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PLANNING OF SUSTAINABLE SMALL-SCALE AQUACULTURE IN MOZAMBIQUE

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ABSTRACT

Aquaculture has the potential to be used as an alternative source of animal protein supply in rural areas in Mozambique. Currently fish farming in rural areas in Mozambique is done in a small-scale but the authorities are interested in spreading and increasing the activity among local communities. So far there are no environmental concerns related to small-scale aquaculture, as it still small and dispersed. However, in the long run it is likely that aquaculture will be practiced by an increasing number of people potentially causing negative impact on the environment.

This study outlines the environmental impact of aquaculture activityand suggests alternatives for mitigating the negative impact. An environmental management plan for small-scale aquaculture in Mozambique is also provided.

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1 INTRODUCTION

1.1 Background

Mozambique is located in southeastern Africa. Covering a surface area of 799,380 km^2. To the east, the country has a coastline along the Indian Ocean that extends for 2,700 km.

Mozambique's water resources include more than 60 major rivers, lakes and lagoons. The climate is predominantly tropical, with three main sub-climates: a humid tropical climate in the north, centre, and southern coastal areas; a dry tropical climate in the south and the Zambezi valley; and a high altitude tropical climate in the interior mountain regions. The country's flora is mainly of the dense, open forest and savanna types (IMF and WB 2001)

Mozambique is one of the poorest countries in sub-Saharan Africa and in the world, with a gross national income per capita of about US$ 210 (IMF and WB 2005).

According to a Household Survey carried out in 2002-2003, the latest comprehensive poverty assessment undertaken in Mozambique, nearly 54 percent of the population lived below the poverty line of US$ 1 per day (IMF 2005).

Aquaculture is a new activity in Mozambique. The first industrial prawn farming was established in the mid-1990s and currently there are three industrial shrimp farming enterprises and one fish farm. However, extensive aquaculture has existed since at least the 1950s (Ministry of Fisheries 2005).

Lack of experience and tradition and the long political instability that ended in the early 1990s, are pointed out as the main reasons for the slow development of aquaculture in Mozambique (Menezes 2001).

The culture systems currently practiced are semi-intensive and extensive. Extensive aquaculture is characterised by cultivation of species captured in the wild or from hatcheries, non-use of mechanical aeration and industrial feed, and use of fertilisers. This system is mainly practiced by communities. Semi-intensive aquaculture is characterised by the use of species cultivated in hatcheries; use of mechanical aeration and industrial feed, and is done by commercial farmers (Ministry of Fisheries 2005).

Both marine and freshwater aquaculture in Mozambique benefits from the diversity of the natural environment and availability of suitable local species for farming. Freshwater culture mainly consists of integrated fish farming systems aimed at improving food safety and availability to the general population, while marine aquaculture is broadly oriented towards both low-cost protein production and high-value products for export (Menezes 2001).

Freshwater aquaculture in Mozambique has been growing since the early 1990s. A study carried out in Manica Province, where most small-scale aquaculture is concentrated in Mozambique, revealed that there were 1539 small-scale aquaculture ponds and 895 families are involved in the activity (Ministry of Fisheries 2004). According to FAO (2004) the main extensively cultivated species in Mozambique are *Oreochromis niloticus, O. mossambicus Tilapia rendalli, and* carp, and production from small-scale aquaculture is around 70 tons/year.

The initialisation of industrial aquaculture gave a boost to the production, increasing from an average of less than 100 tons/year (FAO 2005) to 900 tons/year in the last four years (Ministry of Fisheries 2005). However, aquaculture in Mozambique is still experiencing difficulties related to the lack of human capacity and distrust of financial institutions regarding the risks involved in the development of the sector (Hishamunda 2001).

Assessment of coastal areas for mariculture carried out in the 1980s by the Fisheries Research Institute and France Aquaculture (a French consultancy company for aquaculture and fisheries), estimated the potential for aquaculture in coastal areas in Mozambique to be 33,000 ha (Menezes 2001).

National institutions are working on the planning and development of aquaculture, in order to establish a framework for the management and sustainable development of the sector. Particular attention is given to physical planning, regulation and coordination among stakeholders (Menezes 2001).

There are good future prospects for aquaculture in Mozambique, taking into consideration the available fisheries resources, the environment and the continuing effort of the government towards the promotion of aquaculture in rural areas in order to improve the diet of the population at a low cost.

1.2 Rationale

Aquaculture is at an exciting stage of development. World aquaculture production is currently increasing at a rapid rate. It is increasing much more rapidly than either animal husbandry or capture fisheries, the two main sources of animal protein for the world's population. As seafood production from fisheries is at or near its peak, aquaculture is likely to become the main source of seafood production (Lucas and Southgate 2003). Often, however, aquaculture has not met expectations and in some cases it has even led to serious environmental degradation. This has often been due to a general lack of ecological understanding about the negative impact of cultivation on the environment (J. Fuchs, *et. al.* 1999).

The Ministry of Fisheries of Mozambique is engaged in the promotion of small-scale aquaculture to improve the availability of animal protein to the population. Even though small-scale aquaculture is considered environmentally sustainable, when it is practiced extensively without an environmental plan, the impact can be considerable.

The experience gained in a number of Asia-Pacific countries has shown that aquaculture can lead to environmental degradation, threatening the long-term sustainability of the aquaculture production (J. Fuchs, *et al.* 1999).

According to the Environmental Vulnerability Index (EVI) developed by the South Pacific Applied Geoscience Commission (SOPAC) and the United Nations Environment Programme (UNEP), fisheries, agriculture and biodiversity are among the areas of greatest environmental vulnerability in Mozambique, and many other EVI indicators have a tendency to become vulnerable. Therefore, serious practical action is required to minimise degradation (SOPAC and UNEP 2005).

The existing legal framework in Mozambique does not explicitly state how to manage the likely general and cumulative effects of small-scale aquaculture on the environment. It is realised that over-concentration of a larger number of fish ponds and other related support facilities in a particular area might adversely affect the environment in the long run if adequate steps are not taken to make fish farming activities environmentally sustainable.

If aquaculture development is to be ecologically sustainable, efforts must be directed towards methods that make use of the natural environment without severely or irreversibly degrading it. The benefits derived from the ecological processes and the life-supporting ecosystems must be recognised and must play an important role in aquaculture development.

Hence there is a need to have guidelines for aquaculture that cover issues regarding the prevention and reduction of the negative environmental impact of small-scale aquaculture.

1.3 Objectives

- To identify major environmental concerns and create initial environmental guidelines for small-scale aquaculture in Mozambique.

1.3.1 Goals

- To identify possible general and cumulative effects of small-scale aquaculture on the environment.
- To identify the best available technology and specific measures to minimise the environmental impact of small-scale aquaculture in Mozambique.
- To develop initial environmental guidelines for small-scale aquaculture in Mozambique

2 METHODS

In order to achieve the stated objectives, the following methods were used:

A literature review was compiled in order to gather baseline data from the Internet and library sources. Literature was specifically cited on the environmental impact of aquaculture and aquaculture management in general. Particular attention was paid to effluent treatment, diseases control and fish escapees management. Literature on environmental issues for small-scale aquaculture in Mozambique was also sourced in order to identify the existing gaps in regulations.

Three institutions were visited namely the Veterinary Institute at Keldur, the Environment and Food Agency and the Directorate of Freshwater Fisheries. The Marine Research Institute Laboratory was also visited.

At the Veterinary Institute, an interview with the Veterinary Officer for fish disease was conducted. The interview focused on disease surveillance and management in Iceland, the institutions involved, the procedure for sampling, analyses of the samples collected in rivers and aquaculture farms, and the risk management plan.

At the Directorate of Freshwater Fisheries information about freshwater aquaculture licensing and environmental management was gathered.

At the Environmental and Food Agency information about the environmental licensing in Iceland, the institutions involved in environmental licensing and monitoring, and the requirements for conducting an environmental impact assessment was collected.

In the visit to the Marine Research Institute Laboratory at Grindavik, the objective was to observe the aquaculture effluent treatment system. The visit to Hólar had the same objective but unfortunately the objective of visiting Hólar was not achieved.

The data collected from different literature sources and institutions was used to create an initial environmental guideline for small-scale aquaculture in Mozambique. The guidelines were organised by type of aquaculture and in each type the issues to be considered were specified. Thus, the guidelines were organised in the following way:

- General guidance for site selection which includes the main aspects to be considered in the site selection process, namely the past existing activity influencing the site, weather and climate, hydrology and water quality.
- Guidance for pond aquaculture, which specifies important aspects to be considered for pond siting, pond design, pond construction, pond operation, and pond monitoring and control.
- Guidance for cage aquaculture, which specifies aspects of siting, constructing, operating, monitoring and controlling cages.
- Summary of the environmental impact of aquaculture mitigation and monitoring, which identifies the impact of specific activities and mitigation techniques.

3 IMPORTANCE OF AQUACULTURE FOR FOOD SECURITY

Aquaculture can contribute to human food security either by supplying protein to people or by increasing income and thus increasing the capacity to purchase food on the market.

The development and wider adoption of aquaculture can be considered an important contribution to household food security and general welfare. By supplying food and being a commodity, aquaculture can contribute to enhanced food and nutritional status of people in at least three ways, namely by increasing incomes, providing employment, and providing food.

- Adoption of aquaculture and its effects on income

Income and purchasing power are determinant of household demand for food. Income therefore has a great influence on fish consumption (often a non-staple or not the main staple) and other non-staples with high nutritional content. According to Bouis (2000), quoted in Ahmed and Lorica (2002), empirical evidence suggests that an increase in staple food (e.g. cereal) consumption as income rises is very minimal or nearly zero once a required minimum is reached. But in the case of non-staple foods (e.g. fish and vegetables), it rises rapidly with income on a percentage basis.

- Adoption of aquaculture and its effects on employment

The relationship between aquaculture, employment and food security is based on the hypothesis that the nutritional condition of household members is related to the household's capacity to earn an income, which in turn depends on the nutritional health of the household labour force (Ahmed and Lorica 2002).

In developing countries, such as Mozambique, where the majority of the population lives in rural areas and many families in those areas depend on agriculture, which in turn depends mostly on the family's force labour, it is important to maintain and increase productivity by increasing income. Aquaculture can contribute for increment of agricultural productivity labour and hence engender higher earnings for both own-family and hired labour.

- Adoption of aquaculture and its effect on food consumption

Supplying a household with a large amount of fish, which is rich in nutrients, improves the household's nutritional status. Wide adoption of aquaculture can also increase market supply and hold fish prices down, hence increasing the intake of micronutrient-rich food (Bouis 2000 quoted in Ahmed and Lorica 2002).

Figure 1 illustrates the linkage between adoption of aquaculture, income, employment and consumption of food. It can be seen that aquaculture, by contributing to increasing households' income, will have a positive affect on fish demand and other high quality food. In addition, by providing employment, it will increase ability to earn wages and consequently it will increase the ability to consume nutrient rich fish, hence increasing labour force productivity.

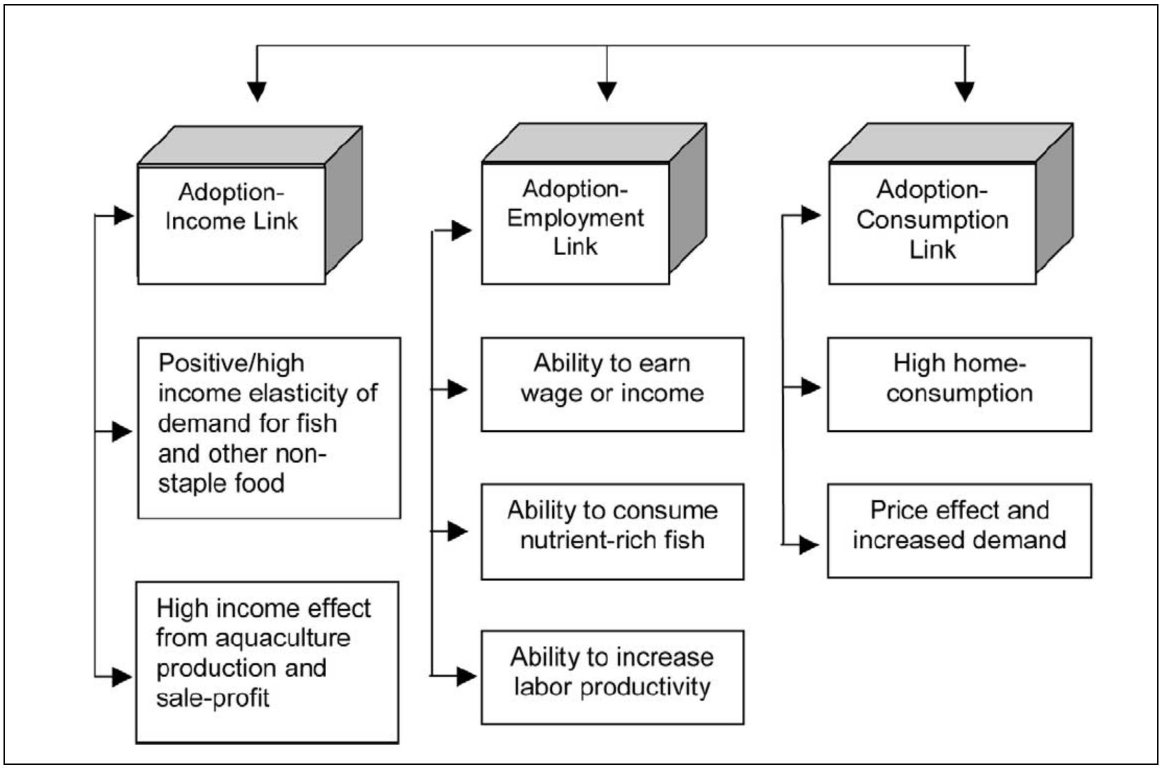

Figure 1: Aquaculture's linkages to food and nutritional security (Ahmed and Lorica 2002).

Widespread adoption of aquaculture on traditional agriculture farms in a number of Asian countries, such as Bangladesh, China, India, Indonesia, Thailand and Vietnam has led to improvements in productivity, diversification of farm operations and the creation of additional employment and income (Ahmed and Lorica 2002).

Aquaculture can help to alleviate poverty and promote food security in rural areas in Mozambique where the majority of the population is dependent on agriculture and has less access to animal protein. By integrating aquaculture with agriculture, small farmers can improve their food supply, increase incomes and better withstand economic shock.

4 OVERVIEW OF THE ENVIRONMENTAL IMPACT OF AQUACULTURE AND MANAGEMENT

4.1 Environmental Impact Assessment

Environmental Impact Assessment (EIA) is a process involving systematic identification and evaluation of potential impact on the environment (physical, chemical, biological and socioeconomic) emanating from the specific action under consideration. The EIA process may pass through multiple steps such as identification of the possible impact, prediction of the magnitude of impact, its evolution and presentation. The results are presented through 'cause-effect' and 'effect-impact' matrices (Patil *et al.* 2002).

The main steps of the EIA process are consultation and public involvement, screening, scoping and pre-application discussions, environmental studies, environmental statement, review of environmental statement, evaluation of environmental information, decision (refuse or grant), and implementation and monitoring. These steps are set out in greater detail below:

- Public participation

Consultation and public involvement includes gathering information from a number of public bodies about the nature and the scale of environmental impact, public knowledge of the sites, which can be useful in determining the scope of the assessment, potential impact and possible mitigation measures (SPICe 2004).

Public participation gives an opportunity to the affected and interested public to influence planning, assessment and monitoring of the project. This process includes public hearings, public meetings, public access and public right to comment (Finnish Ministry of the Environment 1997).

It is an effective way to integrate environmental, cultural, social, economic and technological considerations and provides a forum for the expression, discussion, analysis, and evaluation of issues, information, values, perspectives, and interests. It provides acceptable resolution of conflicts through mediation, negotiation, and public review (Finnish Ministry of the Environment 1997).

- Screening

Screening is the process of defining whether the EIA is required or not. This normally involves discussion with the planning authority on the characteristics of the development, location, and potential environmental impact (Senécal *et al.* 1999).

- Scoping

Environmental studies involve a scoping process to identify significant issues, baseline studies to define environmental characteristics of the project area, the prediction and assessment of impact to consider the possible interactions and effects of development, and mitigation measures to introduce design or operational modifications (SPICe 2004). Scoping should also include social and economic impact especially impact on the traditional uses of resources and livelihoods of the local communities and the consideration of alternatives. Alternatives including the no action alternative are necessary for determining the scope assessment, and allowing a comparison of probable effects and mitigation measures (Finnish Ministry of the Environment 1997).

- Environmental statement

The environmental statement is essentially the developer's statement on the possible environmental effects, the proposed measures to mitigate adverse effects, and the methodology used to achieve it (SPICe 2004).

- Monitoring

Monitoring a systematic observation or tracking an activity to determine whether it is proceeding or functioning as expected. Through monitoring the accuracy of environmental impact predictions are also assessed. A monitoring programme will provide adequate information to measure environmental change (Hambrey *et al.* 1999).

Effective monitoring and follow up actions are essential if EIA is to become an effective tool for environmental management and the promotion of sustainable development. Without follow up, EIA becomes a costly and bureaucratic exercise with little long-term impact. Monitoring is required not only to ensure that mitigation and environmental management plans are implemented, but also to see whether they work, and whether the analysis of impact was accurate. As noted in the section on assessment, impact analysis is extremely difficult and is unlikely to be accurate in the first instance. Only through monitoring, adaptation and evolution will effective environmental management strategies be developed (Hambrey *et al.* 1999).

Environmental assessment monitoring is the planned, systematic and repeated collection of environmental data to meet specific objectives and environmental needs. The objectives of monitoring are broadly similar for project and sector EIA (Hambrey *et al.* 1999). They are:

- to document the baseline conditions at the start of the EIA;
- to assess performance and ensure that conditions of approval are adhered to (project EIA);
- to ensure that the anticipated impact (from the project or sector) are maintained within the levels predicted;
- to ensure that mitigation measures are effectively applied;

- to verify the accuracy of past predictions of impact and the effectiveness of mitigation measures, in order to transfer this experience to future activities of the same type;
- to identify trends in impact;
- to identify, measure, and manage unanticipated impact;
- to provide information for periodic review and alteration of environmental management plans, or sector plans;
- to optimise environmental protection through good practice at all stages of the project or planning process; and
- to provide feedback on how the EIA process is working.

A number of different monitoring activities can be identified:

- Baseline monitoring refers to the measurement of environmental parameters during a pre-project period for the purpose of determining the nature and ranges of natural variation and to establish, where appropriate, the nature of change;
- Effects monitoring involves measuring environmental parameters during sector development or project implementation so as to detect changes in these parameters which can be attributed to the sector or project;
- Compliance monitoring takes the form of periodic sampling and/or continuous measurement of environmental parameters, levels of waste discharge or process emissions to ensure that specific regulatory requirements are observed and standards met;
- Surveillance and inspection may form a part of compliance monitoring but need not necessarily involve measurement of a repetitive activity.

EIA, by predicting, monitoring and auditing environmental impact, allows an improvement in site-specific decision making and planning at the project level. It may also increase public understanding of the development process and help to bring developer and public expectations into alignment, reducing conflict over proposals.

4.2 Environmental impact of aquaculture

Aquaculture, like any human activity, will have some effects on the environment. As long as these activities permit natural adjustment in the environment, it is recognised that their impact will be minimal. In well-managed farms, the water quality of influents and effluents may not be significantly different. Adverse effects associated with aquaculture include habitat destruction, discharge of effluents containing high concentrations of organic matter and the contamination of the aquatic environment and organisms with chemicals. Common-user conflict and the introduction of exotics, which may alter the diversity the natural flora and fauna, and escapees from aquaculture, are also contentious issues (Choo 2001).

The negative environmental impact attributed to aquaculture has mostly resulted from poor planning, inadequate site selection, inappropriate management procedures and lack of attention to environment protection (Lucas and Southgate 2003).

Nevertheless, aquaculture can also have positive effects on the environment, if the right methods are used. For example, in integrated fish farming recycling of wastes or by-products of one culture may occur if wastes from that culture are used as inputs for other culture and an efficient use of farm space for multiple cultures may be observed.

4.3 Cumulative effect

Cumulative effect is defined as an effect on the environment that results from the incremental, accumulating and interacting impact of an action when added to other past, present, and reasonably foreseeable future actions. Cumulative effect may result from addition or extraction of materials from the environment as well as from interaction between man-made and natural stressors. Effects can also result from individually minor yet collectively significant actions taking place over a period of time and/or space (Dubé 2003).

Sustainable development of aquaculture depends upon routine and defensible cumulative effects assessment (CEA). CEA is the process of predicting, the consequences of development relative to an assessment of an existing environment quality (Dubé 2003). Theoretically, it provides an on-going mechanism to evaluate if the level of development exceeds the environment's assimilative capacity, i.e. its capacity to sustain itself.

There are several methods for assessing CEA. In general CEA comprises the following methods (Parr 1999, Walker and Johnston 1999):

- Expert opinion

A panel of experts can be formed to facilitate exchange of information on different aspects of the impact of the project.

Exchange of points of views and effective liaison between members of the project team are extremely important, as for indirect impact, cumulative impact and impact interactions a number of different scientific disciplines are often required to analyse the nature of network of interaction which occurs.

- Consultations and questionnaires

Consultations and questionnaires aim to consider potential impact early on. They gather a wide range information including past, present and future activities which are likely to influence the impact of the project.

Consultation is an important element in the environmental assessment process and can be carried out through meetings or correspondence. It is a way of gathering information for use in the assessment. It is also important for determining the views and concerns of those consulted regarding the project and therefore in identifying the key issues involved.

Consultees may typically be the relevant statutory and non-statutory authorities, experts in a particular area associated with the project and its potential impact, and local community members who may be affected by the project.

Questionnaires are another method of obtaining information from local interest groups and residents who may be affected by the project.

Consultations and questionnaires are used for baseline data collection and allow an understanding of the potential impact of the project, resources affected and possible mitigation measures.

- Checklists

Checklists provide a systematic way to help ensure that all likely events resulting from the project are considered. Standard checklists can be developed for similar projects.

Checklists' form can vary according to the type and detail of information required. They can be developed for a wide range of situations, for example, to enable comparison of alternative options; to take into consideration past, present and future actions; to consider the impact on environmental components (e.g. water quality, ecology), and to consider the impact on sensitive resources or geographical areas. Information in checklists is usually presented in tabular form.

- Spatial analysis

Geographical Information System and overlay mapping help identify where the cumulative impact of a number of different activities may occur, and impact interactions. This type of analysis can also indicate the effects on selected resources and establish areas where the impact will be most significant. Both methods involve the preparation of maps or layers of information, which are then overlaid on one another. This provides a composite of the baseline environment, identifying the sensitive areas or resources; to show the influence of the past, present and future activities on a project or receiving environment; and identify where several types of impact can cumulatively affect one particular receptor.

- Network and system analysis

Analysis of the mechanism of cause and effect is important. The analysis is based on the concept that there are links and interaction pathways between individual elements of the environment, and that when one element is affected this will also have an effect on the elements which interact with it.

Network and system analysis identifies the pathway of an impact using a series of chains or webs between a proposed action and the receptor of an impact.

- Matrices

Matrices are a more complex form of checklists used to evaluate impact quantitatively to some degree and can be extended to consider the cumulative impact of multiple actions on the resource. Matrices cannot in themselves be used to quantify the actual significance of the impact; this can only be done using other methods. However, they can be used to reflect factors such as duration, frequency and extent. They can also be used to score or rank different types of impact. If scoring or weighting are used, the criteria must be clearly established. Ranks and weights depend on expert opinion.

- Carrying capacity analysis

Carrying capacity analysis is based on recognition of the existence of thresholds in the environment. Projects can be assessed regarding the carrying capacity or threshold determined, together with additional activities. It can also be used to determine the sustainability of a project.

Carrying capacity refers to the level of environmental stress, which populations or ecosystem processes can sustain without permanent damage.

For an effective carrying capacity analysis, limiting factors must be selected which best represent the environmental parameters of most concern for a particular resource. Thresholds can be derived from expert opinion or surveys. Mathematical equations can sometimes be used to estimate the critical level. Thresholds can also be set by regulatory authorities.

By establishing limits, projects can be assessed systematically in terms of their additional environmental impact in relation to carrying capacity.

- Modelling

Modelling is an analytical tool, which enables the quantification of cause-and-effect relationships, by simulating environment conditions. It quantifies cumulative effects and usually defines geographical and time frame boundaries. Often models use software technology to predict the chemical or physical effects of a particular action within the environment.

4.4 Impact prediction and mitigation

Negative impact on the environment can be avoided or minimised if provisions are made to incorporate the applicable best management practices into the siting, design and operation of an aquaculture facility. However, even with implementation of best management practices, an aquaculture facility is likely to cause adverse environmental impact, which should be predicted in advance for key environmental resources of concern.

According to EC (2001a), the information needed to predict the impact on resources of concern or Valued Ecosystem Components (VEC) should include the following:

- It should be presented as differences between the condition of a VEC without the project, and the condition of a VEC with the project, over a timeframe that takes into account the life span of the proposed facility;
- It must take into account cumulative effects. This requires consideration of how other past, present, and reasonably foreseeable projects and activities could combine with the impact of the proposed aquaculture project;
- It should be expressed quantitatively where practicable with uncertainties clearly recognised.

Mitigation measures that build on the best practices already integrated into provisions for project management should be identified and implemented to alleviate the predicted impact.

4.5 Site selection

The right site selection for aquaculture is one of the main important factors that determine the feasibility of viable operations. Consideration of environmental conditions is important to anticipating and avoiding many types of adverse impact that could result from establishing an aquaculture project.

The main aspects to be considered in the site selection process may be related to the past and existing activities influencing the site, weather and climate, hydrology, water quality, soil, topography, species at risk and habitat.

- Soil

Soil for pond aquaculture needs to be impervious, preferably clay-loam or sandy clay, to minimise loss of water by seepage and be suitable for building dikes. The impervious soil should be deep enough to facilitate pond and discharge channel construction. Soil with high silt and sand content or organic matter may easily leak or erode (EC 2001a, DPI&F 2006). Alkaline soils (with a pH of 7 and above) are preferable to avoid problems resulting from acid-sulphate soils such as poor fertiliser response, low natural food production and slow growth of cultured species and probable fish kills. Acid and organic soils (high in humus or compost) are not suitable (EC 2001a).

- Past and existing activity influencing the site

It is important to identify and document the following potential influences on the facilities and the environment regarding past and existing human activity in the area (EC 2001a):

- Areas of known or suspected contamination
- Existing infrastructures or activities
- Proximity of other aquaculture operations
- Existing activities and resources that release effluents and contaminated drainage
- Resource uses and activities that place demand on the water resources

- Weather and climate

Climate can influence site selection, choice of material, size and placement of some structures. The following factors should be considered during the site selection process (EC 2001a):

- Wind climatology including monthly means, frequency of wind speed
- Precipitation data including monthly normal and ranges, periods of extreme rainfalls and the frequency and durations of drought conditions

- Hydrology

A number of hydrological characteristics of water bodies can influence both productivity and the potential impact of aquaculture infrastructures, mainly cages. During site selection, the following hydrological characteristics should be taken into consideration (EC 2001a):

- Water depth and volume - Adequate depth is important for trading fish wastes away from the cages, for maintaining adequate circulation through the cages, and for reducing weed fixed around the cages.
- River flow rates, prevailing currents, flushing time.
- Dispersion characteristics of the site and an assessment of the near littoral currents. This information will help to determine the extension of the potential zone of influence.
- Water level fluctuations - Huge reductions in water level may lead to a stressful environment due to increases in temperature and decreases in dissolved oxygen levels.

- Water quality

Aquaculture infrastructures must be places in uncontaminated water, and it is important that the natural water bodies are not degraded by aquaculture activities. It is important to evaluate information related to predicted changes in natural water bodies resulting from aquaculture activity. Some parameters should be taken into consideration when selecting a site for aquaculture (EC 2001a):

- Dissolved oxygen (DO): DO is an important parameter influencing productivity;
- Seasonal temperatures: Temperature affects activity levels, growth, feeding and reproduction;
- pH: fish growth, reproduction and susceptibility to diseases are affected by pH;
- Turbidity and suspended solids: High levels of suspended solids can decrease water clarity and be detrimental to invertebrate and vertebrate feeding;
- It is important to assess nutrients and some biological characteristics influencing water quality, such as: phosphorus, nitrates, nitrites and ammonia, biological oxygen demand, vegetation cover and general riparian habitat, propensity for algal bloom and, type and abundance of biological community.

If other aquaculture operations or other activities are being developed, or there are prospects for such developments, the assimilative capacity of receiving water should be considered. Assimilative capacity is determined by a number of physical, biological and chemical factors. Physical factors include river water and sediment volumes. Chemical factors include nutrient levels and chemical pollutants. Biological factors include plant composition and abundance, fish type and abundance and composition of invertebrates.

Other aspects usually considered during site selection include the species to be cultured, technology to be employed, culture system to be adopted, agro-climatic conditions, access to markets, suitable communications, protection from natural disasters, the existing and future sources of pollution and the nature of pollutants (Pillay 1993).

4.6 Site preparation and farm operations

Preparing a site can involve clearing of vegetation, excavation and grading and infilling. Land disturbance can lead to erosion and degradation of water quality, and some material and wastes pose hazards to environment quality.

An erosion and sedimentation control plan should be developed and implemented to facilitate mitigation of adverse impact on water quality. The plan should demonstrate a preventive approach with the first priority on avoidance followed by control and treatment of sediment-laden water.

According to EC (2001b) the following points are necessary to prevent erosion during farm preparation:

- Preparing a schedule for activities taking into account seasonal constraints such as periods of heavy precipitation (e.g. consulting seasonal forecasts).
- Placing structures for sediment control before any land disturbance.
- Directing sediment-laden water to settling ponds.
- Keeping vegetation between disturbed zones and water bodies or wetland.
- Monitoring effluents from settling ponds or other waste treatment structures to verify that no further treatment is required.

For pond aquaculture it is important to construct ponds with the right characteristics to minimise the potential environmental impact. There are general principles of pond construction that minimise the impact.

Proper construction of dikes is important to keep maintenance costs low and minimise environmental impact.

Dikes should have proper sloping sides. As water pressure increases rapidly with depth, the dikes must be wider at lower depths to support the pressure. Dikes must also have gently sloping sides to reduce erosion and prevent water from damaging the dike. It is important that dikes are well compacted in order to prevent seepage or rupture (Mittelmark and Landkammer 1990).

Aquaculture operations may also involve continual inputs of food, chemicals and other substances to the surrounding aquatic environment. These substances will contribute to degradation of water quality by decreasing oxygen content and increasing concentration of suspended solids, dissolved chemical compounds and organic matter. Other periodic activities like harvesting and cleaning of equipment can cause adverse environmental effects (EC 2001b).

4.7 Sources of pollution in aquaculture effluents

Nutrients and suspended solids in aquaculture have different origins; some come with supplied water and others are produced into the culture system. In flow-through systems, particles consist mainly of uneaten or regurgitated food, faeces and fragmented tissues. In recirculation systems, additional inputs may come from water conditioning devices, such as filter media escaping from retainment vessels or bacterial flocs breaking away from tertiary filter media (Lucas and Southgate 2003). Depending on the species and aquaculture techniques, up to 85% of phosphorus and 52%-95 of nitrogen supplied to an aquaculture system, as food may be lost into the environment through feed wastage, faeces and respiration. Some nutrients may be lost from tanks or pond outlets or through the bottom of cages before the fish have eaten it (Lucas and Southgate 2003).

4.8 Effluent management

Many schemes for effluent treatment have been used over the years. Boyd and Tucker (1998) point out irrigation, settling basins and wetlands to be the most efficient procedures for effluent treatment.

4.8.1 Wetlands

Natural or constructed wetlands act as biological filters and can be used effectively to reduce the content of nutrients and organic matter in wastewater. Wetlands are relatively inexpensive to build up and operate. They have the advantage of contributing to stability of local hydrologic processes, and constitute natural habitat for wildlife. The main disadvantage of this method is the relatively large area required to treat the effluents.

There are a number of designs used for wetland treatment system, however, all can be classified as either surface-flow (SF) or subsurface-flow (SSF) systems. As shown in Figure 2, the SF design incorporates a shallow layer of surface water, flowing over sandy or organic (peat) soils. Vegetation often consists of marsh plants, floating and submerged aquatic vegetation, shrubs and trees. In SSF the basin is filled with gravel or other coarse particles, and the water level is maintained below ground. Water flows through the gravel and the roots of wetland vegetation.

The wetland treatment efficiency may be based on the contaminant concentration in wetland flow or on the total or percent of mass removal of the contaminant. The efficiency of removal decreases as the concentration of nutrients in inflow approaches that of the natural background in the wetland (DeBusk 1999).

The substance removal process by wetlands includes sedimentation of suspended particles, filtration of suspended particles, absorption of organic matter, denitrification, nitrification, and absorption of ions by the soil. Wetlands remove a large amount of nutrients from water wastes (Boyd and Tucker 1998).

Wetlands can achieve significant levels of suspended solids removal efficiency. Suspended solids in water may contain different types of contaminants. These contaminants themselves may be in particulate forms, or they may be physically or chemically bound to the particulate matter. Then, in cases where contaminant load is associated with particulate matter, physical settling of suspended solids will result in the efficient removal of contaminants from the water column (DeBusk 1999).

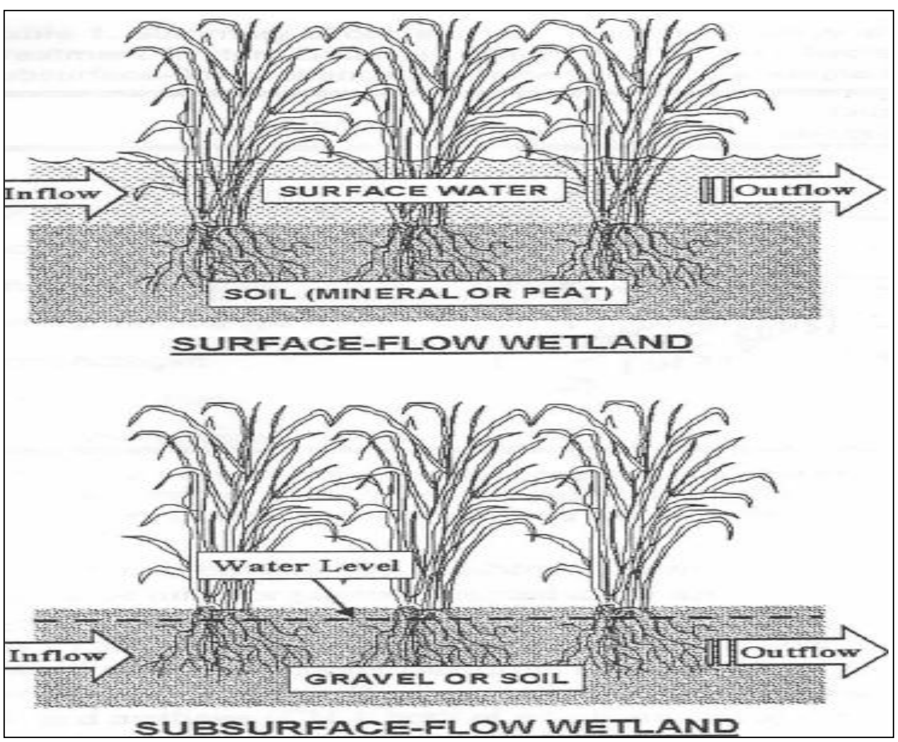

Figure 2: Diagram of surface-flow and subsurface-flow wetlands (DeBusk 1999).

Organic matter contains roughly 45 to 50% carbon, which is utilised by a wide range of microorganisms as a source of energy. A large number of these microorganisms need oxygen to degrade carbon to carbon dioxide in order to get energy for growth. Therefore, the release of large amounts of organic carbon may result in depletion of oxygen and the subsequent mortality of oxygen dependent organisms. Wetlands contain a large number of organic carbon utilising microorganisms. Some of these microorganisms can utilise organic carbon in anaerobic conditions, while others utilise it in aerobic conditions. This makes wetlands capable of removing organic compounds from a variety of wastewaters (DeBusk 1999).

1.1.1 Settling basins

Settling basins are much easier to build and operate than wetlands mainly because they do not have to be seeded by plants. Settling basins can be just as effective as wetlands in the removal of substances from water effluents (Boyd and Tucker 1998).

Settlement basins can largely reduce the concentration of key water quality variables such as total phosphorous, total suspended solids, turbidity and biochemical oxygen demand. This reduction is due to the fact that much phosphorous and organic matter in pond effluents is associated with suspended matter, and suspended solids will quickly sink if water is held in settling basins for a given period of time (Boyd and Tucker 1998). However, it is necessary to have a waste management system that includes frequent solids removal from the settling basins and proper disposal.

4.8.2 Irrigation

Utilisation water from freshwater aquaculture ponds for crop irrigation when the importance of the nutrients from the pond effluents is minor for the crops is an effective solution for effluent treatment (Boyd and Tucker 1998). Also, solids and organic matter in the effluent settle out in the field and do not cause problems provided that application techniques and erosion control procedures prevent them from entering natural bodies of water runoff. Nevertheless, drained water from irrigated fields can be collected and discharged in natural water bodies. In this case, water quality may be affected, and can become improper for aquaculture itself.

4.8.3 Integrated aquaculture

Integrating aquaculture with agriculture can have a positive impact on the environment. In integrated farming, resources such as nutrients and water are recovered and reused, improving the sustainability of the system and minimising environmental pollution. This practice can offer farmers economic improvements while minimising the environmental impact of farming. Integrated fish farming typically involves a combination of fish polyculture, crops and/or livestock production and on-farm waste recycling (Lucas and Southgate 2003).

4.8.4 Control and treatment of effluents from cages

Cage aquaculture presents a serious problem of waste treatment due to the continual flux of effluents with waste. The route of material released in cages is subject to being modified by fluctuating natural factors, such the water currents, wind, and lake inflows and outflows (Choo 2001).

To minimise accumulation of wastes in the bottom of the cages, they should be moved at least once in each growing season and placed in areas with adequate currents. Any waste removed should be disposed of in a responsible manner. Therapeutic agents should be used as a last resource and in accordance with the product label (Choo 2001).

4.8.5 Effluent standards

Discharges of effluents occur when ponds exchange water and are drained for harvest. These effluents can contain nitrogen, phosphorus, and other nutrients, suspended solids and organic matter. These substances can contribute to eutrophication, sedimentation and high oxygen demand in receiving water. Pond effluents have lower dissolved oxygen concentration and greater pH levels than the receiving water. Such conditions can be detrimental to aquatic organisms and limit further use of the water.

Water quality standards are established to prevent negative effects of effluents in receiving waters. Standards normally specify limits for selected water quality and may contain other restrictions, which normally comprise pH, dissolved oxygen, total and suspended solid limits. They may also contain other restrictions such as discharge volume, no discernable odour, no foam, or no visible plume at outfall (Boyd 2003).

4.9 Disease management

The main issues about disease posed by aquaculture can be divided into four categories: importation, amplification, stocking and therapeutants (Mayer 1991).

Pathogens can be introduced in a given area from outside the geographical area. Aquaculture facilities offer an adequate environment for pathogens multiplication and spread from fish to fish. Because fish are concentrated in a limited area, pathogens will be able to reach susceptible hosts to establish a disease outbreak, with a rapid increase in number and the likelihood of spread into the natural environment is high.

Stocking can transfer pathogens to areas where they are not currently enzootic[1] or can exceed threshold levels even in enzootic areas. Stocking can also introduce exotic pathogens.

Many therapeutants may be toxic to aquatic life at a certain concentration, additionally; they may cause resistance to antibiotic by pathogens.

[1] Disease that is constantly present in an animal population, but usually only affects a small number of animals at any one time.

Preventive measures to avoid the introduction or onset of disease are always the most effective, cost-efficient, and long-lasting. According to Mayer (1991), successful preventive measures in aquaculture centre on the following:

- preventing the introduction of pathogens,
- maintenance of good water quality,
- avoidance or reduction of environmental stressors (low dissolved oxygen, temperature control, density control, and removal of metabolic wastes),
- adequate nutrition,
- isolation of cultured animals from wild stocks, and
- immunisation.

Mayer (1991) identifies poor water quality, environmental and physiological stressors, and poor nutrition as the primary causes of disease outbreaks.

Human errors, improper culture systems, and inadequate diets are still a part of current aquaculture operations, regardless of the species being cultured. Thus it is likely that diseases will continue to be a limiting factor and that therapeutants will be needed.

Chemotherapy should be considered as an emergency or last-resort measure. Although chemicals may help reduce the incidence of pathogens or control the abundance of facultative organisms, they also may have negative effects on desirable pond biota and on the flora of biological filters. Some chemicals may be hazardous to the user or leave undesirable or harmful residues in the cultured animals. For efficient use of chemotherapeutants, it is necessary to begin with an accurate diagnosis of disease and causative agents. This information must be coupled with a sound understanding of the physical and biological system in which the animals are being reared.

4.10 Interaction between farmed and wild fish

Aquaculture is an important gateway for the introduction of non-indigenous species and strains of fish. The interactions between farmed and wild fish are problematic for many reasons (Sea Web 2005):

- Genetics – Selectively bred, farm-raised fish that escape from aquaculture facilities and reproduce with wild fish can cause a decrease in the genetic diversity of wild populations.
- Competition – Farm-raised fish that escape into the wild can negatively affect wild populations through competition for food, habitat, and mates.
- Disease – The high densities of fish held at aquaculture facilities can lead to increased levels of disease and parasites; these can be transferred to wild fish residing in the vicinity of the farms, as well as spread to wild fish by escapees.

Interactions between farm-raised and wild fish most often occur when the farmed individuals escape from where they are being cultured. Escapes are typically the result of human error, mechanical failure, or damage caused by storms or aquatic animals, which may tear at the nets in an effort to eat the farmed fish.

While other aquaculture systems can be problematic, cages or net pens, in which there is no effective barrier between the farmed fish and the environment, result in the highest level of interaction and the largest number of escapes.

The most effective method of eliminating interaction between wild and farm-raised fish is to prevent their release altogether. Improvements that can be implemented in order to eliminate or minimise the problems include (Sea Web 2005):

- Containment – As long as net pens are used for the culture of fish, escapes and negative interactions will continue to occur. Land-based, closed systems offer a solution to containment problems as well as other environmental issues.
- Use of triploids – While not 100% effective, a technique that has received some attention by the aquaculture industry is to induce triploids in a fertilised egg. This process renders the resulting offspring sterile. Triploid fish that do escape into the wild are unable to reproduce, but could still impact the wild populations through competitive interactions.

Apart from above, introduction of alien species can have both a negative and positive impact. In Asia for instance, alien species contribute 12% of cultured inland finfish production and approximately 11% of the total value of inland finfish aquaculture (Silva *et al*. 2006). On the other hand, Bartley and Martin (2004) point out a negative case in Venezuela where tilapia has displaced local species as well as the commercially important milkfish from coastal ponds.

The introduction of alien species should be considered if the objective is to increase aquaculture productivity. However, when considering introduction of alien species all precaution must be taken to make sure that they will not enter the natural environment.

5 ENVIRONMENTAL ISSUES FOR SMALL-SCALE AQUACULTURE IN MOZAMBIQUE

The effort of development in rural areas in Mozambique is concentrated on poverty reduction and creation of conditions for increased productivity, especially in the familiar sector. The development strategy includes incentives in the rural population in order to increase agriculture productivity, and the creation of a legal framework and institutional capacity building for decentralised community management of natural resources.

The current culture systems adopted by small-scale farmers in Mozambique are not likely to have a significant effect on the environment. The small ponds with extensive management operate with almost stagnant water, and even when drained the amount of water is too small to cause an adverse effect. In the main cases farm land or areas adjacent to farmland are used for pond construction, and as a result the total area of cultivated land is only marginally increased.

Currently alien species are not being introduced in Mozambique. Import of species needs the approval of the Ministry of Fisheries, which in turn is in charge of issuing a list of species that are forbidden to be introduced in national territory. However the Ministry still has not issued such a list.

The aquaculture system and intensity will determine the type and scale of environmental effects in combination with the physical, chemical, and biological characteristics of the area in question. Large-scale operations may cause more serious environmental damage than small-scale operations.

Mozambique has not yet experienced significant environmental impact due to aquaculture as the activity is still small and dispersed (Menezes 2001).

Small-scale aquaculture in Mozambique has been largely organic with inputs coming from agriculture and animal husbandry with plants and animal residues forming the main component of feed and fertilisers in fish culture. The species used are herbivorous or detrivorous fish. Nevertheless, there may be a threat of pollution, water quality deterioration, disturbance of ecological systems and spread of diseases in the long run if the government does not ensure environmentally sound aquaculture management.

Since 1994, the Ministry of Environment has developed a legal framework for environmental management. Apart from this, a national environmental management programme was formulated. According to the plan, ministries, private and civil groups may work towards the following objectives (Hatton *et al.* 2003):

- The development of intersectoral policies for sustainable development.
- The development and promotion of integrated planning of resource use.
- The promotion of sector legislation and establishment of norms and criteria for environmental protection and sustainable use of natural resources.
- The creation of conditions conducive to law enforcement and monitoring.

Chapter III of the Environment Law (Law nº 20/97 of July 30) states the prohibition of pollution: '*production, deposit in the soil or sub-soil, emission into water or the atmosphere of any toxic or pollution substance as well as the practice of any activities which accelerate the erosion, desertification, deforestation or any form of environmental degradation that are outside of the legally established limits is not permitted in the national territory'.* It is also mentioned in this law that the government should set environmental standards in order to ensure sustainable use of natural resources (AR 1997).

The Environmental Impact Assessment Regulation (Decree nº 45/2004) includes small-scale aquaculture in a category of activities that do not require any kind of environmental assessment because of their minimal impact on the environment, and does not state an environmental management plan for the possible accumulative impact of this activity. The Environmental Impact Assessment framework is too generic and is lacking environmental parameters for aquaculture.

A code of conduct setting the guiding principles for sustainable aquaculture is still not available.

6 CASE STUDIES

To obtain information about environment and disease management in Iceland three institutions and one mariculture laboratory were visited.

6.1 Disease management in Iceland

Surveillance and monitoring of fish disease in Iceland is the responsibility of the Ministry of Education (Institute for Experimental Pathology) and the Ministry of Agriculture (Veterinary Services, The Veterinary Institute) (Jonsson 2006).

The Veterinary Officer for Fish Diseases makes inspections on site, collects samples for laboratory diagnosis and makes necropsies on site when necessary. The Veterinary Officer also keeps a record of all fish farms in the country, conditions and equipment, water sources and use, sanitary conditions of water, origin of breeding stock, purchase and sale of roe and fry, and other important information regarding infectious diseases and their spread. In cooperation with the district veterinarians, the Veterinary Officer issues permissions for the use of veterinary drugs and controls their use (Jonsson 2000).

The Veterinary Officer makes one or two samplings in on-growing farms and five in broodstock farms each year for a disease survey. The samples collected are taken to the Fish Disease Laboratory for diagnosis. The Institute for Experimental Pathology through its Fish Disease Laboratory is responsible for general diagnostic work in the laboratory. Results from on site inspections and necropsies, and from laboratory analysis are used in the process of risk assessment. The main diseases tested in the laboratory are furunculosis, yersiniosis and bacterial kidney disease. In case of occurrence of a disease, the Veterinary Officer for Fish Disease sets up the risk management plan and measures are taken at the fish farm where the disease occurred. Imported animals and eggs are held in quarantine for six months and wastes are disinfected (Jonsson 2006).

Figure 3 illustrates the surveillance and monitoring of the fish disease process in Iceland. The Ministry of Agriculture through the Veterinary Officer for Fish disease collects samples and makes on-site diagnosis. Samples collected are taken to the Fish Disease Laboratory under the Ministry of Education for laboratory analysis. After receiving feedback from the laboratory analyses, the Veterinary Officer sets up the disease management plan.

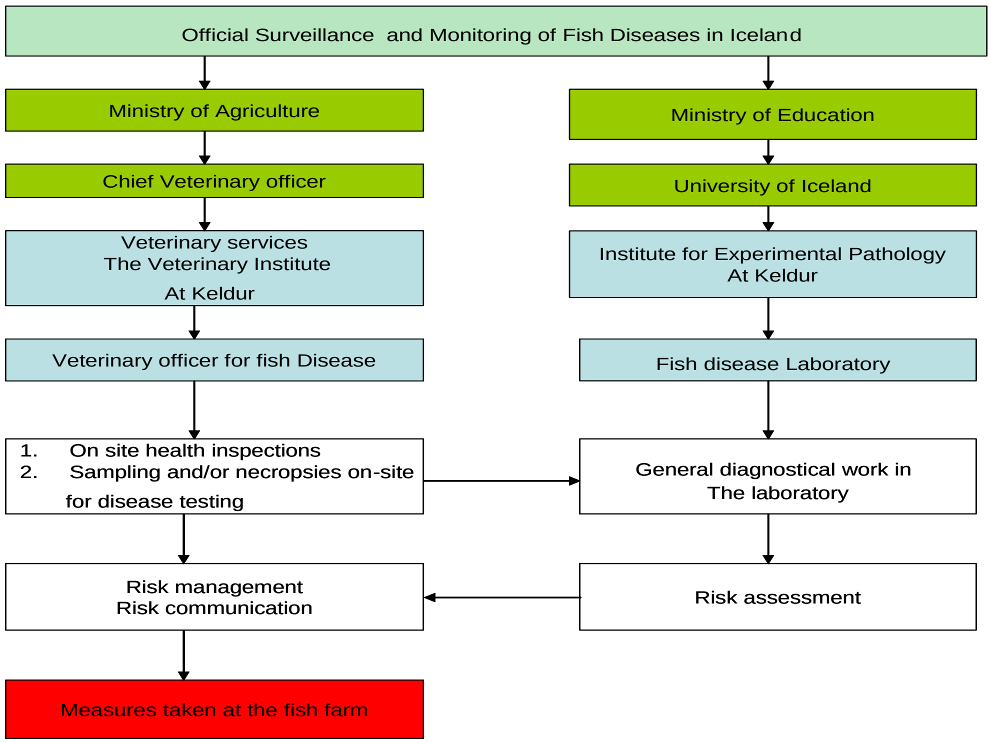

Figure 3: Surveillance and monitoring of fish disease system in Iceland (Jonsson 2006).

For the establishment of a specific disease management plan, diseases are classified into three categories, and for each category there are specific control measures.

As shown in Table 1, fish diseases in Iceland are classified into three categories A, B and C in accordance with the World Organization for Animal Health (OIE) classification.

List A diseases are transmissible diseases which have the potential for very serious and rapid spread and which are of serious socio-economic importance in the international trade of live fish, eggs and gametes. List A diseases will meet with stamping out procedures as these diseases are considered to be dangerous and exotic in Iceland. Measures are taken immediately and reports submitted to the OIE (Ísakson 2001).

List B diseases are transmissible diseases which are considered to be of socio-economic importance within the country and which are significant in the international trade of live fish, eggs and gametes. Measures to control these diseases vary from stamping out to general vaccination. List C diseases are diseases registered once a year (Ísakson 2001).

Table 1: List of potential fish diseases in Iceland (Ísaksson 2001).

List A diseases	List B diseases	List C diseases
Infectious salmon anaemia (ISA) Infectious pancreas necrosis (IPN) Infectious haematopoietic necrosis (IHN) Epizootic haematopoietic necrosis (EHN) Oncorhynchus masou virus (OMV) Viral haemorrhagic septicaemia (VHS) Spring viraemia of carp (SVC) Viral nervous necrosis (VNN) Gyrodactylosis	Furunculosis Atypical furunculosis Piscirickettsiosis Bacterial Kidney disease (BKD) Enteric red mouth (ERM) Systemic spironucleosis Pancreas disease (PD) Erythrocitic inclusion body syndrome Proliferative kidney disease (PKD) Salmon louse infection Marine louse infection Whirling disease Swimbladder nematode of eel	Viral erythrocytic necrosis (VEN) Ulcerative dermatic necrosis (UDN) Papilomatosis Mycobacteriosis Epitheliocystis Winter ulcers Vibriosis

Based on the Icelandic system, it can be understood that for better disease surveillance and monitoring it is important to identify and group diseases according to their potential capacity to spread and cause socio-economic and heath problems. It is also important to have a systematic sampling plan in order to identify diseases as soon as possible and their origin, and define a quarantine plan to avoid introduction of diseases.

6.2 Environmental management in Iceland

- The Environment and Food Agency of Iceland

The Environment and Food Agency is under the Ministry of Environment. Among other activities, it is responsible for monitoring environmental quality, pollution prevention, water quality analyses, environmental education and elaboration of environmental guidelines for public, supervision and coordination of local health inspectorates, and elaboration of environmental laws together with the Ministry of Environment. This agency works together with the Planning Agency in the process of issuing environmental licences for freshwater aquaculture operations with production of over 20 tons and marine aquaculture with production of over 200 tons (Gudmundsdottir 2006).

- Licensing process

The licensing process for aquaculture involves five public authorities, namely, the National Planning Agency, the Local Environment and Health Inspection, the Environment and Food Agency, the Directorate of Freshwater Fisheries and the Directorate of Fisheries.

Issuing licenses for small freshwater aquaculture operations (with production under 20 tons) is the responsibility of the Local Environment and Health Inspection, which is also responsible for issuing environmental licenses for salmon ranching. For aquaculture operations with production under 20 tons a year no environmental plan is required, however, the owners of rivers and aquaculture farms have their own environmental management plans (Gudmundsdottir 2006).

At the beginning of the licensing process the Environment and Food Agency prepares a draft license. The draft is then sent for official comments and public hearing. Thereafter, the Agency issues the final license, which can be subject to appeal by the Minister of Environment. For the issue of licenses, a detailed description of the production process is required, along with information on pollution risk, pollution control, location of the plant, the local environment, and other relevant information. In this process, the Agency consults with Local Health Inspection Authorities, the Nature Conservation Agency, the Planning Agency and the Directorate of Freshwater Fisheries (Jonsson 2000).

- Waste and pollution control

The main environmental issues on freshwater aquaculture are related to eutrophication due to inefficient effluent treatment (only solid particles are removed from water) causing an increase of nutrient flow and high temperature in receiving waters. The Environment and Food Agency and the Local Health Inspection Authorities are in charge of controlling the environmental effects of aquaculture, effluents management, water pollution and water treatment (Gudmundsdottir 2006).

As shown in Table 2, there are regular monitoring visits, the frequency of which is dependent on the plant size. In cases of unexpected negative environmental impact, the plant must take measures to mitigate or eliminate the problem, and the Agency must approve the measures.

Table 2: Frequency of control visits and control measurements for aquaculture plants in Iceland (Jonsson 2000).

	Aquaculture with discharge to the sea		
Size category	Annual production	Control visit	Control measurements
I	> 1000 tonnes	Every 6 months	Every 3 years
II	200–1000 tonnes	Every 12 months	Every 5 years
III	100–200 tonnes	Every 12 months	Every 10 years
IV	< 100 tonnes	Every 24 months	Never

The local authorities are in charge of environmental management planning for small-scale aquaculture operations, but they do not have such environmental plans. However, associations of river owners and aquaculture farms are implementing their own environmental management plan (Gudmundsdottir 2006).

The environmental management process seems to be complicated and involves many institutions. Nevertheless, there are good examples that can be followed such as the specific actions which have been carried out to control pollution, the regular visits to aquaculture plants and measurements taken to monitor the effects of aquaculture on the environment.

- Freshwater aquaculture at Holar

The main objective of the visit to Holar was to visit the effluent treatment facilities, namely the settling tank, of a freshwater aquaculture company. Unfortunately due to the absence of the responsible employee of the company, a permit to visit the facilities was not obtained.

- Marine Research Institute Laboratory at Grindavik

The Marine Research Institute Laboratory at Grindavik is a mariculture laboratory dedicated to studying the farming potential of halibut, cod, turbot and abalone (MRI 2006).

The objective of the visit to this facility was to obtain data related to effluent management. The facility does not treat the effluents. The effluents from the fish tanks are flushed into the sea. The sea currents are strong enough to take the effluents away avoiding its accumulation and consequent impact on the surrounding environment.

Disposal of effluents in the environment without preliminary treatment may not be a recommended practice from an environmental view point, however, taking into consideration the small dimension of the facility, the relatively low production of effluents and the strong currents of the sea, this practice may be considered to have a minimal environmental impact and is hence acceptable.

7 INITIAL ENVIRONMENTAL GUIDELINES FOR SUSTAINABLE SMALL-SCALE AQUACULTURE IN MOZAMBIQUE

Despite the current environmental issues related to aquaculture, Mozambique should adopt a precautionary approach to environmental management for small-scale aquaculture operations in order to avoid significant environmental impact in the long run.

The current environmental guidelines are based on the literature review, the case studies, and the identified environmental issues related to aquaculture in Mozambique. Because small-scale aquaculture in Mozambique produces relatively low incomes, and investment is low, there are aspects that should be considered for such conditions.

7.1 General guidance for site selection

Site selection is one of the key issues for success in aquaculture. Poor site selection will make aquaculture difficult to manage and may also lead to the destruction of critical natural habitats, spread of diseases and contamination of freshwater sources.

When selecting site for aquaculture infrastructure the following points should be considered:

- Maintenance of adequate distance between farms or aggregate of ponds, natural spawning runs, restricted areas (conservation areas) and sensitive ecosystems (including lakes, rivers).
- Choose areas with adequate currents to minimise waste accumulation below the cages. Currents help disperse waste and replenish the water with oxygen.
- Avoid use of sites with incompatible users. Do not use polluted sites with chemicals, pesticides or other pollutants.

7.2 Guidance for pond aquaculture

- Siting ponds

For pond siting the following should be considered:

Locate ponds in sites where they will not cause destruction of habitats such as wetlands, lagoons, rivers, inlets, bays, estuaries, swamps, marshes or high wildlife-use areas.

The site should have good soil, preferably clay-loam or sandy clay, that will retain water and be suitable for building dikes. Alkaline soils (with pH of 7 and above) are preferable to avoid problems resulting from acid-sulphate soils such as poor fertiliser response, low natural food production and slow growth of cultured species and probable fish kills. Acid and organic soils (high in humus or compost) are not suitable.

For brackish water, choose land with an average elevation that can be watered by ordinary tides and by ordinary low tides. Sites with tidal fluctuations above 4 meters require very large, expensive dikes to prevent flooding during high tide. Areas with slight tidal fluctuations, of 1 m or less, cannot be properly drained or filled.

Provide a buffer zone for areas near river banks and coastal shores that are exposed to wave action.

Ensure that the area has a regular supply of water, in adequate quantities throughout the year. Water supply should be free of pollution and with adequate pH.

- Designing ponds

Design ponds in such a way that prevents storm and flood damage that could cause overflow discharges.

Settling ponds for the effluents should be provided and, if necessary, for water intake, if the water supply has high sediment loads.

The pond depth should be shallow enough to prevent stratification (potentially dangerous laying of pond water into a warmer upper layer and a cooler, dense, oxygen-poor lower layer). If not, include a means of providing aeration and other destratifying mechanisms.

Include reservoirs for water storage and treatment.

Isolate supply and effluent canals as far as possible from each other, and from other farms.

Where possible, use closed or re-circulating systems with treatment; do not use more than small amounts of fresh water to top off the pond.

- Constructing ponds

Line bottoms and sides of ponds, levees and canals with impervious matter in order to prevent seepage into surrounding soils and groundwater.

Construct stormwater bypass around the area of the ponds.

Dig ponds deep enough to prevent weed growth.

Minimise sediment erosion by:
- using gradual slopes in construction;
- planting vegetation;
- compacting and lining the banks;
- making discharge channels large enough to handle peak loads without scouring.

Construct wetlands to treat the settling ponds water from fresh water ponds.

- Operating ponds

Operate ponds in such a way that they do not cause loss or significant damage to habitats, including lagoons, rivers, inlets, bays, estuaries, swamps, marshes, and other wetlands, wildlife areas, parks, ecological reserves, or fishing grounds.

Screen pond entrances and exits to keep fish stock in and other animals out.

Prevent erosion by leaving sediment, unless removal is absolutely necessary.

- Monitoring and controlling ponds

Maintain water quality with aeration, sustainable stocking rates and controlled feeding rates, not with water exchange (replacing old pond water with clean water).

Treat effluents in settling ponds with filter feeders, and pass settling pond water from freshwater ponds through a constructed wetland before discharge.

Use the effluents as liquid fertiliser on crops; particularly forage crops where bare ground is minimal.

Monitor and control effluents before discharging to meet water quality standards for turbidity, suspended solids, BOD, pH, dissolved oxygen (DO), ammonia, nitrate, nitrite, disease organisms and pesticides. In freshwater ponds, monitor and control phosphorus.

Alternate freshwater ponds, where possible, and allow ponds to dry out, lie fallow, or grow a crop to reduce the need for sludge and nutrient removal.

7.3 Guidance for cage aquaculture

- Siting cages

Locate cages in a place that receives some wind action. Wind will help flushing and contribute to increases in dissolved oxygen concentration in water.

Consider deep-water sites with no current reversals and avoid areas with aquatic vegetation. Cages should not be placed in stagnant deep water because of the potential deep-water deoxygenation.

When possible, place cages in areas with current action. Currents help water flows through the cages removing metabolites and replenishing oxygen.

Orient cages according to prevailing winds and currents, to minimise shading and prevent debris from collecting between them.

Locate cages where disturbance from people and animals can be minimal.

- Constructing cages

Use strong nets to construct cages.

Construct all cages to prevent break up of facilities and loss of stock, wastes, feed or supplies even in severe weather conditions.

- Operating cages

Move the cages at least once each growing season to minimise sediment accumulation at the bottom.

- Monitoring and controlling cages

Place a bag or other container around all net pens to isolate diseased fish. The bag should be impermeable and capture all fish wastes. Arrange to treat and neutralise bag water or wastewater before discharge.

Collect and dispose of waste feed and faeces from bagged or contained pens as compost.

Avoid discharges near or up current from fishing grounds or other sensitive areas.

Cages should not interfere with other water uses.

Use therapeutic agents as a last alternative. If absolutely necessary, follow the instructions on the product label carefully.

7.4 Summary of environmental impact mitigation and monitoring

Table 3 summarises the environmental impact of small-scale aquaculture, mitigation and monitoring actions to be considered for Mozambican environmental guidelines for small-scale aquaculture.

Table 3: Summary of environmental impact mitigation and monitoring.

Activity	Problem/impact	Applicability	Mitigation techniques
Design, site selection and construction	Habitats preservation	Pond	Choose already cleared areas whenever possible. Reuse existing ponds before digging new ones. Do not place ponds in low areas that can be flooded during the rainy season. The area occupied by ponds should be smaller than that of the natural vegetation. Ponds should be spaced well apart. Vegetation should be retained and replanted as much as possible.
		Cage	Avoid setting cages in areas with aquatic vegetation.
	Control of nutrient loading	Cage	Set cages in areas with good current flows. Currents help to remove sediments and replenish oxygen. When setting cages do it according the direction of the prevailing wind to prevent debris from collecting between them.
		Pond	Consider integrated culture to reduce nutrient loading. Filter feeders help for maintenance of water quality by consuming plankton and preventing eutrophication. Use policulture (at least one herbivorous) to consume excess of food.
	Quality and quantity of water supply and receiving water	Pond/cage	Identify potential sources of water contamination and avoid siting where there may be conflicts with other water users or where there are already other sources of discharge in receiving waters including aquaculture facilities. Identify limiting factors related with carrying capacity and determine treatment requirements for waste water. Ensure that effluent quality will not have a significant impact on down stream riparian uses and fish habitats. Identify parameters of water monitoring to detect water changes. Consider water treatment methods.
	Control of seepage into ground and surface waters	Pond	Build ponds in soils with enough clay content, to hold water.

	Erosion	Pond	The banks of the pond should well compacted and have proper slopes. Design discharge structures and canals to prevent erosion by impact of water or scouring by excessive water velocity. Provide vegetative cover on embankments and above water slopes of canals to prevent erosion. Build settling ponds or other control structures. Plan for seasonal constraints. Avoid disturbance of soil and vegetation.
Operations	Overfeeding	Pond/cage	Use only necessary quantities of food. Use feed pellets designed to float longer in the water column. Use meals made from terrestrial animal by-products, plants, oilseeds, grains, legumes or cereal by products. Avoid use of fish meal. Consider cropping herbivorous fish that do not require other food source.
	Overcrowding	Pond/cage	Use lower densities.
	Escapee	Pond	Place screens in outlet and inlet ditches.
		Cage	Use strong nets.
	Disease prevention	Pond/cage	Use certified pathogen-free stock whenever possible. Consider quarantine for introduced fish. Avoid high-density stocking. Vaccinate fish. Isolate diseased fish. Treat effluents. Minimise stressing fish by unnecessary or excessive handling or activity around the ponds/cages. In cases of disease outbreak do not release effluents to natural water bodies to prevent spreading disease to wild populations.

	Excess of organic nutrients	Pond	Avoid frequent draining of pond in order to allow microbial processes and deposition to remove nutrients and organic matter from within. This will also conserve freshwater. Consider the use of aeration and water circulation to allow degradation of organic matter and avoid anaerobic sediment accumulation at the bottom of the pond. Aeration will also remove ammonia. Use settling basins, wetlands or irrigation to treat suspended solid matter. Settle effluents released during harvesting or other interventions in pond. Avoid discharging nutrient-rich water into fresh water bodies.
		Cage	Move cages periodically to different locations to avoid accumulation of wastes bellow the cages.
	Impact from chemical use	Pond	Use less toxic alternatives to hazardous products. Apply chemicals with proper containment away from water courses and wetlands. Use veterinary drugs only as the last alternative. Consider fertilising ponds with animal manure or plant material.
	Erosion	Pond	Do not let large animals graze on the banks of ponds; they may break the banks down. Do not leave the drain open in empty ponds to prevent rainfall erosion and discharge of suspended solids. Do not allow livestock to walk on pond embankments or wade in ponds.
	Predation	Cages	Place protective netting on the sides and tops of cages to protect fish from birds. Use nets with mesh sizes that will prevent birds from getting entangled. Place protective nets in such a way that they are safe from being pushed together with water movements.

8 RECOMMENDATIONS

Small-scale aquaculture can have an important contribution to the livelihood of many people in rural areas in Mozambique. Integrated aquaculture and agriculture can contribute to the diversification of agricultural production and thus food security.

The existing natural conditions (water resources and suitable species for aquaculture) should be used to improve people's livelihood. Better and affordable technologies should be extended to rural communities to improve productivity. However, they should be used in a rational manner to ensure their long-term sustainability. Involvement of the community in resource management should be fundamental.

The aquaculture policies should assist the achievement of environmental, economic and social sustainability of aquaculture production. Only sites and practices, which are compatible with long-term sustainable operations and with an acceptable ecological impact, should be selected to develop aquaculture.

For environmentally sound aquaculture development in Mozambique, it is important to consider plans to prevent or minimise the impact of the activity. Thus, aquaculture authorities should develop specific environmental guidelines according to physical conditions (hydrology, climatology) and socio-economic characteristics of different regions of Mozambique. For better monitoring of the environmental impact of aquaculture, the authorities should establish environmental standards and set specific actions for disease surveillance and monitoring.

Attention should be addressed to the new tools for identifying environmental changes such as Environmental Vulnerability Index. This will enable policy-makers to draw adequate measures to control environmental degradation and identify and maintain systems that have good resilience.

There are three important examples in the Icelandic disease management system that Mozambique should implement:

- Identify and categorise diseases, and set specific control measures for each category.
- A routine surveillance and monitoring programme should be set up to minimise risks of diseases outbreaks.
- A quarantine regime should be considered for imported species to avoid introduction of exotic diseases.

Although, the environmental management system in Iceland seems to be complicated, it provides some good examples that Mozambique should implement such as institutional coordination, decentralised management for small operations making the process more efficient, and the involvement of the farm owner.

The initial guidelines of the current study should be considered by Mozambican fisheries authorities as a basis for establishing definitive environmental guidelines for aquaculture.

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