions of local governments. The local governments therefore are responsible for the protection of the environment at local levels.
Uganda Wildlife Act, 2000	Protects the wildlife resources of the country (wild plant and animal species native to Uganda or that migrate through Uganda). It provides the framework for the sustainable management of these resources.
Regulation	Content
The Fish (Aquaculture) Rules, 2003	Stipulates the guidelines for the farming, breeding and marketing of fish and other aquaculture products. Permits and licensing procedures for aquaculture are provided for in these rules.
Uganda Statute on BMUs, 2003	Guides community involvement in fisheries management. Enables fishing communities to have rights of access and decision-making in the use of fishery resources within the framework of the National Fisheries Policy.
The Water Resources Regulations, 1998	The water resources regulations provide for the control of the extraction, discharge and pollution.
The Environmental Impact Assessment Regulations, 1998	Regulate in consultation with the Lead Agencies the use of the country's natural resources to ensure compliance with the National Environment Act. It provides criteria and guidelines under which EIAs should be undertaken, evaluated and monitored.

2.3 Consultation with Stakeholders

The development and adoption of the Aquaculture Park Concept has involved an almost ten-year participatory consultative process (Table 3). Stakeholder consultations between the public and private sector were done through all stages of concept development. These included public awareness programs. Within the public sector, the different key agencies notably fish/agricultural production, fish trade, water development and management, environmental management, local governance, community development as well as research and training were consulted. Within the private sector, producers, traders, fishermen, farmers, manufacturers, input suppliers, extension service providers and local communities were consulted. Development agencies were also consulted. Studies were done to advise the process (USAID, 2009, EU/MAAIF, 2013, EU/MAAIF, 2011).

TABLE 3. Documents in which zoning for commercial Aquaculture Development and/or Aquaculture Parks have been discussed.

Author	Title
MegaPesca, 2006	'Aquaculture in Uganda: A review of the sub-sector and a strategy for its development' suggests Aquaculture Parks as a possible option for expanding Uganda's aquaculture.
Wathum and Rutaisire, 2008	'Uganda National Aquaculture Development Strategy' mentions the establishment of aquaculture zones to ensure the development of commercial aquaculture is forwarded.
NORAD, 2009	Identification of Potential Aquaculture and Fish Processing Investment Projects and Partners in Selected Countries in Africa.
EU/MAAIF, 2011	Study on Promoting Commercial Aquaculture in Uganda. Recommends support for zoning exercise to identify priority areas for aquaculture development.
MAAIF, 2012	National Investment Policy for Aquaculture Parks in Uganda.
MAAIF, 2013	Feasibility Study for Development of Infrastructure for Water for Production in Uganda.
MAAIF/EU, 2013	Feasibility Study to design, cost and operationalize model commercial Aquaculture Parks in Uganda.

As a result of this process, the Aquaculture Working Group that comprises representative stakeholders from both the private and public sectors was set up. The role of this working group is to continuously advice and give feedback on policy and the status of commercial aquaculture development in the country (MAAIF, 2012).

The outcome of this process has been the Concept of Aquaculture Parks. The feasibility of undertaking this approach has been found to be potentially among the most viable options for promoting sustainable aquaculture development in the country, in a manner that accommodates smallholder producers and stimulates rural development. None of the above studies undertook spatial analysis.

3. ZONING

3.1 Definition of Boundaries

Boundaries to define boundaries for aquaculture zoning in Uganda have not yet been defined so far. The identification of areas with high potential for aquaculture has so far been based on information that could easily be obtained from secondary literature and participatory rapid site appraisals. Broadly, zones had to be based on criteria defined by MAAIF (2013) such as:

i. *Political Boundary.* Sites for both land and water-based aquaculture had to be within the jurisdiction of Uganda.
ii. *Water Management Zone.* Areas with adequate year round water supply of suitable quality. Hence internal zonal boundaries cut across political district boundaries.

3.2 Assessment for Aquaculture Potential

3.2.1 Identification of Areas Suitable for Fish Pond Culture

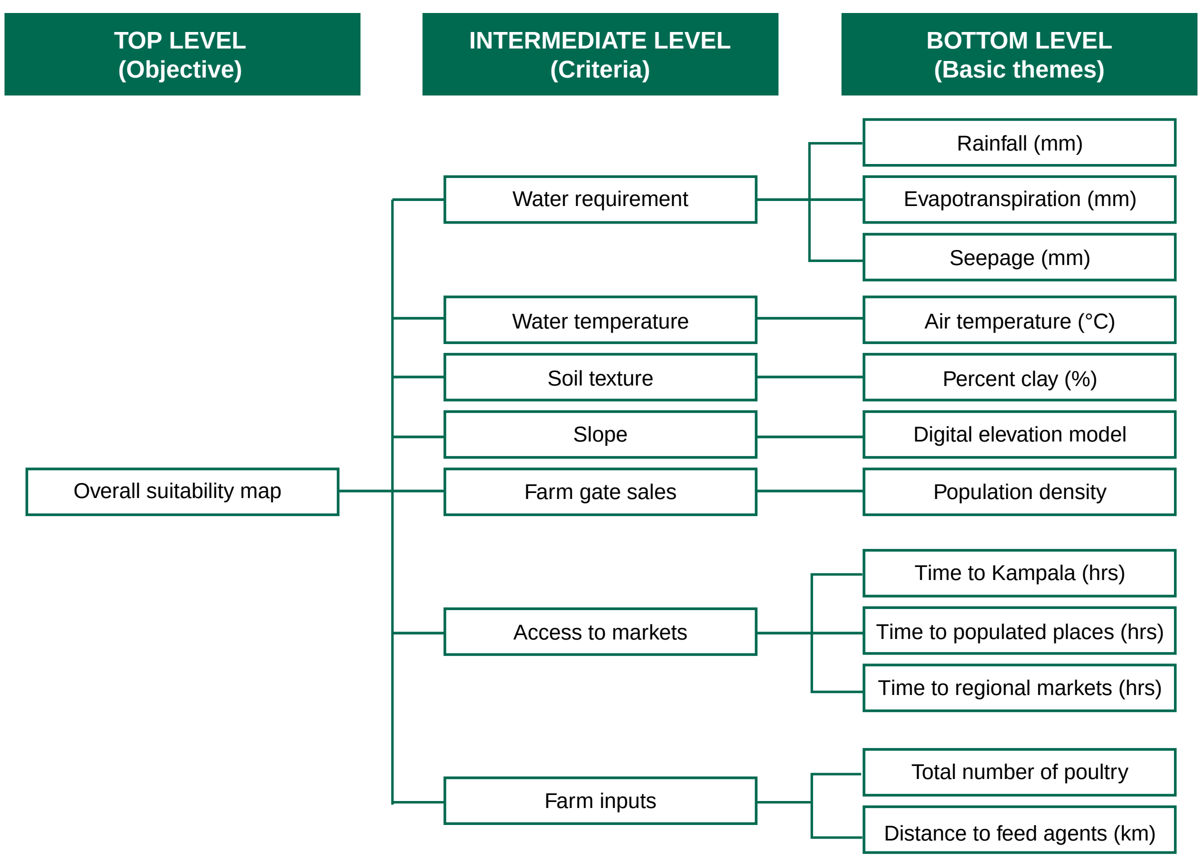
Uganda has the potential to support commercial aquaculture. A continental assessment on fish farming potential in Africa by Aguilar-Manjarrez and Nath (1998) indicates Uganda has favorable conditions for aquaculture. This was largely attributed to Uganda's water resources and climate. Eighteen percent of Uganda is covered by water and its average precipitation is about 1,000 million per annum. Ambient temperatures range between 16–30°C. In addition, because Uganda lies along the equator, air temperature and day-length fluctuations are low permitting year round fish growth.

Uganda's freshwater resources are suitable for cage, pond and tank based aquaculture systems. Its agricultural and fisheries sector produce all the raw materials required to make commercial fish feeds, except for some of the micro ingredients such as mineral and vitamin premixes. The country already makes commercial extruded fish feed. The species of choice for commercial aquaculture, the Nile tilapia (*Oreochromis nilotics*) and African catfish (*Clarias gariepinus*) are indigenous to the country. They are fast growing and have been proven under local commercial production settings (EU/MAAIF, 2011).

Uganda's local and external market potential for fish is also good. Uganda is traditionally a fish eating country. The country also has established marketing channels for fish that it cannot satisfy within the region and internationally. A well-developed fish processing sector that is underutilized due to inadequate supply of raw fish is in place. Increased fish production from aquaculture would benefit from the already present fish processing infrastructure.

Information from previous assessments (MAAIF, 2013) and Ssegane, Tollner and Veverica (2012) were used to evaluate the potential for pond aquaculture. Ssegane, Tollner and Veverica (2012) provides a comprehensive spatial assessment for the potential of pond-based aquaculture in Uganda. Seven criteria (water requirement, water temperature, soil texture, terrain slope, potential farm gate sales, availability of farm inputs, and access to local and regional markets) were analyzed by Ssegane, Tollner and Veverica (2012) to determine site suitability for tilapia and clarias farming in Uganda. Figure 3 depicts the seven criteria used to assess site suitability for fish farming. For each criterion, the corresponding data requirements were defined as basic map themes.

FIGURE 3. Criteria used in geospatial modelling of sites suitable for pond fish farming in Uganda.



Source: Ssegane, Tollner and Veverica (2012).

Based on suitability thresholds, each criteria was classified into four suitability groups across the seven criteria (Table 4). The groups Include Very Suitable (VS), Suitable (S), Moderate Suitability (MS), and not Suitable or Unsuitable (NS).

The study by Ssegane, Tollner and Veverica (2012) revealed the areas around Lakes Victoria and Kyoga as being most suitable for pond aquaculture (Figure 4). The least suitable areas for pond production were the northeast and southwestern parts of the country due to prolonged dry spells and low temperatures respectively.

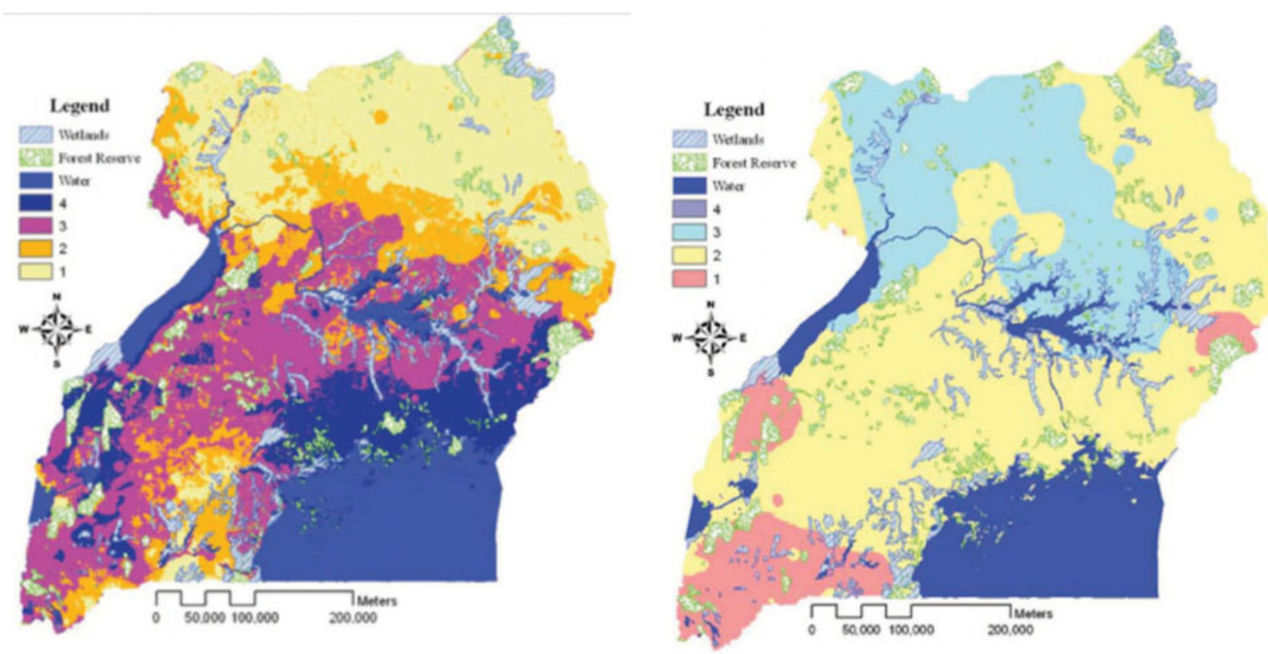
Additional maps representing soil texture; percent slope, farm gate sales; access to markets; and access

TABLE 4. Summary of values for each suitability group across the seven criteria.

	Criterion Thresholds			
Criterion	**Very Suitable**	**Suitable**	**Moderately Suitable**	**Not Suitable**
1. Water Requirement (ha—required drainage area)	<5	5–20	20–100	>100
2. Water Temperature (°C).	28–32	24–28	20–24	<20 or >32
3. Soil Texture (% clay)	15–30	10–15 or 30–40	5–10 or 40–50	<5 or >50
4. Slope (%)	<2	2–5	5–15	>15
5. Farm Gate Sales (people/km^2)	200–1,000	30–200	5–30	<5 or >1,000
6. Access to Local and Regional Markets (travel hours)	<1	1–3	3–6	>6
7. Farm Inputs				
• Total number of poultry	>100,000	40,000–100,000	15,000–40,000	<15,000
• Distance to feed agents (km)	<30	30–50	50–100	>100

Source: Ssegane, Tollner and Veverica (2012)

FIGURE 4. Fish pond farming suitability maps based on water availability and water temperature.



Source: Ssegane, Tollner and Veverica (2012).

to farm inputs were analyzed by Ssegane, Tollner and Veverica (2012). The final results after combining all criteria showed that 0.09 percent (16,322 hectares) of the land area in Uganda was very suitable. More than 98 percent of the area was classified as suitable or moderately suitable; however, the distributions of the suitability values on each map varied. The very suitable locations are areas near Lake Victoria, while the unsuitable locations are areas in the northeast and southwest of the country. The northeast areas are characterized by dry periods, while the southwest areas experience low temperatures.

3.2.2 Identification of Areas Suitable for Aquaculture Parks

Assessments by the National Fisheries Research Institute (NaFIRRI) to identify potential zones for Aquaculture Parks within areas identified as having high potential for aquaculture by Ssegane, Tollner and Veverica (2012) were mainly qualitative comprising of rapid site appraisals, stakeholder consultations and analysis of secondary information. Inter-disciplinary teams comprising personnel from the fisheries department, other arms of MAAIF, Directorate of Water Development, local government departments, and the private sector formed the sited evaluation teams. Consultations were undertaken between and within line departments, local communities, district administrators, and community based organizations (notably Beach Management Units, farmer groups) as well as ordinary people living within the communities from all sectors of life and security agencies. The above processes additionally served to verify secondary information and assess public opinion. Consultations with local communities revealed a lot of important information about the ecosystems that had not been documented. For example, seasonality of water sources, migration routes of wild animals including aquatic animals, incidences and cycles of fish kills in certain areas of lakes, wave characteristics and so on.

Specific studies were also commissioned in which local aquaculture production, environmental and market data were obtained with the objective of validating assumptions proposed in the "Aquaculture Parks" concept. This enabled the planners and stakeholders to re-adjust production targets more realistically in tandem with local constraints. The process has helped create more positive public attitudes towards the Aquaculture Parks concept, particularly for the water-based parks where public skepticism was initially high.

4. SITE SELECTION FOR AQUACULTURE PARKS

The information above in addition to site specific measurements of water quality was used to select potential sites for aquaculture parks. Two sites, one for ponds by the River Nile downstream of Lake Kyoga and the other for cages in Lake Victoria close to Bugala Island were thus identified.

4.1 Aquaculture Parks for Fish Ponds

Table 5 summarizes the criteria selected to identify pilot sites for aquaculture parks for fish ponds in Apac district along the Kyoga Nile. The site is within the Kyoga Water Management Zone and is part of the Olwenyi Catchment. It has access to the Great North Road from this site and is also possible from Masindi port. Potential areas for aquaculture parks for fish ponds are presented in Figure 5.

4.2 Aquaculture Parks for Lake Fish Cages

The following were key suitability considerations measured to determine the site locations of aquaculture parks for fish cages:

- Sufficient water column depth, to allow wastes and leftover food to settle and decompose at safe distance without causing competition for oxygen between the cultured fish and the decomposition bacteria. A cage depth to water column depth ratio of 1:3 is ideal.
- A water current flow rate that will effectively wash fish wastes and un-eaten food through and out of the cage at a rate such as to constantly maintain the optimum water quality balance for best production results. A water current flow rate of 1 to 6 meters per minute is usually effective in delivering optimum production results.
- A consistent supply of naturally occurring dissolved oxygen at such concentration levels as to support the high fish densities that are characteristic of cage culture. 5mg of dissolved oxygen per litre of water

TABLE 5. Summary of scoping site appraisals for fish ponds for Aquaculture Park sites in Uganda.

Factors Considered	Parameters
Political Boundary	Region of the country. Two regions were taken into account—Western Uganda (Kabarole District) and Eastern Region (Kamuli, Namutaba, Budaka, Kibuku, Dokolo and Lira districts).
Water Catchments	Kyoga Water Management Zone (Olwenyi Catchmentin Lira and Dokolo Districts and Mplogoma Catchment in Kamuli, Namutaba, Budaka and Kibuku districts), Albert Water Management Zone (Rivers Mpanga, Mahoma, Nsonja and Rwimiin Kabarole District). Lake Victoria for water based aquaculture parks.
Water Sources	Seasonal availability of ground water and surface water based on historical observations of communities, fisheries officers and where available secondary information.
Basic Water Quality for Production	Data taken at time of visits, so not conclusive. Measured temperature, Ph, conductivity.
Physical Characteristics	Visual assessment of terrain, flow of water and soils.
Land Use and Ownership	Description of current use of land and establishment of land tenure/ownership of sites (i.e., public land, communal or individual ownership).
Fish Species	Fish species in water bodies and under aquaculture.

Adpated from MAAIF (2013).

FIGURE 5. Potential areas for Aquaculture Parks for fish ponds in Apac.

Source: MAAIF/EU (2013).

and above, at water temperatures between 28–30°C is ideal.

- Turbidity levels, secchi disc readings of between 80–200 cm, to ensure a biomass balance in favour of the cage farming activities and at the same time keeping environmental impact in check.
- Water alkalinity and hardness above 20 mg/l in order to ensure water pH within safe range for fish life sustainability.

In addition to the general requirements for water based aquaculture establishment, the following were taken into account in view of the fact that an Aquaculture Park would be a large commercial entity:

Close proximity to land for the establishment of:

- Fish landing facilities;
- Construction of support facilities such as a hatchery and/or nursery, feed store, net making and mending workshop among others;
- Proximity to marketing outlet complete with one or more quality maintenance and preservation infrastructures such as an ice machine, a cold room and live fish handling facility;
- Access to industry support infrastructure, mainly electricity and good transport network;
- Community perceptions and activities.

Based on the initial identification of potential sites for aquaculture undertaken by NAFIRRI, the best lake based site and the best river based sites were chosen for further analysis. The site survey team visited these areas and further undertook basic site suitability survey including topography, bathymetry, water current speed and direction, water temperature, transparency. At the same time the land ownership issues were ascertained. As a result of this process, three potential sites within Apac district by the Nile River were identified and the best site chosen for a pond based Aquaculture Park. The potential sites on Bugala Island were surveyed and the best site identified at Mweena, Kalangala District for cage culture (EU/MAAIF, 2013).

A summary of key parameters for tilapia cage culture is presented in Table 6.

TABLE 6. Tilapia cage culture options at proposed Mweena Aquaculture Parks site within Lake Victoria.

	Input Levels		
Key Parameters	**Small-Holder**	**Medium Scale**	**Large Scale**
Size of Cage (m^3)	2.5 × 2.5 × 2.5 m deep	4 × 2 × 3 m deep	12 m-D × 10 m deep
System	LVHD[1]	LVHD	HVLD[2]
Stocking Density	150–200 kg/m^3	150–200 kg/m^3	12.5 kg/m^3
Water Quality Management	Water depth + 6m	Water depth + 8 m	Water depth + 25 m
	Net depth 2.5 m	Net depth 3 m	Net depth 10 m
	Current 1–10 m/min (Optimum 5 m/min)	Current + 5 m/min	Current + 5 m/min
	Water transparency + 1 m	Water depth + 1.5 m	Water transparency + 2 m
Feed	High quality extruded, min 30% CP, 5 kg/ha	High quality extruded, min 30% CP, 5 kg/ha	High quality extruded, min 30% CP, 5–7 Kg/ha
Yield	800–1000 kg/per cage	3,600 kg/per cage	12 to 15 tonnes/cage

Note: LVHD[1]—Low Volume High Density; HVLD[2]—High Volume Low Density.
Source: EU/ MAAIF (2013).

5. AUTHORIZATION ARRANGEMENTS FOR AQUACULTURE PARKS

5.1 Licensing Requirements

Table 7 lists the specific regulatory requirements for aquaculture parks. The primary permits focus at monitoring aquaculture establishments, water use and environmental management (details in Annex 1).

5.2 Regulations

Currently there are no specific regulations governing Aquaculture Parks. The Aquaculture Parks are considered as aquaculture establishments with additional regulations applying as appropriate (see Tables 2 and 6). Upon their establishment, appropriate regulations can be developed depending on what management and environmental issues arise.

5.3 Environmental Impact Assessments

The following are potential environmental issues likely to arise from pond aquaculture parks (Table 8).

Table 9 below lists the groups recommended mitigation measures arising from the proposed marine cage park at Mweena.

An environmental permit would need to be obtained for all sites that address environmental, socio-economic and governance issues. The initial step in the environmental assessment is scoping out where an environmental brief that identifies potential benefits and risks is produced. The contents of an Environmental Brief are set out by law (Table 10). The outcome would be a project brief that shall be reviewed to ascertain whether or not an Environmental Impact Assessment should be undertaken and what should be considered within it. Environmental Brief's are reviewed by the various key agencies and stakeholders who provide their feedback to NEMA for a final decision.

Given that Aquaculture Parks are large scale operations, a full EIA will be required. This will entail that the status of the environment prior to the implementation

TABLE 7. Specific regulatory requirements for Aquaculture Parks.

	Mweena (Fish Cages)	Apac (Fish Ponds)
Fish Farming	• Aquaculture Establishment Permit (Site to be designated by GPS readings); • Seed Production Permit; • Fish Transfer Permit.	• Aquaculture Establishment Permit; • Seed Production Permit; • Fish Transfer Permit.
Land	• Land based structure are on government land. Since it is a government facility designated for fisheries marketing, there are no encumbrances; • Building permits for the construction of additional structures from the local government.	• Family owned land. Local inhabitants will have to be compensated if they are made to move to pave way for the construction of the aquaculture park; • And title for the aquaculture park; • Planning and building permits from permission from local government.
Water	• No obstruction of water ways; • Water abstraction permit; • Effluent discharge permit.	• Drilling permits; • Water abstraction permit; • Effluent discharge permit.
Environment	Certificate of Approval of Environment Impact Assessment.	Certificate of Approval of Environment Impact Assessment.
Trade	Trading license.	Trading license.

TABLE 8. Environmental issues arising from pond Aquaculture Parks.

Major Concerns	Issues
Ecosystem Health	• Changes in biodiversity, aquatic and terrestrial habitats; • Changes in water volume, quality and catchment hydrology; • Pollution arising from use of chemicals and by-products of production; • Bio-security, particularly spread of diseases from farmed to wild fish populations.
Socioeconomic	• Land conflicts arising from changes in ownership, competition for specific sites, changes in land use patterns; • Strain on municipal resources and services due to increase in local population; • Security concerns; • Profitability of individual enterprises and park as a whole; • Effectiveness and transparency of Aquaculture Parks management; • Access routes as well as access to utilities; • Appropriateness of technology; • Competence levels of personnel including farmers; • Technical and socioeconomic performance of systems.

TABLE 9. Issues arising from cage Aquaculture Parks.

Major Concerns	Issues
Ecosystem Health Biodiversity	• Changes in biodiversity, aquatic and terrestrial habitats; • Pollution arising from use of chemicals and by-products of production; • Bio-security, particularly spread of diseases from farmed to wild fish populations.
Socioeconomic Access to lake by other users	• Continued accessibility for other users, notably navigation routes, fishing grounds and recreation centres; • Collective responsibility in management of shared resource. Cage Aquaculture Parks should be part of and cooperate with local Beach Management Units; • Establishment and respect of Aquaculture Parks boundaries; • Local employment; • Reduced markets and prices for fishermen's catch; • Increased demand on public services; • Increase in local population, hence more conflicts; • Security; • Profitability of individual enterprises and park as a whole; • Effectiveness and transparency of Aquaculture Parks management; • Access routes as well as access to utilities; • Appropriateness of technology; • Competence levels of personnel including farmers; • Technical and socioeconomic performance of systems; • Adequate supply of inputs (especially seed, feed, cage netting) of right quality.

TABLE 10. Outline of the environmental brief.

Chapter	Content
1. Background of the project	Description of the basis of the project.
2. Overall purpose of the project	Description of project objectives, goals and targets.
3. Nature of the project	Description of the ownership, e.g., social project, private enterprise, etc.
4. Site analysis	Comprehensive description of the site based upon physical characteristics, environmental status, land use and other socio-economic activities in the area.
5. Project activities	Description of what is likely to be entailed in the setup and operations of the project in order that the goals be accomplished.
(i) Design of the project	Describe how the project has been set up and will run.
(ii) Technical operations	Description of the technical operations indicating technical viability using the given resources.
(iii) Socioeconomic	Description of what benefits are likely to accrue from the project directly, e.g., economically viable.
6. Potential environmental impacts	Description of likely environmental impacts, assessment of their likelihood, likely impacts and what mitigation measures need be put in place. This includes impact on natural resources as well as social and economic impacts.
7. Anticipated benefits of the project	Positive benefits likely to accrue from the project on the socio-economic status of the community and environment. Among the positive benefits likely to accrue from Aquaculture Parks is the managed harnessing and use of water.

TABLE 11. Template for compliance and monitoring plan.

Issue	VECS	Drivers	Parameters to Be Monitored	Baseline Conditions	Type of Monitoring	Monitoring Location	Frequency	Monitoring Institution

of the project is ascertained, necessitating an environmental baseline survey. Out of this, the main drivers likely to cause environmental changes during the construction, operation and maintenance phases of the Aquaculture Parks shall be identified. A compliance and monitoring plan is consequently developed (Table 11). Upon the approval of this, the EIA permit shall be granted.

Table 12 gives a summary of what parameters are likely to be required for in the Aquaculture Parks EIA based upon the issues raised form the Aquaculture Parks feasibility study (EU/MAAIF, 2013).

5.3.1 Ecological Carrying Capacity

The ecological limits for carrying capacity within the selected Aquaculture Parks pilot sites were calculated based on results from the previous USAID FISH project (Auburn University, 2009).

TABLE 12. Issues to be monitored.

Area of Concern	Issues to Be Monitored
Ecosystem Health	• Changes in physico-chemical characteristics of water • Changes in aquatic and terrestrial ecology • Changes in hydro-geology for land-based Aquaculture Parks • Changes in lake sediment profiles • Differences in water nutrient levels between inflowing and outflowing waters
Socioeconomic	• Changes in socio-cultural environment • Changes in community uses of natural resources • Changes in demography and household characteristics • Changes in local livelihoods • Nature of arising conflicts and conflict resolution • Markets • Changes in land ownership, education, urbanization, power and other utilities, etc. • Benefits arising from Aquaculture Parks to communities • Development and adoption of Best Management Practices • Enterprise performance, compliance to legal and statutory requirements
Technical	• Predator control strategies • Handling of effluent • Training of personnel, farmers and communities • Number, location of cages and their production levels

Pond Culture

The carrying capacity for tilapia ponds averaging 1-m deep under static green water and fed nutritionally completely floating diets was found to average 10 tonnes per hectare. The carrying capacity of catfish ponds averaging 1-m deep under static water (without fertilization) fed nutritionally completely extruded floating diets was found to average 20 tonnes per hectare.

Cage Culture

For tilapia raised in LVHD cages 150–200 kg/m^3, data on cage performance was obtained from cages set within open water bodies (Lake Victoria) and farm dams. The carrying capacity was taken as the point from which total increase in cage biomass ceased to increase and key water quality parameters started to consistently become limiting factors for fish performance, notably dissolved oxygen and ammonia. This together with an analysis of the long-term sustainable production results from a commercial cage LVHD farm in Lake Victoria (Source of the Nile) revealed that an annual production of 175 tonnes per hectare of lake was the sustainable carrying capacity.

A definitive assessment of what zonal carrying capacities are likely to be can only be obtained after the EIA analysis. Aquaculture Park operations and management should accordingly be flexible to ensure adaptability to EIA requirements for sustainability.

6. COST-BENEFIT ANALYSIS FOR AQUACULTURE PARKS

Based upon the findings from the 'Feasibility Study to Feasibility study to design, cost and operationalize model commercial Aquaculture Parks in Uganda' APs can be viable operations supporting both small and large scale producers (EU/MAAIF, 2013). Table 13 shows the comparative cost-benefit findings from this study between cage and pond Aquaculture Parks.

TABLE 13. Comparison of this production and economic potential of two selected potential sites.

Analysis	Mwena Cage Based Aquaculture Park	Apac Pond Based Aquaculture Park
Planned annual production	3,000t	2,380t
Estimated cost to build	8.2bn USh (existing Mwena site reduces this cost to 5.6bn USh)	9.6bn USh (using MAAIF pond construction, not commercial rates)
AP Generating revenue from a variety of sources (seed and feed sales, marketing fee and a service charge) at full capacity	79%	51%
The break-even point	600t (20% of capacity).	1,120t (47% of capacity)
Time taken for construction	1 year	2 years
Direct jobs created	280	400
Profitability with production assumptions based on improved culture practice at different scales of farmer	7% for small scale 28% for medium scale 40% for large scale	19% for small scale 31% for medium scale 38% for large scale
With the reduced borrowing for capital investment	Small-scale investors achieve a positive NPV indicating it is worth investing in the park.	Unlikely to be open to small-scale farmers. Groups of farmers, potentially under a co-operative structure are more likely investors.
Profitability for the medium-scale investor.	Comparatively low investment costs and good profits.	Positive NPV with good returns.
Profitability for the large scale investor	Substantial capital costs in shares and cages (positive cumulative cash flow in year 6); the park represents a long-term investment. 68% IRR after 10 years.	Production investment is at a lower level than the cage-based model (positive cumulative cash flow in year 4). 53% IRR after 10 years.
Aquaculture Parks Returns on investment (based on 50% of company profits being distributed to shareholders)	Achieved after 10 years at Mwena (13 years in the model case).	While investment in the Aquaculture Parks company should provide returns in the long term, the IRR after 10 years is –6%.
Notes	A more positive outcome would be achieved with quicker phasing of production.	It should therefore be considered as providing access to the benefits of operation within the Aquaculture Parks.

Societal benefits likely to be derived from the development of Aquaculture Parks include:

- **i.** Increase in fish supply
- **ii.** Diversify and increase in rural employment
- **iii.** Stimulate development and/or expansion of rural towns and local services available
- **iv.** Increase in local earnings
- **v.** Improvement in the viability of commercial small-holder operations

On the other hand, societal challenges likely to be faced as a result are:

- **i.** Limited human capacity. New system of production and aquaculture has not yet become an art for most of Uganda.
- **ii.** Increase in conflicts arising from access to resources, e.g., land, fishing grounds, etc.
- **iii.** Ensure benefits accrue not just to those directly involved in the Aquaculture Parks.

7. DISCUSSION AND CONCLUSIONS

Uganda has significant potential for development of a commercial aquaculture industry. However, despite the policy intention and the obvious physical potential, there are few examples of profitable aquaculture businesses in Uganda. The technical and financial feasibility study for establishing Aquaculture Parks in Uganda indicates that Aquaculture Parks can result into sustainable economic and social benefits. Indications are that the cage culture based Aquaculture Parks would have higher profitability, faster establishment time and a faster payback period for infrastructure than pond based Aquaculture Parks. Consequently, the government of Uganda is considering establishing pilots.

The use of baseline information will be important to guide and monitor these developments. Undertaking Strategic Environmental Assessments of potential zones that include selected sites for this at this stage would be beneficial as they would ideally provide the information to guide development based upon ecosystem constraints. Table 14 gives a summary of the status of zoning in Uganda. In this regard, the strengths and weaknesses for the development of Aquaculture Parks in Uganda are summarized in Table 15.

TABLE 14. Summary Uganda case study.

Phase/Step	Well Done/Achieved	Not Done/Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)
Phase 1 Step 1 Scoping				
Definition of the ecosystem boundary (spatial, social and political scales)	Broadly done based upon water catchments and climatic conditions and general socioeconomic factors notably current land use.	Specific guidelines for defining ecosystem boundaries (spatial, social and political scales) not yet defined.		2
Identify over-riding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	Aquaculture parks policy has been developed. Aquaculture parks water supply needs included in NDPs Water for Agricultural Production.	Over-riding policies and legislation such as rights of use within public water-bodies have yet to be streamlined to aquaculture parks settings. Likewise, specific regulations guiding the implementation of aquaculture parks.	Need for zonal aquaculture production and planned development has been realized. Stakeholder consultations.	2
Phase 1 Step 2 Zoning				
Zone selection based on selection criteria	Locally developed guidelines for selection of bays for LVHD cage culture.	Criteria for selecting land and water-based sites as well as identification and application of spatial techniques based on ecosystem quality objectives (environmental and socio-economic) need be identified and agreed upon by relevant stakeholders.	Scientific information. Feasibility studies have been undertaken of two pilot potential sites.	2
Gross estimation of potential areas and production	Estimation of two pilot potential sites has been done based upon carrying capacity information from local pond and cage systems within Lake Victoria.	Gross estimation of all identified potential sites not yet done. Estimation protocols used have not yet factor N and P discharges from current commercial systems.	Collection of data from individual farms.	1
Allocation of the zone for aquaculture purposes		Not yet	Stakeholder consultation and sourcing of development finance to legally secure and develop identified pilot sites for aquaculture yet to be done.	0

TABLE 14. Continued

Phase/Step	Well Done/Achieved	Not Done/Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)
Phase 2 Site Selection				
Carrying capacity estimation	To be conducted for identified pilot sites.		Coarse estimates of carrying capacity for pilot sites were based mainly on production and water quality in production units. Baseline environmental data still needs to be obtained and appropriate tools identified for analysis and development of ecosystems management programs.	1
Set license production limits within zone or water body carrying capacity		Not yet	Zones yet to be established. Likewise appropriate tools yet to be developed/identified to establish these limits locally.	0
Allocation of licenses and permits	Done		Aquaculture Rules, EIA regulations and Water Act.	3
Phase 3 Area Management				
Identify management area boundaries		Partially	Delineation for the management area boundaries of aquaculture parks have been proposed.	1
Estimate total carrying capacity if appropriate based on the risks		Not yet		0
Organize formal association of all farmers in that area		Not yet		0

TABLE 14. Continued

Phase/Step	Well Done/Achieved	Not Done/Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)
Phase 3 Area Management				
Agree on common management monitoring and control measures		Partially	Concept for the management of aquaculture parks have been proposed.	2
Monitor and enforce management measures		Not yet		0
Phase 4 Monitoring and Review				
Regular monitoring and evaluation		Not yet	Guidelines for monitoring of water quality in water bodies around aquaculture establishments and this task is to be undertaken jointly by NaFIRRI and DWD with DWD being the Lead Agency.	0
Periodic review and adjustment		Not yet		0
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**		**Approximate production from each aquaculture zone or AMA**	
Number of zones and range of implementation	About 10 potential land-based sites have been identified. One pilot site has been designated in Lake Victoria. None of these sites are in operation yet.		Pilot sites planned based on production of 5,000 tonnes/annum.	
Other notes (especially social issues)	**Positive Issues**		**Negative Issues**	
	Generally, a positive public attitude towards the establishment of aquaculture parks. Stakeholder consultation has been very wide and is ongoing at different levels. For cage culture, pilot cage farms and the approach to their establishment that followed EIA guidelines has helped establish positive attitude by stakeholders.		Aquaculture parks not yet established.	

TABLE 15. The strengths and weaknesses for the development of Aquaculture Parks in Uganda.

Advantages	Disadvantages
• Concentrated area of production within high potential areas. • Make it easier to support development of and monitor appropriate production systems matched zonal constraints. • Improve access to inputs, technical services and markets for producers.	• Large scale operations likely to have significant demand on environmental resources particularly for land-based Aquaculture Parks.
Strengths	**Weaknesses**
• Wide private and public stakeholder consultations, hence positive public attitudes and support.	• Inadequate baseline data to ascertain ecological limits of sites and guide management. • Lack of finance to implement project and conduct appropriate preliminary studies. • Low levels of human capacity.

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ANNEX 1. GUIDELINES FOR ASSESSING SUITABILITY OF BAYS FOR LVHD CAGE CULTURE

The following outlines guidelines developed based on data collected during the trials to enable one assess a potential site for cage culture:

(1) Distance to nearest to obvious source of pollution:

Criteria	Score
>1,000 m	**3**
500 to 1,000 m	**2**
<500 m	**1** secchi disk visibility
>200 cm	**3**
100 to 200 cm	**2**
<100 cm	**1**

(2) Dissolved oxygen profile measured before 0800 hours is:

Criteria	Score
>6 mg/L surface to mid depth and >5 mg/L at bottom	**3**
>5 mg/L surface to mid depth and >4 mg/L at bottom	**2**
>5 mg/L surface to mid depth and >3 mg/L at bottom	**1**

(3) Water depth at proposed position for cages is:

Criteria	Score
>8 m	**3**
4 to 8 m	**2**
<4 m	**1**

(4) The connection of the bay to open water of the lake is:

Criteria	Score
>1,000 m	**3**
500 to 1,000 m	**2**
<500 m	**1**

(5) The long axis of the bay is:

Criteria	Score
Parallel to prevailing wind	**3**
Oblique to prevailing wind	**2**
Perpendicular to prevailing wind	**1**
• Not obstructed by islands, peninsulas, or aquatic weed infestations	**3**
• <50% obstructed	**2**
• >50% obstructed	**1**

The characteristics of the bay determine what scale of operation is feasible and what feeding levels are most appropriate. This is to ensure the operation runs within the limits of the sites carrying capacity and water quality remains optimal for production. Therefore, that analysis of the above scoring system gives the following results:

A. Overall site rating.—Sum the points given to the site to provide a score, and assign the overall site rating as follows:

Score	Overall Site Rating
1 to <7	Unacceptable
7 to 10	Poor
11 to 17	Fair
18 to 21	Good

B. Determination of allowable daily feed input.—Determine the area of the bay. Estimate the maximum allowable, daily feed input as follows:

Max Allowable Daily Feed Input (kg/ha)
2.5
5.0
7.5

C. Determination of maximum, allowable standing crop in cages.—The maximum allowable standing crop could be used for open water sites, for this approach also limits the maximum, allowable daily feed input

Site Rating	Max. Standing Crop
Poor	**<250**
Fair	**250 to 500**
Good	**>500**

ANNEX 2. DETAILS OF LICENSING REQUIREMENTS FOR VARIOUS COMMERCIAL AQUACULTURE OPERATIONS

1. Permits Required for Commercial Fish Farming in Uganda

Activity	Permits/Certificates Required	Conditions
Semi-Intensive or Intensive Grow-Out Operations	Aquaculture establishment certificate	EIA of project proposal Annual aquaculture farm data (due at end of each fiscal year)
Fish Seed Production	Aquaculture establishment certificate Fish seed production certificate	EIA of project proposal Annual aquaculture farm data (due at end of each fiscal year)
Fish Breeding	Aquaculture establishment certificate Fish seed production certificate	EIA of project proposal Annual aquaculture farm data (due at end of each fiscal year)
Commercial Bait Production	i) Aquaculture establishment certificate	EIA of project proposal Annual aquaculture farm data (due at end of each fiscal year)
Ornamental Fish Farming	i) Aquaculture establishment certificate	EIA of project proposal Annual aquaculture farm data (due at end of each fiscal year)
Marketing of Farmed Fish (transfer within Uganda)	i) Fish transfer permit	
Export of Farmed Fish	i) Fish import/export permit	
Genetic Material for Aquaculture	UNCST certificate	National Bio-safety guidelines followed

2. Water Use

Do I Intend to:	Permits/Certificates Required	Conditions
Drill a borehole on my land to supply water to my fish farm	Drilling permit Construction permit	Register works and use of water with the Directorate of Water Development (DWD) Renewal of permit after the stipulated number of years
Use a motorised pump to pump the water from the borehole either temporarily or permanently	Ground water permit	Register works and use of water with the Directorate of Water Development (DWD) Renewal of permit after the stipulated number of years
Impound a waterway to extract 270 litres of water per minute or more in a 24 hour period	i) Surface water permit ii) Construction permit	Register works and use of water with the Directorate of Water Development (DWD) Renewal of permit after the stipulated number of years
Use a motorised pump to pump water either temporarily or permanently from a waterway	i) Surface water permit	Register works and use of water with the Directorate of Water Development (DWD) Renewal of permit after the stipulated number of years
Discharge large amounts of effluent from the farm	Waste discharge permit	Register works and use of water with the Directorate of Water Development (DWD)
Undertake cage culture	Surface water abstraction permit	Apply to NEMA—submit EIA Apply for permit from DWD

3. Environmental Issues

Do I Intend to:	Permits/Certificates Required	Conditions
1. Establish a large-scale commercial aquaculture	i) Certificate of Approval of Environment Impact Assessment	Project brief (10 copies submitted to NEMA) Environment impact study iii) Environment impact statement

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Aquaculture Zoning, Site Selection and Area Management in Scottish Marine Finfish Production

Alexander G. Murray and Matthew Gubbins[1]

ABSTRACT

Scottish aquaculture is dominated by Atlantic salmon, for which it is the world's third largest producer. Salmon farming has developed since the 1970s and spatial management has become increasingly important to ensure sustainability, particularly for fish health and environmental protection. Area management involves collaboration between government and industry and both parties operate area management systems. Disease Management Areas (DMAs) are used by government to control notifiable disease, particularly ISA. They are defined using a simple model and government policy is against new sites that would join DMAs. Farm Management Areas (FMAs) are industry defined areas in which farms collaborate on management issues, including sea lice treatments. Sea lochs (small fjords) are assessed for carrying capacity and maximum biomass consent is limited to prevent environmental impacts arising from cumulative discharges. At a larger spatial scale large areas are reserved with no aquaculture, including the North and East coasts of Scotland, the United Kingdom of Great Britain and Northern Ireland where the most significant wild salmonid populations in Scotland are found. New farms are given development consent under Town and Country Planning by Local Authorities, taking into account views of consultees, stakeholders and in accordance with established policies in Scotland's National Marine Plan and any local plans. Standards are enforced through official inspectors working for the Fish Health Inspectorate and the Scottish Environment Protection Agency and by industry codes of practice.

INTRODUCTION

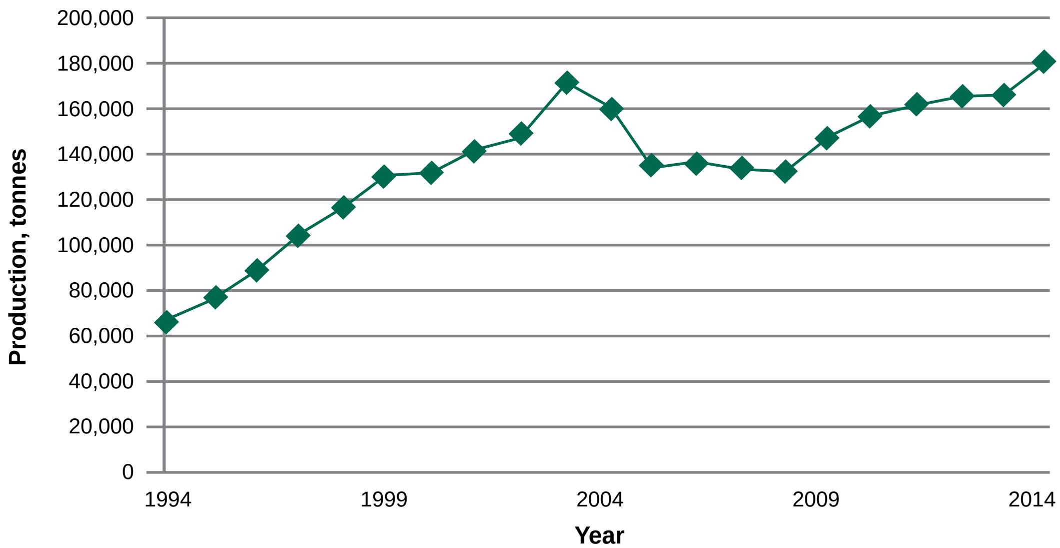
Scottish marine aquaculture is dominated by salmon, which at 179,000 tonnes[2] production (Figure 1) is the world's third largest and is Scotland's largest single food export. Salmon producers share marine waters

1 The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or the World Bank Group.

2 www.gov.scot/Publications/2015/09/6580

Murray, A. G. & Gubbins, M. 2017. Aquaculture Zoning, Site Selection and Area Management in Scottish Marine Finfish Production. In J. Aguilar-Manjarrez, D. Soto & R. Brummett. *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Full document*, pp. 358–373. Report ACS113536. Rome, FAO, and World Bank Group, Washington, DC. 395 pp.

FIGURE 1. Annual Scottish salmon production 1990–2014.



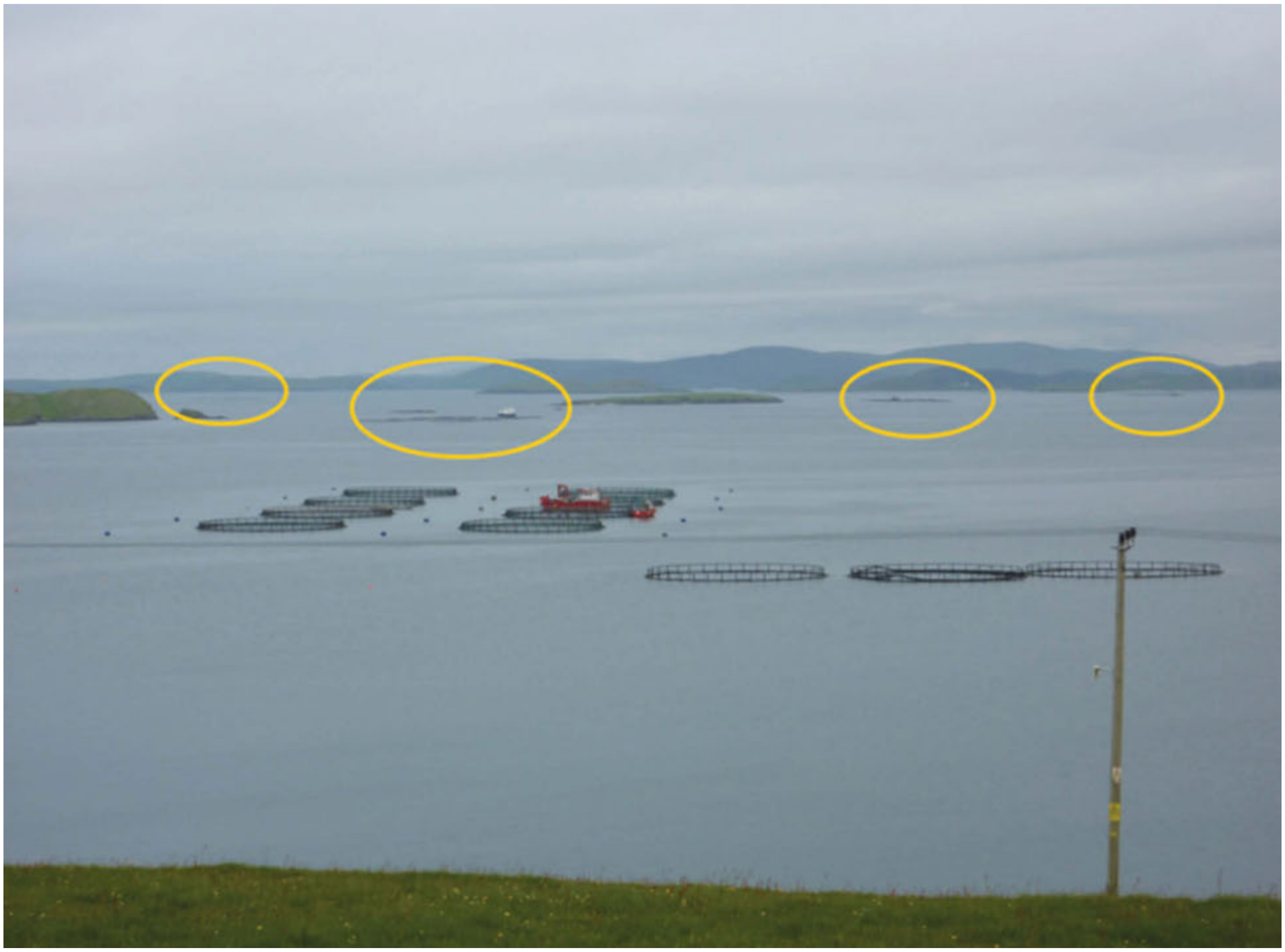
with a smaller production of marine farmed trout and other fish species such as halibut, together with shellfish production which is mostly of mussels and oysters.

Scottish aquaculture is strategically managed using area management principles in order to protect both production and the environment. Area management is used to control the spread of diseases and to ensure aquaculture production is in unpolluted waters, while at the same time ensuring waste products such as excess nutrients and organic wastes do not pollute the environment, keeping production levels within carrying capacity of the relevant water body. Landscape and conservation issues can also influence the siting of aquaculture out of sensitive zones.

The basic legal framework developed with the 1937 Disease of Fish Act (UK legislation) which established concepts of notifiable diseases and official movement controls to prevent the spread of infection in aquatic environments. With the establishment of marine salmon aquaculture in the 1970s the interactions of local groups of farms (Figure 2) with hydrodynamic movement required the development of local co-operation in the management of furunculosis and sea lice. From these local informal agreements, farm management areas were developed by industry and are enshrined in a Code of Good Practice for Finfish Aquaculture. This code is maintained and developed by a management group that consists of representatives from a range of major aquaculture producers and producers organisations (including government observers). In parallel, government and industry developed a system of official Disease Management Areas in the wake of a devastating outbreak of the notifiable disease, Infectious Salmon Anaemia (ISA). In addition since the late 1990s, inshore water bodies with restricted tidal exchange (sea lochs, sounds, coastal embayments) have been used to manage nutrient and organic discharges and so limit allowable biomass at a water body level to stay within capacity to assimilate such wastes.

Scottish aquaculture's area management is underpinned by considerable investment in Science, both directly through Marine Scotland Science and Scottish Universities, which include specialist centres such as the Scottish Association for Marine Science (University of the Highlands and Islands) and The Institute of Aquaculture (Stirling University). Research also occurs with collaboration at the UK, EU and global levels, for example the recently funded AQUASPACE project.

FIGURE 2. Example of a farm with 4 neighbours from southeast Shetland's DMA 3a (Photo Sonia Duguid). During an ISA outbreak 4 of the 5 farms were infected, but infection did not spread outside the DMA.



Owing to the evolutionary process of establishing area management, Scotland has a range of differently defined, but in practice often very similar, areas over which aquaculture is managed. These have proved essential for managing epidemic Infectious Salmon Anaemia (Scotland is currently the only country to have successfully eradicated this disease) and in day-to-day management of fish health (particularly management of sea lice) while reducing conflict with other users of the coastal marine environment as a component part of Scotland's National Marine Plan.[3]

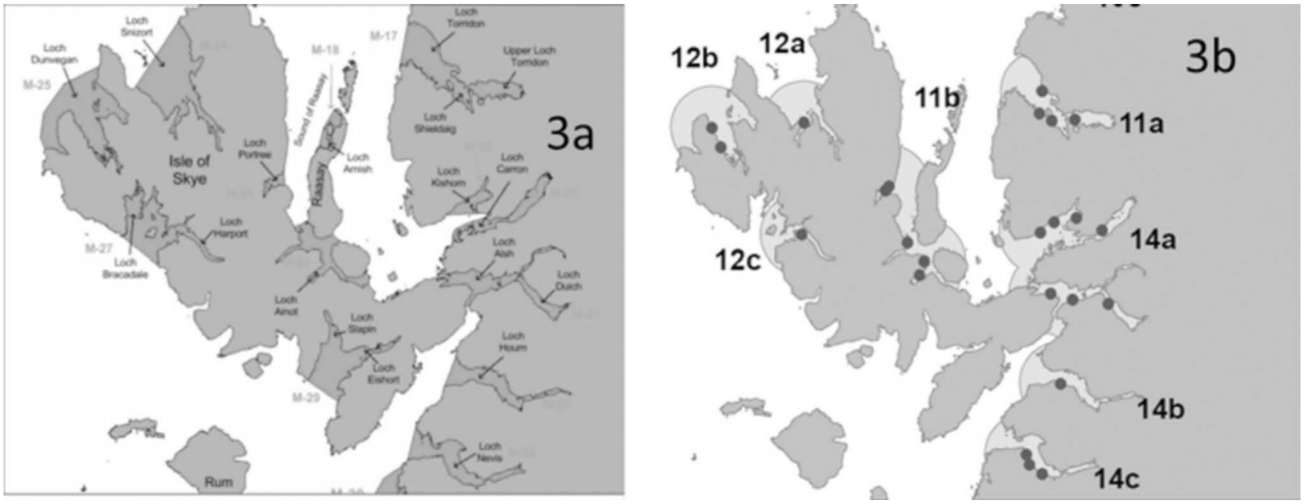
3 www.gov.scot/Publications/2015/03/6517

AQUACULTURE ZONES

Aquaculture is absent from large zones of the Scottish coastal environment. There is a policy presumption against further marine finfish farm development on the north and east coasts Thus a very large proportion of the Scottish coast remains undeveloped. This area includes the mouths of most of the rivers with larger populations of wild salmon, such as the Tweed, the Dee and the Spey.

Aquaculture is excluded from other zones for purposes such as shipping, naval activity, offshore energy production and conservation purposes.

FIGURE 3. 3a. Example of Farm Management Areas (FMAs) and 3b. Disease Management Areas (DMAs) maps in the area of the Isle of Skye, west coast of Scotland. FMAs and DMAs are generally similar, but differ in detail (e.g., FMAs M-19, M-20 and M-21 are all in DMA 14a).



Within the areas where aquaculture is practiced (the west coast, the Western Isles, Orkney and Shetland) farms are grouped into areas of interaction. There are three such areas designed for different purposes. These are Farm Management Areas, Disease Management Areas and 'Categorised' inshore water bodies (mostly sea lochs) in the 'Locational Guidelines for Marine Fish Farming' (Figure 3, Figure 4).

Farm management areas (FMAs) are groups of farms whose interaction requires collaboration (Figure 3a). The FMA boundaries are defined by industry on the basis of local knowledge and practicalities, although Scottish Ministers reserve the power to revise these boundaries. Boundaries do change with experience, for example FMAs in southeast Shetland were amalgamated after ISA spread across the FMA boundaries. The boundaries are shown in the Code of Good Practice[4] and farms within such areas require a Farm Management Agreement (FMAg) or a Farm Management Statement (FMS) that specifies their activities under the Aquaculture and Fisheries Act (Scotland) 2013; many FMAs existed on a voluntary basis, sometimes for many years, before the passing of the Act. There are currently 89 FMAs in Scotland.

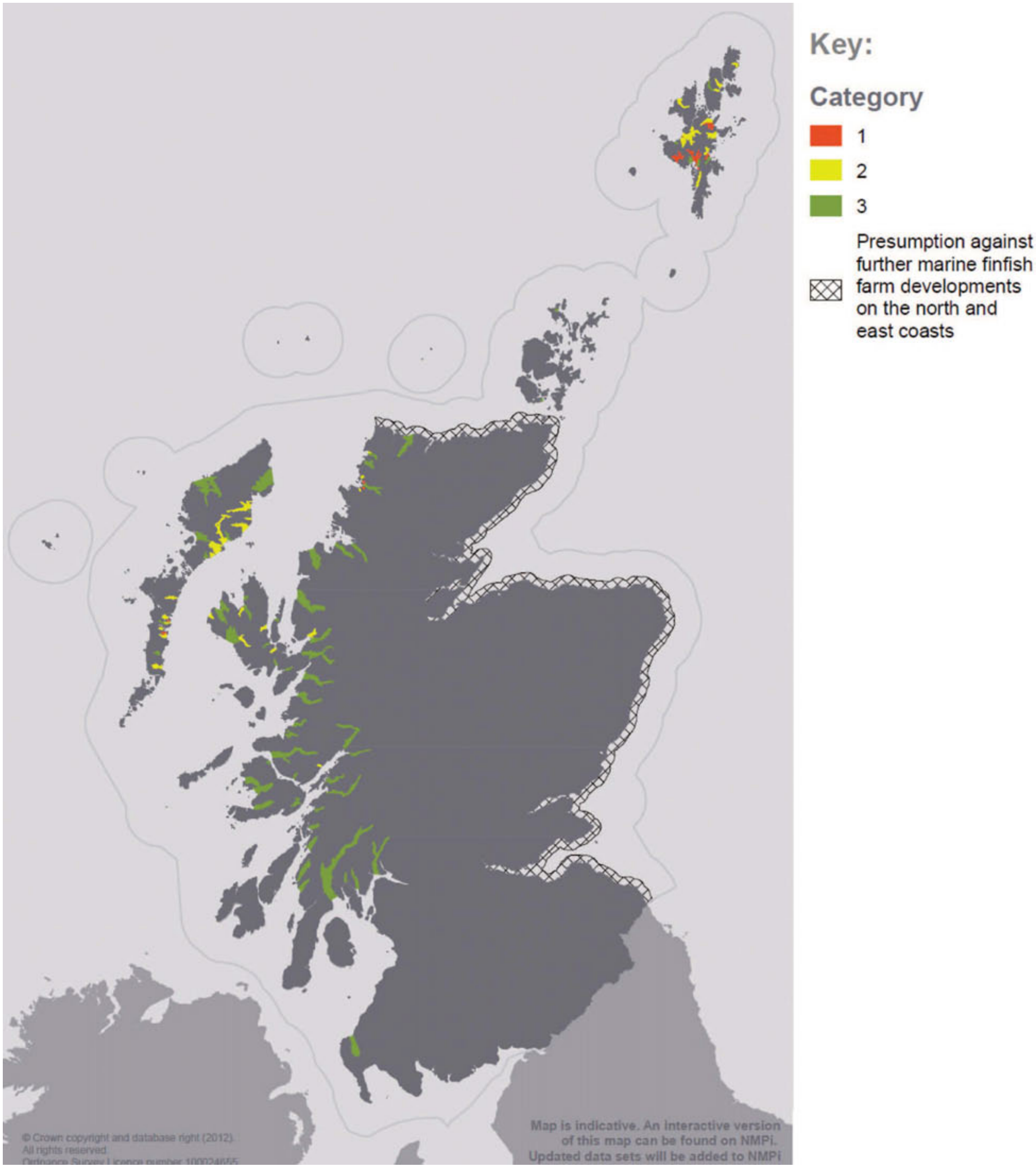
Disease Management Areas (DMAs) are used for the control of notifiable diseases (Figure 3b),[5] particularly Infectious Salmon Anaemia (ISA). These DMAs were developed during a severe ISA outbreak in 1998/9 and were used to contain and eventually eradicate this. The boundaries are defined using an epidemiologically significant distance, (3.629 km in Shetland and 7.258 km elsewhere in Scotland), around each farm. Where these circles overlap, farms are included within the same DMA, which stretches until a separation of twice the circle radius is encountered. These boundaries are thus easily and explicitly defined and establishment of new farms in areas that would join existing DMAs is contrary to Scottish government policy. There currently are 52 DMAs in Scotland.

Sea lochs are defined geographically. These are small fjordic inlets along the Scottish coast that have been systematically catalogued and described by oceanographers since the 1970s. Information on the volume and

4 http://thecodeofgoodpractice.co.uk/

5 www.scotland.gov.uk/Topics/marine/Fish-Shellfish/FHI/managementagreement

FIGURE 4. Spatial planning policy for aquaculture as laid out in the National Marine Plan. Finfish aquaculture is excluded on the North and East coasts. Inshore water bodies on the West coasts and islands are categorised according to their capacity potential to accommodate more finfish aquaculture.



turnover time of the waters in these lochs, together with biological models of fish metabolism, are used to categorise sea lochs into categories 1, 2 or 3, dependent on how much environmental stress the sea loch is subjected to. This status informs these areas' suitability for further aquaculture development.

SETTING CARRYING CAPACITY LIMITS

Site specific capacity thresholds are determined through the licensing process, where benthic impact modelling (AutoDEPOMOD) is used to set peak biomass thresholds on the basis of predicted impacts on seabed infaunal diversity. The development consent process (planning consent administered by Local Authority also considers a number of other environmental impacts through Environmental Impact Assessment) may limit site specific biomass on the basis of expected environmental impacts or the ability of a site to use (discharge) medicines to treat pathogen infections.

At a water body level (sea lochs), simple models are employed to predict a precautionary threshold for assimilative capacity based on the predicted nutrient enhancement and benthic impacts arising from cumulative discharges from multiple developments in the water body. The models used and the framework in which the outputs are used are explained in the referenced report.[6] These are simple precautionary models able to be used across all 100+ sea lochs that support aquaculture in Scottish waters (Figure 4). Efforts to produce more sophisticated estimates of assimilative carrying capacity have been made and complex multilayer coupled physical biological models have been developed to improve estimates of assimilative capacity at a water body level, but application of these in a robust way across multiple water bodies requires extensive forcing data and significant effort and expense. It is hoped future efforts will improve estimates, but for the time being, monitoring data suggest the current regime is sufficiently precautionary to prevent eutrophication effects arising from cumulative discharges from marine finfish aquaculture.

SITING, PLANNING AND LICENSING

Finfish aquaculture developments need several permissions in order to produce fish in Scottish marine waters. These include planning consent, a Marine Licence for placing equipment and point source discharge and business authorisation. The statutory authorities issuing these permissions must do so in light of various strategic planning guidance, such as the objectives in the National Marine Plan, Scottish Planning Policy, Locational Guidelines, and any current Local Development Framework Plans containing spatial guidance on the siting of new farms.

Planning Consent

Since April 2007 Scottish Local Authorities have had responsibility for issuing planning consent for fish and shellfish farms under The Town and Country Planning (Scotland) Act 1997. Planning permission is usually permanent (although temporary planning permission is possible) and, for most finfish applications, the approvals process is subject to Environmental Impact Assessment (EIA) to comply with the EIA Directive (2011/92/EU) transposed into UK law by The Environmental Impact Assessment (Fish Farming in Marine Waters) Regulations 1999 (Statutory Instrument 367). Intensive fish farming is listed in Schedule 2 to the Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011 (and, before that, the 1999 Regulations). An environmental impact assessment is not mandatory in all cases but 'Schedule 2' development will require an EIA if it is likely to have a significant effect on the environment, by virtue of factors such as its size, nature or location. Where an application meets the relevant criteria it will undergo EIA Screening and Scoping and produce an Environmental Statement if required, covering all the potentially significant environmental impacts likely to result from the development. Shellfish and macroalgae farms are not currently required to produce EIAs but, if appropriate the consenting authority can seek additional environmental information to inform their decision.

Where an authority concludes that a development proposal is likely to have a significant effect on a site designated under the Habitats Directive (The Conservation (Natural Habitats, &c.) Regulations 1994), it must also undertake an Appropriate Assessment (AA) of the implications for the conservation interests for which the area has been designated.

The Crown Estates own the seabed in Scotland and aquaculture facilities granted planning permission by Local Authorities require a seabed lease from The Crown Estates in order to operate. Crown Estate responsibilities in Scotland is in the process of being devolved to Scotland following a recommendation of the Smith Commission on constitutional settlement. Prior to the extension of planning controls to Local Authorities in 2007, the seabed lease (or a works licence in Orkney and Shetland) was the primary development consent required for aquaculture development in marine waters and was subject to EIA and AA where required. Where sites were established prior to 2007, operators were able to apply to Scottish Ministers for planning permission.

Strategic planning of aquaculture sites in marine waters is achieved through Locational Guidelines[6] that address water body carrying capacity issues as well as some regional-level Local Authority Development Framework Plans which identify acceptable sites for finfish and shellfish cultivation. Following the adoption of the National Marine Plan and in the future, Regional Marine Planning Partnerships, such strategic planning guidance will be improved upon and expanded.

Operational Consents

All finfish aquaculture sites require a point source discharge authorisation issued under The Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended), referred to as a CAR licence. Operators are required to make an application for a CAR licence and the successful conclusion of the application determination leads to the issue of a CAR licence by the Scottish Environment Protection Agency (SEPA). The licence sets out conditions to control all aspects of effluent discharges from the farm and limit potential environmental damage. Specifically it controls maximum onsite biomass of fish and the range and quantity of chemicals released to the environment from site operations as well as a range of other operational matters. This includes chemotherapeutant treatments for sea lice infestations, but pathogens (including sea lice) are not considered to be discharged and are not controlled via the CAR licence.

In regulating the fish farming industry SEPA endeavours to base its licensing regime on sound scientific principals using the best available knowledge and techniques to control and monitor the impacts of the industry. Hydrographic modelling techniques are employed to predict the quantities of chemicals and biomass of fish that can be used onsite without resulting in exceedence of a range of Environmental Quality Standards (EQS). These modelling results are used to set conditions of the CAR licence, which includes a requirement for operators to monitor environmental conditions onsite to ensure both compliance with EQS and as a check on modelled outputs. In instances where monitoring suggests failure of EQS consistent with either noncompliance or inappropriate consent conditions, SEPA may alter consent conditions to reduce consented fish biomass or chemical quantities or in serious cases withdraw consent. Such sanctions can be undertaken in discussion and with the co-operation of the farm operator or if required on SEPA's own initiative.

A two-tier approach is taken to ensuring protection of the marine environment from discharges at finfish farms. The concept of an "Allowable Zone of Effects" is applied for solid wastes, where within a given area around a farm (calculated by hydrographic modelling) higher EQS are applied. Thus, far-field effects on the wider environment are limited by ensuring EQS compliance, but under and close to the cages higher environmental concentrations of certain contaminants and a greater level of effect on benthic infaunal communities from organic matter deposition are permitted and accepted. Similarly for soluble wastes the concept

6 www.scotland.gov.uk/Topics/marine/science/Publications/publicationslatest/farmedfish/locationalfishfarms

of an initial mixing zone is applied and EQS compliance is ensured at a specific time after initial dilution (e.g., 6 hours). This approach accepts that risk of effects from discharges may be higher (within limits) locally either immediately after discharge or within the vicinity of fish cages, but ensures EQS compliance within the wider marine environment. This approach is similar to that taken for more conventional discharges from outfall pipes where EQS compliance is required outwith a zone where initial mixing occurs.

All aquaculture sites also require a Marine Licence under the Marine (Scotland) Act 2010, administered by marine Scotland's Licensing Operations Team. This is required in all instances for assessment of navigational safety associated with aquaculture sites and where aquaculture chemotherapeutants for treating fish for sea lice infestations are discharged from wellboats. This is an emerging husbandry practice in Scotland and is regulated under Marine Licence using the same principles and conditions as under CAR above.

Business Authorisations

In Scotland, The Aquatic Animal Health (Scotland) Regulations 2009 (2009 Regulations) implement the Council Directive 2006/88/EC on animal health requirements for aquaculture animals and products thereof, and on the prevention and control of certain diseases in aquatic animals. The 2009 Regulations require the authorisation of all Aquaculture Production Businesses (APBs) a definition which includes all fish and shellfish farming companies. The authorisation procedure is undertaken on behalf of the Scottish Ministers by Marine Scotland's Fish Health Inspectorate (FHI).

Authorisations are conditioned to require that APBs: provide details of their business; make movement and mortality records available; participate in risk-based disease surveillance; implement good hygiene practice including biosecurity measures; notify Scottish Ministers in the event of a breach in containment; and facilitate access by inspectors for inspection and sampling as required. Authorisations may be suspended or revoked (subject to appeal) in the event of breach of these conditions. All APBs planning to operate new fish or shellfish sites are required to apply for their authorisation to be amended prior to operating any proposed new site.

The Aquaculture and Fisheries (Scotland) Act 2013 (and prior legislation, the Aquaculture and Fisheries (Scotland) Act 2007) provides powers relating to containment and parasite (sea lice) control. These require operators to adopt satisfactory measures to ensure the prevention, control and reduction of parasites (sea lice), containment and the prevention and recovery of escapes. It also requires operators to maintain records to be made available for inspection. The legislation also provides powers of inspection and entry for Fish Health Inspectors and ultimately provides provisions for enforcement action should such be required.

OPERATION AND MANAGEMENT OF AREAS

Aquaculture production in areas is coordinated through a number of different routes. Farms in a FMA have stocking and treatment plans that are coordinated through a FMAg, if this is in place, or less formally if farms have individual FMS. Areas have moved towards synchronised fallowing, which is now widespread and recommended under the Code of Good Practice.[3] All farms within an area should wait until the last farm in that area is empty before restocking. This is an important tool for disease control and in the management of sea lice. In the event of notifiable disease, synchronised fallowing may be legally enforced across the affected area of the DMA.

Treatment for sea lice is often coordinated, as untreated farms can act as refuges for lice that allow infection levels to re-increase rapidly. However, treatment presents logistical challenges and so may be applied to neighbouring sites over a short period rather than be strictly synchronised.

A trend that has improved coordination within areas has been a movement towards single operator FMAs, with companies strategically exchanging sites so that one company owns all the sites in a particular FMA. This allows coordination to be achieved more easily. Some FMA boundaries have also extended closer to

DMA boundaries, for example the merger of several FMAs in southeast Shetland after ISA spread across the FMA boundaries. The new FMA in this case now matches the local DMA boundaries. If FMA and DMA activities occur within the same boundaries this makes for easier management. In some areas, DMAs have been split and separated by the strategic closure of sites to form smaller areas that can be managed more easily.

Movements of fish, equipment and personnel may be prevented both in and out of areas with notifiable disease (except movements to authorised biosecure processing plants). Sites that are not themselves infected may be covered by these movement restrictions. This area approach reduces the risk of spread and can be effective in containing infection to a limited area. Local processing plants, with locally operating vessels, may also reduce risk of long-distance spread of infection.

Locational Guidelines Categorisation of sea lochs into 1 (no increase in biomass permitted), 2 (limited potential for expansion of the sector) and 3 (greatest expansion potential) are applied at both the development consenting and licensing processes to restrict any increases in maximum permitted biomass of farmed finfish in areas which are thought to be close to capacity. Estimates of the nutrient enhancement and impacts of benthic enrichment of the seabed are updated quarterly on the basis of changes to biomass consent under CAR, and water body categories in the guidelines are updated as required.

Sea lice chemotherapeutant discharges (bath treatments) are also logged by the various regulators (SEPA for treatments in cages, Marine Scotland Licensing for treatments from well boats) and in the event of multiple planned discharges in the same water body predicted to exceed Environmental Quality Standards (EQS), either regulator may restrict use of the compound in that water body.

Monitoring and Enforcement

Controls on aquaculture at a site or area level require monitoring and enforcement to be effective. These include inspections by fish health inspectors from Marine Scotland and environmental inspectors from SEPA.

Fish health inspectors (FHI) visit farms according to a risk-based surveillance schedule (annually for high risk, every 2 years for medium risk and every third year for low risk). In the event of the inspector suspecting any health problems, a diagnostic sample will be taken and screened for notifiable pathogens. FHI also visit sites when notified of suspicion of the presence of a notifiable disease. Recently the Scottish Salmon Producers Organisation (SSPO) agreed its members should report marine mortality events in excess of 1 percent per week or totalling 4 percent over 5 weeks (1.5 percent and 6 percent when fish <750 g) and this too may provide information to target inspections. FHI also inspect records maintained on sites, including for sea lice, and collect the movement records for that site. This FHI activity, and industry reporting, is vital for detection of notifiable disease required for the timely establishment of controls in DMAs.

SEPA inspectors visit sites regularly to test for residues of medicines and to confirm records on the disposal of mortalities are correctly recorded. This is essential to ensure treatment is according to approved schedules and SEPA will prosecute if unauthorised substances are detected.

SEPA and FHI inspectors will notify each other of suspicions that lie in the other's competency and may also inform other authorities, such as the official APHA (Animal and Plant Health Agency) vets if welfare breaches are observed, the APHA vets may decide to prosecute in this case.

As well as official regulators, the industry itself collects data and ensures compliance with the Code of Good Practice. Although compliance is voluntary, the SSPO can decide to suspend its members following any breach of the Code. The CoGP is independently audited and the majority of the industry are signed up to following the Code. Documented production standards can be important in supermarket purchasing decisions. The SSPO also maintains a database for monitoring sea lice and other health issues (such as gill pathologies) which is useful for cooperation between farms in an area. Published summary data identifies area performance (although at a slightly larger scale than FMAs) which is an incentive to improve performance.

The Royal Society for the Prevention of Cruelty to Animals (RSPCA) also ensures welfare standards through their Freedom Foods standard, which 70 percent of Scottish salmon industry, by biomass, is signed up to. The World Wide Fund for Nature, through the Salmon Aquaculture Dialogue has developed standards for sustainable salmon that are maintained by the Aquaculture Stewardship Council. Both standards include requirements for cooperative management with other farms in the same area, especially for sea lice control.

CONCLUSIONS

Fish farming is a mature industry in Scotland with a long history of regulation to ensure production is sustainable from an environmental and fish health perspective. As such it operates a fairly complex, but effective system of planning and licensing including spatial management and zoning for multiple purposes, rather than a single zoning and permitting system. With the advent of Regional Marine Planning in Scotland over the next few years we may see much of these spatial management policies and zones integrated into Regional Marine Plans.

ANNEX 1. EFFECTIVENESS MATRIX FOR SCOPING, ZONING, SITE SELECTION, AREA MANAGEMENT AND MONITORING OF SCOTTISH FINFISH AQUACULTURE

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.1 Definition of the broad ecosystem boundary (spatial, social and political scales)	Different boundaries are assigned for different purposes by the various regulators. Inshore water bodies defined by typography for carrying capacity. Regional planning boundaries set according to biogeography and jurisdictional boundaries. Areas for disease management set according to hydrography and topography.		• National Marine Plan for Scotland, derived with public consultation exercise; • Code of Good Practice for Finfish Aquaculture derived by industry with government overview; • Marine Scotland Disease Management Areas from modelling; • Marine Scotland Locational Guidelines for Fish Farms from modelling.	5	
1.2 Identify overriding policy, legislation (such as land and sea rights) and regulations (such as ecosystem quality standards, water quality standards)	These policies are laid out in the National Marine Plan and the policy documentation of the various regulatory bodies (Scottish Environment Protection Agency (SEPA); Local Authority; Marine Scotland, Crown Estates). Seabed out to 12 nautical miles from coast is owned by the Crown Estate who charge a levy for lease and aquaculture activities must be licenced by SEPA.		• Aquaculture and Fisheries Acts (Scotland) 2007, 2013; • Town and Country Planning (Marine Fish Farming) (Scotland) Order 2007; • The Environmental Impact Assessment (Fish Farming in Marine Waters) Regulations 1999; • The Conservation (Natural Habitats, &c.) Regulations 1994; • The Water Environment (Controlled Activities) (Scotland) Regulations 2011.	5	

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 1 Scoping (Scoping involves compiling essential background information required to start an aquaculture project)					
1.3 Setting the broad development objectives and identifying the main issues	Development objectives left to the developer. Main issues dealt with on a site specific basis through formal "screening and scoping" stage prior to preparation of an EIA. Environmental targets set in regulation and assessed at the regional and site level. National level targets for the sector identified in the National Marine Plan.		• National Marine Plan for Scotland; • Developer prepares Environmental Impact Assessment for consideration.	3	
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.4 Zone boundary definition based on relevant criteria	Some zoning is defined through ICZM plans and Local Development Framework Plans. Other zones are created based on environmental 'risk' from nearing capacity limits. Others for disease management purposes. Local Development Framework Plans and future Regional Planning may adopt a more formal zoning type approach in some cases. Examples of considerations are: • Areas of conservation importance • Use by other sectors • Landscape impacts • Navigational importance • Carrying capacity • Disease management based on simple spatial models of pathogen risk, etc.		• Final report of the Joint Government-Industry working group on Infectious Salmon Anaemia 2000; • Code of Good Practice for Finfish Aquaculture (with legal backing from Aquaculture and Fisheries Act 2013) lists farm management areas; • Scottish Natural Heritage lists Marine Special Areas of Conservation. Areas based on EU Habitats Directive.	5	

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 1 Step 2 Zoning (Zoning or allocation of space is a mechanism for more integrated planning of aquaculture development, as well as its better regulation. It may be used either in planning to identify potential areas for aquaculture or a regulatory measure to control the development of aquaculture)					
1.5 Gross estimation of potential production/ area	Left to the industry to determine their own production targets at a site/regional basis. Upper thresholds for standing stock set for environmental purposes by Locational Guidelines.	Not done	• Sea loch carrying capacities estimated using mass balance models under Marine Scotland Locational Guidelines.	2	
1.6 Formal allocation of the zone for aquaculture purposes	Applied only to water bodies subject to Development Framework Plans, ICZMs, Marine Spatial Plans, i.e., not designated in all areas. Elsewhere there is a presumption in favour of development if there are no excluding regulatory factors and subject to site specific EIA and licence application, taking into account cumulative impacts.	Geographically variable in application.	• National Marine Plan for Scotland.	3	
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.1 Location of the farm sites	Multiple options considered as a requirement of EIA. Technical suitability assessed by the developer. Must consider (as part of the planning application) environmental sensitivity, presence of sensitive species and habitats, use of space by other sectors eg shipping/fishing, fish health and welfare risks, biosecurity, etc.		• Field data collected and environmental study carried out for site by developer; • Farm business presents application to local authority for consideration; • Local planning meetings; • local authorities must consult with statutory consultees: Marine Scotland, Scottish Natural Heritage, SEPA.	5	

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 2 Site Selection (Site selection is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system)					
2.2 Carrying capacity estimation	Calculated for water bodies on the basis of precautionary assessment of risks arising from discharges by regulators/government. Assessed on a site specific basis through modelling done by the applicant and assessed by the environmental regulator.		• Marine Scotland Fish Farm Location Guidelines assessed using model.	5	
2.3 Set licence production limits within zone or water body carrying capacity	Done by the environmental regulator in accordance with limits defined above. Done on the basis of standing biomass rather than production.		• CAR licence under The Water Environment (Controlled Activities) (Scotland) Regulations 2011.	5	
2.4 Allocation of licenses and permits	Full and permanent planning permission. Discharge consent licence. Seabed lease. Business authorisation. Marine Licence (navigational issues/ well boat discharges).		• Crown estate lease granted; • Rent approximately 1% of turnover; • Planning permission granted by local authority planning committee; • Marine Licence granted for constructions under Marine Scotland Act (2010); • Aquaculture Production Business must be authorised by MS. APBs must provide data on fish movements, participate in risk-based surveillance and have a biosecurity measures plan.	5	

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 3 Area Management (Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common relevant water body or source and that may benefit of a common management system including minimizing environmental, social and fish health risks)					
3.1 Identify management area boundaries	For fish health management, based on either hydrographic/topographic factors (Disease management areas) or based on an epidemiological assessment of likely connectivity between clustering sites (Farm Management Areas).		• Marine Scotland Disease Management Areas from simple model; • Code of Good Practice for Finfish Aquaculture; • Edwards and Sharples 1987 Scottish sea lochs catalogue, in updated version, defines coastal water bodies used in Locational Guidelines.	5	
3.2 Estimate total carrying capacity if appropriate based on the different risks	Done for inshore water bodies (sea lochs through Locational Guidelines) based on risks to water quality. Not done routinely for offshore waters.		• Marine Scotland Locational Guidelines for finfish aquaculture.	4	
3.3 Organize a formal association of all farmers in that area	Done in most areas for fish health and welfare coordination under AMA/FMA.		• Aquaculture and Fisheries Act 2013;	4	
3.4 Setting the broad development objectives and identifying the main issues agree on common management,[7] monitoring and control measures	Signed Area Management Agreements. Done for fish health objectives. Farmers in a locality share information through a database run by the Scottish Salmon Producers' Organisation. This particularly applies to sea lice and other health issues.	Farms can use individual Farm Management Statements instead of AMA.	• Aquaculture and Fisheries Act 2013; • Code of Good practice for finfish aquaculture; • Information sharing through SSPO's database.	3	
3.5 Monitoring of relevant variables and enforce management measures	Monitoring of fish health and environmental parameters are a requirement of Business Authorisation and Discharge consents. Results are reviewed by the various regulators. This is done at all sites and not on an area basis only.		• Risk-based inspection regime of sites for fish health by Marine Scotland Fish Health Inspectors; • Inspection by SEPA.	5	

7 An agreed management plan for the aquaculture management area covering the most relevant issues in environmental socioeconomic aspects and governance/external forcing factors.

Phase/Step	Well Done/Achieved (briefly describe main activities/steps)	Not Done/ Not Achieved	Associated Activities and Tools	Rating (0 not achieved to 5 fully achieved)	Approximate Investment Needed for Each Step (US$)
Phase 4 Monitoring of the Management Plan and Review. Monitoring and review of performance is a critical step in the adaptive management planning process. It is essential both to ensure adequate performance is being generated against current objectives and to warrant that aquaculture is maintaining relevance with community expectations. Monitoring the implementation of the management plan should include environmental, social and governance indicators.					
4.1 Regular monitoring and evaluation	AMAs reviewed and updated periodically.		• Farm Management Agreements and farm Management Statements inspected by MSS FHI; • DMA boundaries update whenever new farm opens or old one closes.	3	
4.2 Periodic review and adjustment	Depending on outcome of above.			4	
Extent of use of zoning and area management development (quantifiable)	**Approximate number of designated aquaculture zones or AMAs**	**Approximate production from each aquaculture zone or AMA**			
Number of zones and range of implementation	There are 54 Disease Management Areas defined using overlapping separation distances and used to manage notifiable disease. There are 89 Farm Management Areas which are groups of farms within a local area that work together for management, particularly of lice and non-notifiable diseases. FMA are legally required to have shared management plan. FMA boundaries defined by industry, but government has powers to object. All farms are in a DMA and an FMA.	The 2013 163,000 tonnes production averages DMA 3022, FMA 1834 tonnes. Largest single area had 27 sites (not all active) and a 2013 harvest of 15,978 tonnes (DMA and FMA coincide); this was a synchronous harvest of 18 months production period and corresponds to about 10,600 tonnes per year, smallest areas often contain a single farm.			
Other notes (especially social issues)	**Positive issues**	**Negative issues**			
	Structures designed for specific purposes. Relatively simple to assess if a new farm would join two DMAs, and any new farms that did this will be objected to by Marine Scotland.	Different structures for management, although boundaries often very similar.			

Workshop Report

Patrick White and Pedro B. Bueno

Izmir, Turkey, 5–8 July 2015

CONTENTS

1. BACKGROUND

Around the globe the availability of and access to aquaculture zones and sites with favourable characteristics, including those areas that minimize interactions and conflicts with other activities, are constraints to the expansion of the sector. Meeting the future demand for food from aquaculture will, along with intensification, largely depend on the availability of space. Site selection and carrying capacity considerations, which includes assessment of risks and opportunities, are among the most important initial steps towards the establishment and development of a sustainable aquaculture. They should be carried out in accordance with sustainability objectives, the Code of Conduct for Responsible Fisheries (CCRF), and the ecosystem approach to aquaculture (EAA).

The FAO in partnership with the World Bank are preparing a guide on aquaculture spatial planning and management to improve biosecurity, minimize environmental impacts, maximize income and social benefits and improve interactions with other users of common resources. It will provide practical guidance to a broad range of stakeholders including farmers on the processes and steps for aquaculture zoning, site selection and area management. Planning and management of aquaculture development within the framework of the EAA are reviewed and recommendations to facilitate implementation using a zonal approach are provided. The guide recommends steps and processes as well as policy recommendations. Ways to implement them in different national and local contexts are illustrated by case studies from different countries.

2. OBJECTIVES

The main objective of the workshop was to find ways to support the goal of sustainable aquaculture development based on consideration of governance, economic, environmental and social factors following the Code of Conduct for Responsible Fisheries. Specifically, it sought to improve the FAO-World Bank Handbook on aquaculture zoning, site selection and area management and to plan for its further adoption in, especially, developing countries.

The specific objectives of the workshops were to:

1. discuss the generic process and steps for identification of potential areas for aquaculture: zoning, site selection and the design and management of aquaculture management areas (AMAs) considering the environmental, socioeconomic and governance objectives;
2. present and discuss key findings from the country case studies;
3. conduct group discussions to validate and improve the generic processes and steps required for spatial planning; and
4. derive recommendations for spatial planning and management of aquaculture under the EAA.

3. PARTICIPATION AND ACTIVITIES

The workshop took place in Izmir in Turkey on 6–8 July 2015. It was organized by FAO and the World Bank and hosted by Dokuz Eylul University's Institute of Marine Sciences and Technology.

Participants included the authors who prepared the case studies. Experts hailed from Brazil, Chile, China, Indonesia, Oman, Mexico, Philippines, Turkey and the United Kingdom. The workshop included additional experts from other countries to ensure wider representation. Participants also included authors who have contributed to the drafting of the thematic chapters as well as staff members from the Fisheries and Aquaculture Department and a few key experts from other Departments at FAO.

On the first day of the workshop, the participants visited sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) floating cage farms in Izmir. The system consisted of circular cages measuring 12 to 50 m in diameter. A site with large 50–75 m diameter cages used for Atlantic bluefin tuna (*Thunnus thynnus*) fattening was also visited. The visits revealed that the development opportunities for coastal aquaculture in Turkey are limited because of the many constraints and hurdles to obtaining access to suitable sites. Its expansion in coastal waters has added pressure to marine and coastal ecosystems and created conflicts among users of the coastal resource. Recently, marine farms have been ordered to relocate to more exposed areas or secondary bays. This prompted some changes on types and sizes of the cage systems used. Consequently, there was a need for more space to accommodate the industry's growth, which has led to the issuance of new planning and management policies by the Turkish government.

At the opening session, Thomas MothPoulsen, Senior Fisheries and Aquaculture Officer (FAOSEC) informed attendees that through the FAO-Turkey Partnership Programme, the countries in Central Asia have benefitted from intensive capacity building on aquaculture through joint workshops and projects.

This was followed by FAO and the World Bank representatives describing the processes and steps of spatial planning for aquaculture growth according to the EAA and how these can be implemented. FAO staff and consultants gave presentations on the tools that can be used to support the process. Consultants presented the thematic aspects of zoning, siting and area management (i.e., biosecurity, social, certification and legal aspects). The case study authors presented their studies.

Group sessions discussed the processes and steps on spatial planning for aquaculture and drafted recommendations. The participants evaluated the current status, processes and practices for aquaculture zoning, site selection and area management for each of the ten case studies together with one presentation from each working group to share the lessons learned. The workshop participants were divided in two groups: one group discussed the recommended contents for a "policy brief" for policy makers and regulators, the other group focused on the contents for a document for the private sector. Results of these discussions were presented in plenary.

4. WORKSHOP PRESENTATIONS AND CONCLUSIONS

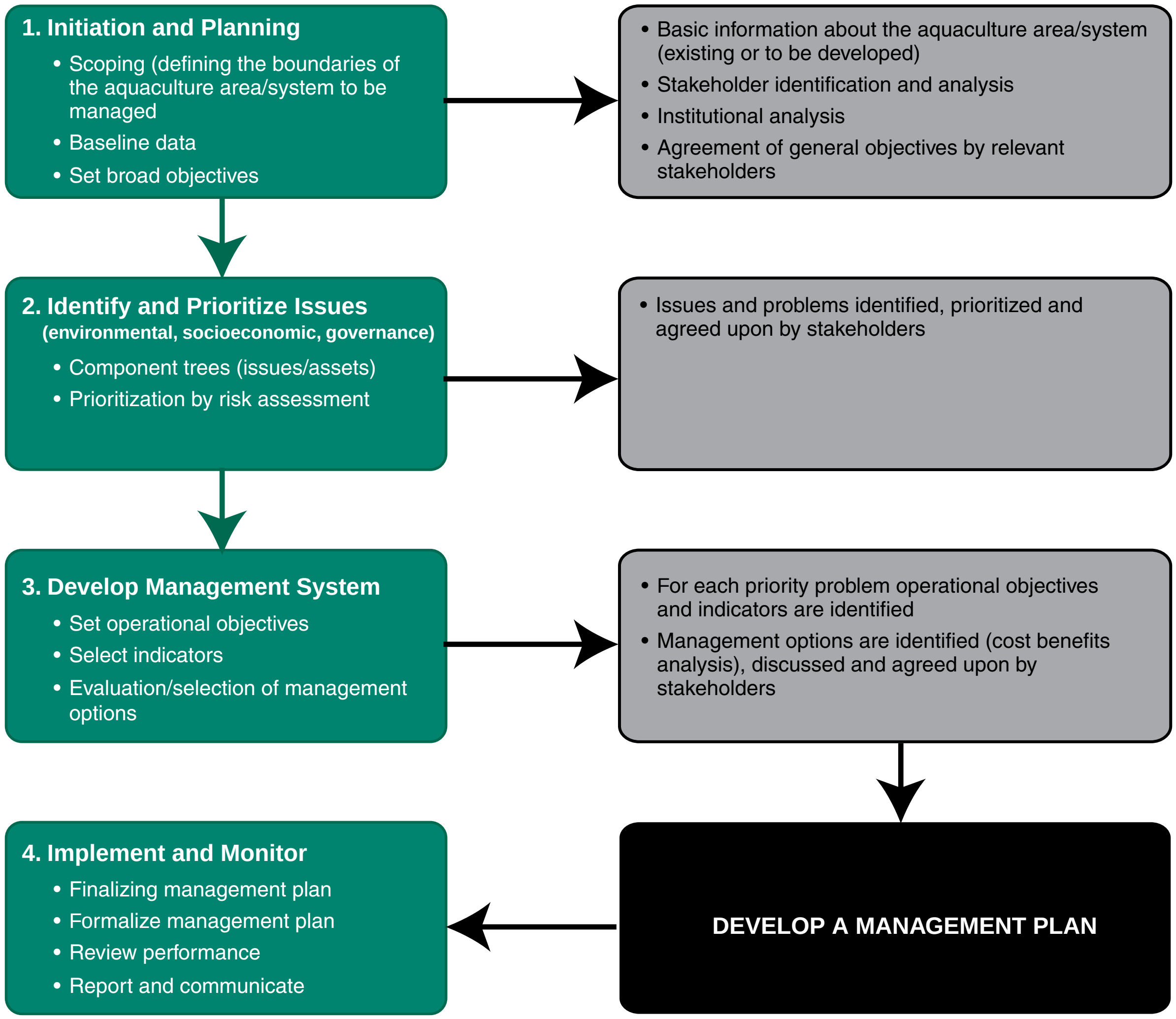
4.1 Zoning, Siting and Area Management under the EAA

An ecosystem approach to aquaculture (EAA)[1] 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." The EAA provides a planning and management framework by which parts of the aquaculture sector can be effectively integrated into local planning and affords clear mechanisms for engaging with producers, government and other users of coastal resources. This leads to the effective management of aquaculture operations by taking into account the environmental, socioeconomic and governance aspects and explicitly including concepts of carrying capacity and risk.

The EAA normally starts with a scoping and definition of the boundaries of the system to be managed, followed by the identification of issues and some risk assessment to prioritize those that require more immediate management. Operational objectives are then agreed upon and management plans developed to address the more relevant issues. A monitoring and evaluation system is embedded to periodically assess the level of implementation and the ability to address the selected issues. The Figure illustrates the process of EAA and steps in the process.

EAA can be implemented at any scale to address the development or to address aquaculture issues at local level, be it a cluster of farms, a cooperative of farmers.

1 FAO. 2010. Aquaculture development. 4. Ecosystem approach to aquaculture. *FAO Technical Guidelines for Responsible Fisheries.* No. 5, Suppl. 4. Rome, FAO. 53 pp. (also available at www.fao.org/docrep/013/i1750e/i1750e00.htm).



It can be applied to a water body such as a small aquaculture watershed, a lake, a coastal area, a province, or at the national level. Implementation can be best achieved in designed Aquaculture Management Areas (AMAs) or local management units. These can be aquaculture parks, aquaculture clusters or any aquaculture area where farms share a common water body or source that allows a common management system. The spatial planning of aquaculture is an essential tool in the implementation of EAA and in the design of AMAs (FAO, 2013[2]; Ross *et al.*, 2013).[2,3]

The EAA is best implemented under a national aquaculture policy or other relevant policies (e.g., food security). It requires adequate and fair regulations which permit the growth of a healthy aquaculture sector capable of competing in the local, national or world markets at the same time protecting the sector from threats such as disease, chemical contamination, overcapacity, displacement by other sectors and environmental harm. Often EAA implementation requires reviewing and improving current norms and

2 FAO. 2013. *Applying spatial planning for promoting future aquaculture growth.* Seventh Session of the Sub-Committee on Aquaculture of the FAO Committee on Fisheries. St Petersburg, Russian Federation, 7–11 October 2013. Discussion document: COFI:AQ/VII/2013/6. (also available at www.fao.org/cofi/43696051f ac6d003870636160688ecc69a6120.pdf).

3 Ross LG, Telfer TC, Falconer L, Soto D, Aguilar-Manjarrez J, eds. 2013. Site selection and carrying capacities for inland and coastal aquaculture. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop, 6–8 December 2010. Stirling, the United Kingdom of Great Britain and Northern Ireland. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 46 pp. Includes a CD-ROM containing the full document (282 pp.). (also available at www.fao.org/docrep/017/i3099e/i3099e00.htm).

regulations. The implementation of EAA management plans in the mentioned AMAs can significantly improve local adoption and implementation of national strategies. Such management plans use different approaches and tools such as strategic environmental assessment (SEIA) and risk assessment (RA). The plans require the application of better management practices and biosecurity protocols.

Aquaculture Zoning: Why This Is Needed and How to Go About It

Aquaculture zoning can be used to identify potential areas for aquaculture growth where aquaculture is new, and to help regulate the development of aquaculture where aquaculture is already well established. In some countries, aquaculture farms have been organized into small management groups such as "clusters," "aquaculture parks," "regions" or "zones." These can increase social and economic benefits to small-scale producers by promoting collective action. However, any clustering initiative requires prudent observation in order not to exacerbate biosecurity (disease) and environmental capacity issues through over concentrated development.

Zoning can help address a number of issues such as integrated management, risk assessment, coastal aquaculture development, expansion of mariculture further offshore, aquatic animal health (biosecurity), better management practices, watersheds management, and aquaculture in the context of competing, conflicting and complementary uses of land and water. Finding optimal solutions to these issues depends in part on finding a suitable zoning strategy supported by zoning policies. The zoning process is normally led by national and/or local governments with important stakeholder participation, equipped with relevant information and supported by relevant regulations.

Individual Site Selection

Site selection (or physical carrying capacity) is based on the suitability for development of a given activity, taking into account the physical factors of the environment and the farming system. In its simplest form, it determines the development potential of any location, but is not normally designed to evaluate that against regulations or limitations of any kind. In this context, this can also be considered as identification of sites or potential aquaculture zones from which a subsequent more specific site selection can be made for actual development.

Site selection is highly dependent on the type of aquaculture system, the location and interactions between the systems, and the surrounding environment. However, decisions on site selection are usually made on an individual basis in response to applications for tenure; therefore this mechanism ignores the fact that many of the major concerns involve regional or cumulative impacts.

This process is normally led by private sector, local land owners, or villagers. Government assists with clear regulations for the process and requirements for site licensing.

Aquaculture Management Areas AMAs, Why They Are Needed and How to Approach This

Aquaculture Management Areas (AMA), can be aquaculture parks, aquaculture clusters or any aquaculture area where farms are sharing a common water body or source and may benefit from a common management system including minimizing environmental, social and fish health risks. AMAs can also be quite beneficial when clustering small farmers that can benefit from joint access to feed, seed technical support and access to markets and postharvest services.

The designation of an AMA relies on some form of spatial risk assessment where the understanding of physical factors such as water flow, currents and the system's capacity to assimilate organic matter is at the core of biosecurity and environmental health. Considerations of socioeconomic carrying capacity are also needed for example regarding provision of services to the farmers, access to markets and, very important, conflict resolution with other users of the common resources and to enhance the potential for integration with other sectors (e.g., with fisheries, agriculture, etc.).

In most countries where aquaculture is practiced, EIA is the most commonly applied environmental regulation but it applies mostly to large-scale intensive farming (cage farming, shrimp). Full EIA is not applied to the bulk of global aquaculture production because most production is small scale, and in many cases a traditional activity. However, it is important to recognize that many small-scale aquaculture activities could have significant impacts on the recipient water body and therefore some form of strategic environmental management is needed.

The need to develop management plans and biosecurity frameworks is even more obvious at the level of AMAs where the farms are closely sited and/or connected by the water flow; addressing disease risks needs to be done in a concerted way for the relevant spatial unit.

AMAs require a structure and management system that may include setting some limits to the maximum production per area, distance among farms, and stocking density. It includes monitoring (of environmental, fish health, socioeconomic aspects, etc.) and evaluation. EAA provides the steps and describes the process to develop management plans for AMAs that go beyond individual farms.

The establishment of AMAs could be a significant step towards the sustainable intensification of aquaculture, especially in regions such as Asia where the farms are already there (especially ponds) and therefore a step forward in environmental management and assurance of biosecurity.

4.2 Thematic Issue Presentations

FAO consultants presented the thematic aspects of zoning, siting and area management (i.e., biosecurity, social, certification and legal aspects).

Aquaculture Certification (Jesper Hedegaard Clausen)

The development and intensification of aquaculture has been outstanding over the last couple of decades with annual growth rates of around 8–10 percent, outpacing other animal protein production systems. Products from aquaculture are widely traded on the international market, and are at the same time providing an important source of animal protein for national consumers. There have been concerns among academia, consumers and NGOs that certain forms of aquaculture, mainly high value species for export, are environmentally unsustainable, socially inequitable, raising issues of animal welfare and having issues with food safety. This is how both the legal mandatory certification requirements for food safety and aquatic animal health developed, as well as the voluntary certification systems concerning environmental and social issues.

In areas or zones that are favorable for aquaculture there is often a concentration of aquaculture operations that could create management issues and challenges for the surrounding environment and for certified farms in these areas. This case study explores how spatial planning and certification can together help aquaculture towards better management and sustainable intensification with a focus on the four areas identified in "FAO's Technical Guidelines for Aquaculture Certification," namely, food safety, environmental impacts, social impacts, and animal welfare. Regulation of density of farms within a zone, better carrying capacity tools, quarantining, and better control of movement of live aquatic animals between zones are suggested as means that should be implemented and addressed in any certification program addressing zones and not individual farms.

Biosecurity (David Huchzermeyer)

The capacity to contain, control and eradicate contagious diseases and the ability to move and trade aquatic animals and their products free of specific pathogens depend on the implementation of national, regional and zone level biosecurity programmes. Planning based on epidemiological principles and a science-based approach provides the means of implementing disease control and risk management at multiple levels. The aim of biosecurity is to protect public health, the environment, and biological diversity. It is applied from a farm to national level based on effective separation of populations with different health status, zones demarcated by geographical boundaries, and compartments defined by management and biosecurity practices, and may be classed as infected or disease-free, and provides an important means for disease control and eradication. Surveillance and diagnostic activities provide information on the occurrence of important aquatic animal diseases. For maintaining international trade opportunities, control measures are the direct responsibility of a competent authority; the standards, guidelines and recommendations are provided by the World Organization for Animal Health (OIE). Emergency response is a critical element of risk management and requires relevant policy, procedures and regulations as well as adequate human, infrastructural and financial resources. Surveillance data on occurrence and prevalence of regulated and emerging aquatic animal diseases need to be reported on national, regional and international reporting systems. A number of regional organizations, and various codes and conventions contribute to standardization of international protocols and responsibilities.

Social Aspects (Pedro B. Bueno)

Any development activity impacts a community—directly or indirectly, in whole or in part, for better or for worse. An impact either enhances or reduces welfare. Impacts include fiscal, environmental, social and economic, and health. Fiscal consists of the public costs and revenues associated with the development. Environmental—almost always negative—includes alteration of land and water resources, loss of open space, change in groundwater and surface water quantity and quality, air quality, alteration of wildlife habitat and changes in landscape aesthetics. Social and economic impacts are those that a development intervention would have on the lives and circumstances of people and their communities.

The positive impacts include employment, higher wages, increased supply of goods for the community, and multiplier effects on the economy and appreciation of property values. Impacts on health, often associated with environmental impacts, are lumped with social impact. But health impacts can be quantified in terms of additional cost of health care, cost of mitigating health hazards, and implications on insurance premiums. It then becomes part of economic impact assessment. Conflicts are the most obvious negative social impact of a development intervention, arising from a number of causes, usually perceived or real unfairness in allocation or sharing of benefits and access to opportunities offered by the activity, competition for resources, and opportunistic behavior. Impacts have varying consequences on different stakeholders. This underlines the importance of a multi-stakeholder participation in planning a development activity and assessing and understanding its potential impacts.

Legal Aspects (David L. VanderZwaag)

Suggestions were made for strengthening the international law and policy discussions. These included thoughts for enhancing the national law and policy components. The main focus was on the international law and policy dimensions by describing the relevance of the international binding agreements with special emphasis on these key agreements:

- UN Law of the Sea Convention (LOSC). The LOSC provides the overall governance framework for aquaculture developments by establishing both State rights and responsibilities;
- Convention on Biological Diversity (CBD) (1992). Although the CBD does not specifically mention aquaculture, the Convention is relevant to aquaculture activities in four ways:
  - Through general obligations for Parties under the Convention,
  - Through guidelines, e.g., Guidelines on Implementing the Ecosystem Approach (2004) through Decision VII/11,
  - EIA guidelines,
  - Through Biodiversity decisions;
- Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971);
- Convention on the Conservation of Migratory Species of Wild Animals (1979);
- UN resolutions and processes relevant to aquaculture, e.g.:
  - FAO Code of Conduct for Responsible Fisheries
  - Technical Guidelines for Aquaculture Development (1997),
  - Technical Guidelines on Ecosystem Approach to Aquaculture (2010).

The presentation identified two ways to enhance national law and policy components:

1. Setting out a spectrum of national approaches to marine and coastal planning, e.g.:
   a. Policy-based call for marine spatial planning (USA)
   b. Bare-bones legislative framework for integrated marine planning (Canada)

c. Sectoral aquaculture legislation requiring aquaculture zoning (Chile)
d. Detailed legislative guidance on marine spatial planning (Scotland, the United Kingdom of Great Britain and Northern Ireland)

2. Recognizing the special challenges of integrated aquaculture management in federated states.

4.3 Case Study Presentations

The case study authors presented their case studies.

Brazilian Aquaculture Parks—Fish Farming and Mariculture (Felipe Matias)

In Brazil, the waters are either owned by the federal government (Union) or by the states. Union waters hold a great potential for Brazilian aquaculture. More than 200 reservoirs (to generate electricity) are available for aquaculture with a carrying capacity of almost 2.5 million tonnes of fish per year. For over 20 years we attempted to achieve the use of these reservoirs for fish production, but the existing legal framework at that time did not make it possible. In 2003, Decree 4895/2003 enabled the legal certainty necessary for the implementation of aquaculture areas and aquaculture parks; the first concessions were awarded in 2009. There are now fish farms in more than 10 reservoirs.

Demarcation of the areas and parks requires expensive and lengthy studies, which measure technical, geographical, social, economic and environmental parameters. After the studies, the parks are demarcated and public hearings held to discuss the implementation and their occupation. There are two crucial issues surrounding this program: i) environmental monitoring, which should allow a simple and faster environmental licensing process and ii) the management of parks, which should enable an orderly settlement.

The exchange of experiences with other countries working on aquaculture parks and the support of institutions such as FAO and the World Bank will be very useful for Brazil to move forward with this public policy. It could make Brazil one of the largest aquaculture producers in the world with sustainability.

Chile Case: The Spatial Planning of Marine Cage Farming (Salmon) (Adolfo Alvial)

The Chilean salmon farming has shown impressive growth. In 25 years the country became the leader in farmed trout production and second in farmed salmon production. In general, regulations moved the industry growth back, generating several gaps that did not help prevent environmental and fish health problems. In fact, in 2007 the ISA (infectious salmon anemia) crisis caused serious social and economic impacts on the industry and the country. This has prompted significant changes in regulations triggering the spatial management that complements the initial Appropriated Areas for Aquaculture (AAA) and Licenses. Groups of licenses (AMAs or neighborhoods) were established as well as macro zones.

An integrated spatial management system is now in place which, despite some weaknesses, has contributed to coordinating the efforts to control diseases, improve efficacy of measures to address sanitary risk and create better conditions for environmental/sanitary recovery of the macro zone. Improvements still have to be done to move closer to an ecosystem approach to aquaculture, principally emphasizing carrying capacity studies and tools, interaction with communities and other sectors, increasing participation and developing incentives. The most significant contribution of the AMA system has been the increase in social capital in the industry and a higher level of public-private interaction.

Zonal Aquaculture Management in China and Indonesia (Anton Immink)

The best examples of zonal management are seen in the salmon industry and were developed, in the pioneering countries of Norway and the United Kingdom of Great Britain and Northern Ireland. The systems are far from ideal but they have helped protect the environment, minimise disease impacts and support the industry to flourish in a sustainable manner. Sustainable Fisheries Partnership (SFP) is using the zonal management model developed in Scotland, the United Kingdom of Great Britain and Northern Ireland, to apply in tilapia, pangasius and shrimp industries in Asia through Aquaculture Improvement Projects (AIPs). Zonal management in salmon production was a response to both chronic and acute disease outbreaks, production issues over continuous use of the same sites and continued external pressure over environmental impacts.

The geographic translation to Asia mandates a shift in cultures, species, capacities and systems. There are challenges interpreting lessons from a relatively low farm density region to areas with almost contiguous production and from cages to ponds, but these challenges need to be overcome in order to ensure sustainable production for the industry, the environment and the local population. SFP is working with local aquaculture sectors in China, Indonesia, Thailand and Vietnam to strengthen the scientific advisory to support effective policy for realistic industry development and to ensure the producers themselves use better practices on farm and are organised to enable them to have a unified voice in their future. Case studies in China and Indonesia are provided.

Spatial Planning of Marine Finfish Aquaculture Facilities in Indonesia (Roberto Mayerle and Ketut Sugama)

This paper presents results of the application of a procedure for supporting decision makers in the sustainable management of finfish coastal cage aquaculture in Indonesia. The investigations were carried out under a project commissioned by the German and Indonesian governments. The aim was the development and application of a stepwise procedure according to zoning, site selection, carrying capacities and biosecurity for the estimation of the sustainable fish farm production in coastal areas. These have been carried out in several coastal sites in Indonesia. The case study presents results from a site in the northwest of Bali.

Aquaculture management areas were designated and recommendations on the suitable locations of cages and carrying capacities to ensure environmental sustainability proposed. The recommendations are being implemented in cooperation with the local authorities. The methodology adopted, which is integrating field measurements and high-resolution numerical models within a decision support system, proved to be effective for Indonesian conditions and well suited to the estimation of the country's potential in coastal cage aquaculture. Recommendations to improve existing aquaculture regulations were made. The need for intensifying communications between public institutions and stakeholders to facilitate the enforcement of the results was pointed out.

Shrimp Farming in Mexico (Giovanni Fiore Amaral)

Mexico's shrimp farming industry began in the 1970s in the northwest states of Sonora, Sinaloa and Nayarit. Farming was in ponds with low stocking rates. Current estimates indicate that the national surface area of shrimp ponds is around 70,000 hectares, however the technology has changed little. Nevertheless, shrimp farming represents one of the most profitable aquaculture sectors in Mexico. The legal regulation and development of shrimp farming has to be coordinated between two federal agencies, the National Commission of Aquaculture and Fisheries (CONAPESCA), which is responsible for the regulation of aquaculture in water bodies of federal jurisdiction and the Secretariat of Environment and Natural Resources (SEMARNAT), which regulates the development of inland aquaculture by requesting environmental impact assessments.

The Federal Government through CONAPESCA recognizes the need for the aquaculture sector to sustainably grow and has allocated public resources to improve this sector through specific strategies, such as the National Program for Aquaculture Management to: (i) enable an orderly, sustainable and competitive aquaculture sector, and (ii) regulate and administer the sector, using processes and tools for the delimitation of aquaculture zones. Shrimp farming in Nayarit State illustrates the methodology used to demarcate and manage aquaculture zones based on the scoping of the aquaculture activity and the zone. It was carried out by the Aquaculture Health Committee of Nayarit State with federal funds. Zoning results are uploaded in a web spatial database to facilitate the regularization of farms through legal mechanisms.

Aquaculture Site Selection and Zoning in Oman (Dawood Suleiman Al-Yahyai)

The vision of the Ministry of Agriculture and Fisheries (MAFW) is to develop aquaculture in a sustainable, competitive and environment-friendly basis that meets the needs of customers of high quality aquaculture products. Several features make Oman attractive to local and foreigner investors. These include long coastlines with diverse natural marine resources, world-class infrastructure, close proximity and easy access to export markets, attractive financial incentives, commitment of support from government authorities and well organized institutional and legislative frameworks.

The Ministry of Agriculture & Fisheries carried out a detailed survey of the Omani coast at the beginning of the last decade. An atlas for suitable sites along the coast was prepared which includes oceanographic and environmental descriptions of the coast of Oman and information on suitable methods for aquaculture as well as the major constraints.

The sites for aquaculture projects were allocated in cooperation with the Ministry of Housing and the Ministry of Environment & Climate Affairs. A recent project was started by the Ministry of Agriculture & Fisheries to select suitable sites for marine cages in Musandam Governorate using GIS and remote sensing tools. This also allows the assessment of the carrying capacity of each site. The project will also develop a model for sustainable aquaculture development applicable to the other regions of Oman.

Mariculture Parks in the Philippines (Nelson Lopez and Patrick White)

The Government through the Bureau of Fisheries & Aquatic Resources promotes the development of mariculture zones and parks as a responsible and sustainable development option in coastal cage aquaculture. The social objectives are to provide livelihood to local communities and contribute to food security. There are now more than 60 mariculture parks throughout the Philippines. The concept of the Mariculture Park (MP) is akin to an industrial estate. In a designated zone within municipal waters, aquaculture plots are leased to small- to medium-sized aquaculture farms. Infrastructure (mooring systems, navigation lanes and docking areas), utilities, and technical services are provided by the government. The development process for setting up and operating a Mariculture Park follows a well-defined set of steps.

The main features of a Mariculture Park are: (i) Shared infrastructure—multiproduct onshore warehouse, cold storage and ice plants facility, service as well as ferry boats, communal mooring system; (ii) Shared services—availability of seeds and feeds supplier, cage fabricator and manpower services; (iii) Shared security—internal and external security; and (iv) Sustainability—well-selected sites for small-, medium- and large-scale investors. Other features are controlled maximum production and environmental monitoring.

Mariculture Parks in Turkey (Güzel Yücel Gier)

Turkish marine aquaculture has seen rapid growth along the Aegean coast since 2000. This case study focuses on mariculture parks in Gulluk Bay where 55 percent of total marine aquaculture production occurs. Conflict with other coastal zone stakeholders had spurred the Ministry of Environment and Urbanization (MEU) to issue new regulations. In 2008 new regulations for Gulluk Bay led to the definition of two mariculture zones. These cover 20.8 percent and 0.45 percent of the area licensed for the cages on the Bay. This was done by a Turkish Inter-Ministerial Consortium, in cooperation with the Mugla Fish Farmers Association. Site selection and zoning addressed basic issues and were carried out through a participatory process among stakeholders, scientists and central government. This has subsequently proved to be a weak point in the whole process. The two mariculture zones were evaluated separately in Gulluk Bay. Two total zoning EIA reports were separately produced for the Bodrum zone and for the Milas zone. Monitoring is done by government officers.

Aquaculture zoning, spatial planning, aquaculture management and risk mapping are among the most important issues for the success of aquaculture. They need to be carried out in accordance with sustainability and best practice guidelines. Turkey has recently focused on such issues and is trying to set guidelines which would enable true sustainability to take place. The whole EIA process needs the estimation of carrying capacity of a new aquaculture potential area and harmonisation with the monitoring and management system to be used.

Aquaculture Parks in Uganda (Nelly Isyagi, unable to attend)

Fisheries are Uganda's third source of foreign exchange and contribute to the livelihoods of about 5.3 million people. To sustain economic growth arising from the sector an additional 300,000 tonnes/year of fish is required. However, Uganda's natural waters have reached their maximum sustainable yield. Large-scale commercial aquaculture is the only feasible option for achieving the additional production needed in the medium term.

Aquaculture production is from isolated small farms. This makes it difficult to establish efficient production and marketing value chains. Increasing the number of such units would pose challenges for environmental management. The strategy is to produce large volumes of fish and related services from "Aquaculture Parks" located within designated high aquaculture potential areas using an ecosystems approach. The Government of Uganda has conducted broad studies to identify such potential areas. Findings suggest good potential in most parts of the country as well as for operating aquaculture parks.

Considering the level of investment and production objectives of Aquaculture Parks, for success and sustainability, it is crucial that they be established within appropriate frameworks. Actual spatial scoping, demarcation of ecosystem boundaries, selection of specific zones and sites based on natural resource capacity, and development of targeted management policies and plans for the aquaculture zones have yet to be done. Ecosystem characteristics will determine the location, number, size and appropriate operating systems of the parks.

Aquaculture Zoning, Site Selection and Area Management in Scottish Marine Finfish Production (Matthew Gubbins)

Scottish aquaculture production is dominated by Atlantic salmon of which it is the world's third largest producer. Salmon farming has developed since the 1970s, and spatial management has become increasingly important to ensure sustainability, particularly for fish health and environmental protection. Area management involves collaboration between government and industry and both parties operate area management systems. Disease Management Areas (DMAs) are used by government to control notifiable disease, particularly ISA. They are defined using a simple model and current government policy is against new sites that would join DMAs.

Farm Management Areas (FMAs) are industry defined areas in which farms collaborate on management issues, including sea lice treatments. Sea lochs (small fjords) are assessed for carrying capacity and maximum biomass consent is limited to prevent environmental impacts arising from cumulative discharges. At a larger spatial scale large areas are reserved with no aquaculture, including the North and East coasts of Scotland, the United Kingdom of Great Britain and Northern Ireland, where the most significant wild salmonid populations in Scotland are found. New farms are given development consent under Town and Country Planning by local authorities, taking into account views of all primary stakeholders and in accordance with established policies in Scotland's National Marine Plan and any local plan. Standards are enforced by official inspectors working for the Fish Health Inspectorate and the Scottish Environment Protection Agency and through industry codes of practice.

5. CONCLUSIONS AND RECOMMENDATIONS

The workshop enabled a better understating and streamlining of the process and steps for aquaculture zoning, site selection and area management. It highlighted lessons learned from case studies and identified gaps for improvements.

The ecosystem approach to aquaculture provides an opportunity for countries to develop aquaculture in a responsible and sustainable manner. EAA should have a central position in the planning and management of aquaculture development in any country. Through a participatory process, EAA should facilitate the appropriate balance between the socioeconomic, environmental and governance objectives and the associated measures.

The country case studies provided examples of the broad range of situations in which spatial planning has been fully implemented and where spatial planning for aquaculture is only just beginning. It was very clear on the other hand that Aquaculture Area Management is either absent or poorly implemented although it is extremely needed to address fish health issues and biosecurity, environmental issues and socioeconomic issues. It was agreed that AMAs could provide a way forward to sustainably intensify aquaculture, particularly in Asia.

While countries are advancing with their spatial plans, some of the major gaps appear to be: (i) limited or total absence of coordinated environmental monitoring at the relevant ecosystem scale; (ii) insufficient capacity to implement regulations; (iii) no methodologies for or limited estimates of carrying capacity; and (iv) lack of assessment of risks to aquaculture posed by climatic variability, climate change and other external threats such as industrial pollution of water sources.

5.1 Governance Issues

The working group on Governance issues identified the importance and benefits of the aquaculture zoning, siting and area management. These include:

- Ensuring aquaculture development in a sustainable and responsible manner;
- Minimizing disease outbreaks and other risks;
- Avoiding social conflicts and conflicts with other sectors; and
- Avoiding boom-bust cycles of development in the absence of good planning and management.

These aquaculture zoning and area management guidelines offer flexible and adaptable advice, for example:

- Countries differ in aquaculture development. Countries with well-developed aquaculture can use the guidelines to help set up Aquaculture Management Areas and encourage farmers to cooperate in biosecurity, environmental and socioeconomic management of their shared water resource.
- Countries new to aquaculture can use the guidelines to help identify suitable potential zones for aquaculture development and identify farm sites and levels of production within the carrying capacity of the zones.

Different levels of Government may be involved with the different steps from zoning to site selection to delineation of AMAs and setting up the governance frameworks and mechanisms for a zone, a site and an AMA. However, this depends on the existing level of government control for planning and management (whether control is centralised or devolved).

- National government is typically involved with the identification of the aquaculture zones at the national level and estimating potential production within those zones.
- Provincial or local government is typically involved with the setting up of AMAS.
- Local governments are typically involved with siting and licensing of individual farms.

The introduction of zoning, siting and area management can be made in a number of ways. It can be introduced through:

- National aquaculture policy, strategy, medium- and long-term plans;
- Aquaculture legislation, regulation or guidelines;
- National Good Aquaculture Practice guidelines or Codes of Conduct; and
- Licensing by including the requirement for farms to cooperate with neighbors within an area agreement.

Zoning, siting and area management can be introduced in a step-wise approach or all at once. Area management can start with cooperation on disease control and biosecurity and then developed further over time to include environmental, socioeconomic management, marketing cooperation and use of shared infrastructure.

The introduction of zones, siting and area management requires significant resources including staff with knowledge of the process and trained in the methodologies and use of tools, This capacity can be developed within the Government staff through training, or some aspects can be outsourced to research units, universities or service providers with the technical competence.

Zoning for aquaculture can be exclusive or integrated. Zones can be designated exclusively for aquaculture use (e.g., Turkish case study) or aquaculture can be integrated with other sectors and uses within a zone (e.g., Scotland case study).

5.2 Private Sector Issues

The private sector working group tried to identify the aspects of the process that could appeal to entrepreneurs and farmers and how the private sector can be better involved in the establishment and management of AMAs. The working group agreed that aquaculture tends to get into trouble if left to develop organically and that problems occur when there is unregulated growth with new entrants not following good management practices. It noted that the AMA scheme, based on the case studies, works.

The process can address most of the private sector concerns including:

- Disease prevention—by improving ecosystem health and fish welfare leading to improved disease management;
- Long-term improvement of fish stock performance while addressing genetic quality and feed availability;
- Risk mitigation and coping by increasing access to insurance at the AMA level;
- Encouraging responsible investment thus increasing finance availability;
- Making space for aquaculture—protecting the rights of fish farmers in a common property context; protecting the rights of locals and smallholders; equitable access;
- Encouraging stable production resulting in fewer crashes and fish kills;
- Integrating aquaculture with multiple uses—to reduce conflict, which can be expensive to resolve when it flares up;
- Potential for common action to address externalities (e.g., pollution, encroachment of other sectors);
- Improving access to markets and certification;
- Improving the perceptions for aquaculture products by the market;
- Demonstrating the economic benefits of EAA—that investment in EAA is cost-effective; and
- Encouraging the sustainable use of common water bodies and working with others interested in using the commons for community benefit.

In order to implement the process, there is need to:

- Establish a zone/AMA management committee that will lead the process—includes government, other sectors, academia, NGOs and the private sector;
- Focus on specific activities to be undertaken by the committee—AMA level within top-down mandate of zones, and EAA strategy;
- Draft general aquaculture management plan and review and adapt the process as it is a living, evolving concept;
- Develop a flowchart for the implementation;
- Establish a basic mechanism of linking farmers to each other and with government by:
  - Communication of significant mortalities to the network,
  - Access to veterinary services—mechanism for delivery at AMA level—examples from case studies,
  - Collective biosecurity plan,
  - Access BAP/efficient technology—linked to research; and
- Establish and monitor agreed indicators of carrying capacity limits—progress towards an agreed standard and definitions of limit. Initially in tonnes of production/year, evolving to include other indicators such as mortality, sediment, turbidity and DO variability.

There is also a need to;

- Clarify if it applies to either or both existing sites or new zones;
- Find ways to:
  - Improve profitability while maintaining stable production and increasing efficiency,
  - Reduce feed costs,
  - Reduce disease occurrence and impacts; and
- Assess how it affects product quality—monitoring to ensure food safety and improve market access.

6. POTENTIAL ROLE OF FAO

The results of this workshop created baseline information to enable FAO/World Bank to complete the FAO/World Bank publication and to make plans for its wider adoption. The main outputs from the workshop are:

1. a policy brief for policy makers and regulators;
2. a concise document for the private sector, managers, scientists, farm developers, and extension service personnel.

To further validate and strengthen the Guide, the steps and processes are currently being used in a questionnaire survey as part of a new Horizon2020 EU funded project (AquaSpace). This allows a first assessment of the current status, processes and practices for aquaculture zoning, site selection and area management in marine and freshwater environments in Europe plus non-EU Mediterranean and Black Sea countries (covering the General Fisheries Commission for the Mediterranean area of competence), plus Canada and the United States of America as part of the Galway Statement on Atlantic cooperation. The results of this survey were used to prepare a review of current approaches to spatial planning. The details of this review were finalized at a workshop that was held in Venice in February 2016.

FIRA will need to seek funds to assist developing countries in implementing "aquaculture zoning and aquaculture management areas under the EAA." This is a potential area of global interest in which FAO and countries as well as other partners could make good use of the documents being produced from this initiative by FAO and the World Bank. At a national level, activities could include (i) the generation of baseline information, and (ii) the implementation of pilot projects. At a global level, efforts could be on capacity building for policy makers and managers and training for technical personnel covering such topics such as area-based planning and management for policy and regulatory frameworks, biosecurity, environmental impacts, and certification.

ANNEX 1. WORKSHOP AGENDA

Day 1 Sunday 5 July	Activities	Presenter/Facilitator
09:00	Departure from hotel	All
10:00	Arrive at Pınar-Deniz hatchery	All
10:00–12:00	Visit Hatchery	All
12:00–13:00	Lunch on the farm courtesy of Pınar-Deniz	All
13:00–16:00	Boat visit to Seabass, Seabream and Tuna cage (Çamlı and Sagun companies) Brief discussion on lessons learned from field visit	All
16:00	Depart from Pınar Deniz	All
17:00	Arrival at hotel	All

Day 2 Monday 6 July	Activities	Presenter/Facilitator
08:30–09:00	**Registration**	All
09:00–12:00	**Opening remarks**	FAO/Turkey representative
	Self-introduction of workshop participants	All
	Background, objectives and contents of the workshop	Brummett/Soto
	Group photo and coffee break	All
	Presentation of the draft publication	Soto/Aguilar
	INTRODUCTION TO COUNTRY CASE STUDIES. Do current spatial planning and management follow suggested steps?	White
	Zoning and site selection	
	Mariculture Parks in Turkey	Yucel-Gier
	Mariculture Parks in the Philippines	White/Lopez
	Spatial planning of marine sea cage farming (salmon) in Chile	Alvial
	Fish cages in reservoirs in Brazil	Matias
	Coastal cage aquaculture in Indonesia	Mayerle/Sugama
	Lunch	
13:30–17:00	Fish cage culture in Oman	Dawood
	Aquaculture parks in Uganda	Isyagi
	Shrimp ponds in Mexico	Fiore Amaral
	Discussion	
	Area management	
	Zonal aquaculture management in China and Indonesia	Immink and Morales
	Zoning and area management of Scottish aquaculture	Gubbins
	Discussion	
	Coffee break	
	Summary of case studies	
	Analysis of case study scoring	Selected participant
	Discussions on lessons learned from case studies	All
	Presentation of the scores	Selected participant
	Case study wrap-up	All

Day 3 Tuesday 7 July	Activities	Presenter/Facilitator
09:00–12:00	**THEMATIC PRESENTATIONS**	
	Biosecurity	Huchzermeyer/FAO
	Certification	Hedegaard Clausen
	Discussion	
	Coffee break	
	STEPS AND PROCESSES FOR ZONING, SITE SELECTION AND AREA MANAGEMENT	
	Processes and steps	
	Review of the processes and steps	FAO
	Discussion	All
	Lunch	
13:30–17:00	**WORKING GROUP DISCUSSIONS**	
	Presentation on the steps **for scoping**	Aguilar
	Plenary discussion on scoping	All
	Consensus on scoping	All
	Three working groups for discussion: (i) zoning, (ii) site selection and (iii) aquaculture management areas	World Bank
	Presentation on the steps **for zoning**	Appointed rapporteur
	Working group discussion	
	Working group presentations at plenary	
	Consensus on zoning	
	Coffee break	
	Presentation on the steps for **site selection**	Appointed rapporteur
	Working group discussion	
	Working group presentations at plenary	
	Consensus on site selection	
	Presentation on the steps for **area management**	Appointed rapporteur
	Working group discussion	
	Working group presentations at plenary	
	Consensus on area management	
18:30	**RECEPTION DINNER**	All

Day 4 Wednesday 8 July	Activities	Presenter/Facilitator
09:00–12:00	**Three working groups for discussion: case study evaluation and lessons learned**	FAO
	Evaluation of **Case studies** and review	3 Appointed rapporteurs
	Scoping for zones	
	Broad risks and opportunities	
	Coffee break	
	Effective tools	3 Appointed rapporteur
	Working group discussion	
	Working group presentations at plenary	
	Lunch	
13:30–15:00	Presentation on **Governance issues** and **Private Sector issues**	White/Brummett/FAO staff
	Working group discussion	
	Working group presentations at plenary	
	Consensus on the key Governance and Private Sector issues	
	CONCLUSIONS	World Bank
	Consensus on the ideal processes and steps	Soto/Aguilar
	Plenary discussion on way forward to implement aquaculture zoning, site selection and area management	FAO/World Bank
	Recommendations for FAO publication	FAO/World Bank
	Wrap up closing session	Turkey representative

ANNEX 2. WORKSHOP ORGANISERS

FAO/World Bank Secretariat:

Doris Soto (FAO)
José Aguilar-Manjarrez (FAO)
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Date and hosts: The workshop was held in Izmir, Turkey from 5–8 July 2015. The workshop was hosted by Dokuz Eylul University, Institute of Marine Sciences and Technology.

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The ecosystem approach to aquaculture provides the conceptual guideline for spatial planning and management. This publication describes the major steps related to these activities. The rationale for and objectives of each step, the ways (methodologies) to implement it, and the means (tools) that are available to enable a methodology are described in a stepwise fashion. Recommendations to practitioners and policy-makers are provided. A separate policy brief accompanies this paper. The benefits from spatial planning and management are numerous and include higher productivity and returns for investors, and more effective mitigation of environmental, economic and social risks, the details of which are provided in this paper.

This publication is organized in two parts. Part one is the "Guidance"; it is the main body of the document and describes the processes and steps for spatial planning, including aquaculture zoning, site selection and area management. Part two of the publication includes six annexes that present key topics, including: (i) binding and non-legally binding international instruments, which set the context for sustainable national aquaculture; (ii) biosecurity zoning; (iii) aquaculture certification and zonal management; (iv) an overview of key tools and models that can be used to facilitate and inform the spatial planning process; (v) case studies from ten countries – Brazil, Chile, China, Indonesia, Mexico, Oman, the Philippines, Turkey, Uganda and the United Kingdom of Great Britain and Northern Ireland; and (vi) a workshop report.

The country case studies illustrate key aspects of the implementation of spatial planning and management at the national level, but mostly within local contexts. Take-home messages include the ways in which institutional, legal and policy issues are addressed to implement the process, or parts of the process.

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