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INTERAFRICAN BUREAU
FOR ANIMAL RESOURCES

REGIONAL FRAMEWORK ON ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE AQUACULTURE DEVELOPMENT IN AFRICA -

West Africa Region

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ACRONYMS AND ABBREVIATIONS

AU-IBAR	African Union Inter African Bureau for Animal Resources
EAA	Ecosystem Approach to Aquaculture
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
GIS	Geographic Information System
HSE	Health and Safety Equipment
IUCN	International Union for Conservation of Nature
NGO	Non-Governmental Organization
SEA	Strategic Environmental Assessment
WB	World Bank

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FOREWARD

Aquatic ecosystems provide several goods and services including for fisheries and aquaculture production. Aquatic ecosystems are also the ultimate recipients of pollution from human activity, including from aquatic production practices. The productivity of aquatic production systems, aquaculture not withstanding depends on the status of aquatic resources. Aquatic resources are generally considered renewable. However, even while this might be so, they are not infinite. They need to be properly managed if their contribution to nutrition, economic and social well-being of the growing world's population is to be sustained. Irresponsible aquatic production practices can have significant adverse environmental and social impacts.

Africa's continental fisheries and development strategy, **The Policy Framework and Reform Strategy for Fisheries and Aquaculture in Africa** (PFRS) consequently advocates for the sustainable management of aquatic resources for sustainable fisheries and aquaculture development. The FAO Code of Conduct for Responsible Fisheries encompasses this approach. The paradigm of this is enshrined in the Ecosystem Approach to Aquaculture. The ecosystem approach to aquaculture (EAA) is a strategy for the integration of aquaculture within the wider ecosystem to ensure sustainable development, equity and resilience of interlinked social-ecological systems.

In line with these, several African Member States require Environmental Impact Assessments as part of the requirements for the approval of large commercial aquaculture projects. However, it is the Continent's overall objective to expand commercial aquaculture to the level whereby aquaculture becomes a major contributor to fish production, rural employment, income as well as food and nutrition security. This infers that the number and size of operations as well as technologies employed shall increase and become more diversified.

Sustainable aquaculture development at such a scale entails that the application of strategic sectoral environment management approaches that do not just focus at the farm but also factor in the wider environment. This is because in practice, aquaculture is dependent upon the entire ecosystem. For example, at geographical level, clusters of farms that share a common waterbody or watershed need coordinated management to ensure sustainable utilisation and biosecurity. Cultured species are sensitive to water quality and are therefore extremely vulnerable to the damage inflicted by other users of the waterbody or watershed. Furthermore, while disease incidences can be controlled at farm level, their effects occur at the watershed level and often do require control, management and mitigation at the watershed level. Likewise, exotic fish that escape from fish farms often impacts on biodiversity across the entire watershed. External drivers of aquaculture such as population growth and development, trade and climate change also affect entire ecosystem. Watershed boundaries, trade and climate change transcend national boundaries.

Sustainable aquaculture development founded on the principles of EAA therefore requires transboundary initiatives. Common, coherent and practical regional frameworks and policies that promote sustainable development and responsible practice of aquaculture within watershed resource limits are inevitable necessary if the Continent's sustainable commercial aquaculture development goals are to be achieved. Given the importance, this Regional Framework was thus developed as a result of a consultative process that involved a **Consultative Regional Workshops on Aquaculture Environmental Management** to draft the framework that drew participants from the public and private sector involved in producers and other sector actors, environmental management agencies and aquaculture managers. The draft was circulated to Member States and Regional Economic Communities for review prior to validation.

Having frameworks for Environmental Management for Sustainable Aquaculture Development shall strengthen the capacity of Member States to make more realistic and appropriate aquaculture development plans, approve appropriate projects and institute environmental management assessments more effectively.

Additionally the adoption and mainstreaming of the Regional Frameworks into National Aquaculture Development Plans and Strategies shall facilitate the development and implementation of BMPs for all stakeholders, lower costs for undertaking Environmental Impact Assessments for practitioners, make it easier to implement labelling and certification of products and zone areas for aquaculture.

Prof. Ahmed El-Sawalhy
Director, AU-IBAR

1. BACKGROUND AND INTRODUCTION

Africa is endowed with enormous fish and fishery resources which offer great opportunities and benefits to the continent through employment, revenue and general contribution to socio-economic growth and development. The policy framework and reform strategy for fisheries and aquaculture in Africa (PFRS) advocates for sustainable management of aquatic resources to ensure sustainable fisheries and aquaculture development (AUC-NEPAD 2014). The continent, however, continues to be burdened with numerous problems that are hindering long term resource sustainability, thereby reducing prospects for increasing fisheries contribution to food security, poverty alleviation and wealth creation (http://www.au-ibar.org/fish-about/fish-project-background). Under the "Fish Gov" project, AU-IBAR seeks to improve institutional and policy environment for sustainable management and utilization of fisheries resources in Africa (http://www.au-ibar.org/fish-about/fish-project-objectives). Based on this background, AU-IBAR organized regional workshops to develop frameworks on environmental management for sustainable aquaculture development in four sub-regional workshops with the aim of harmonising policies for sustainable aquaculture development based on the ecosystems approach to aquaculture (FAO 2013).

Presented in the report is the regional framework on environmental management for sustainable aquaculture development in West Africa.

2. FRAMEWORK RATIONAL AND JUSTIFICATION

For sustainable aquaculture development, there is a need to develop and implement strategic sectoral environment management approaches which focus not only on the farms but also factor in the wider environment. This is necessary because in practice, aquaculture is dependent upon the entire ecosystem. Cultured species are also sensitive to water quality and are therfore extremely vulnerable to the damage inflicted by other users of the waterbody or watershed. Furthermore, while disease incidences can be controlled at farm level, their effects occur at the watershed level and often do require control, management and mitigation at the watershed level. Likewise, exotic fish that escape from fish farms have impacts across the entire watershed. In addition, are the external drivers of aquaculture such as population growth and development, trade and climate change.

Sustainable aquaculture development founded on the principles of EAA therefore requires transboundary initiatives. Common, coherent and practical regional frameworks for policies that promote the development and practice of aquaculture within watershed resource limits is necessary for sustainable sectoral aquaculture development. This will enable member states make more realistic and appropriate aquaculture development plans, approve appropriate projects and institute environmental management assessements more effectively.

2.1 Development Objective

The objective of the assignment is to draw up an appropriate regional framework on Environment Management for Sustainable Aquaculture Development based on the outputs from the regional workshop; to serve as a guideline to Regional Agencies, Member States and stakeholders of the West African Region

3. AQUACULTURE IN THE WEST AFRICAN REGION

3.1 The West African Region

West Africa lies between latitudes 4°N and 28°N and longitudes 15°E and 16°W (FAO 1983). It is made of eighteen countries, namely: Benin, Burkina Faso, Cape Verde, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, The Island of Saint Helena, Senegal, Sierra Leone, Sao Tome and Principe, Togo (Fig 1). Total land area for the region is 6,140,000 km2 with a population of about 340 million.

3.1.1 Climate

Climatic conditions play important role in aquaculture development. The climate determines what species to culture and which methods of farming shall be suitable. Countries in the region general have tropical and humid climatic conditions with average air temperatures ranging from 17°C to 33°C. All the countries experience wet and dry seasons resulting from the interaction of two migrating air masses, the hot, dry tropical continental air mass of the northern high pressure system, which gives rise to the dry, dusty, Harmattan winds which blow from the Sahara over most of West Africa from November to February and the moisture-laden, tropical maritime or equatorial air mass which produces southwest winds. Some characteristics of the rainfall of West Africa are: (i) frequent heavy rainstorms of short duration which cause severe soil erosion, particularly on cleared, bare cultivated land; (ii) the occurrence of a belt of bimodal rainfall some distance inland from the coast eastwards from Sierra Leone to Nigeria, and (iii) the variability in amount, time of onset, duration and cessation which increases from the wetter areas to the drier areas. In the coastal areas the percentage annual variability ranges from 10 to 20 percent, while close to the Sahara in the Sahel it may exceed 40 percent (FAO 1983).

Figure 1: *Map of West Africa*

3.2 Status of aquaculture in the study area

Aquaculture for most countries in the West African region started somewhere in the 1950s. Although the interest is wide spread, its growth has been very varied. Whiles countries like Ghana, Nigeria and Ivory Coast are making good progress, aquaculture in other countries in the region are yet to make relevant contribution to their respective domestic fish production (Table 1). Production levels vary from subsistence in rural communities to commercial in peri-urban centres.

Aquaculture fish production is in both freshwater and marine environments employing both land-based and water-based facilities. Production in the freshwater however dominates; estimated production figures for Africa in the freshwater and marine environments in 2013 were 1,594,096 tonnes and 21,539 tonnes respectively; increasing its share to the world farmed food fish production, up from 1.3 percent in 2003 to 2.3 percent in 2013 (FAO 2015). Contribution to world aquaculture fish production by West Africa countries only to the global aquaculture fish food production is about 0.44 % (ftp://ftp.fao.org/FI/STAT/summary/a-0a.pdf). Existing production systems include cages, pens, earthen ponds and concrete/fibre/plastic tanks (Asmah 2013). The most commonly cultured freshwater species are Oreochromis niloticus (Tilapia) and Clarias gariepinus (Catfish). Other less but commonly cultured species include intensive production of Chrysichthys nigrodigitatus (Bagrid catfish) in freshwater lagoons in the Ivory Coast (Sanogo 2008), and trial productions of Heterobranchus, Notopterus spp, and Mugil spp in Sierra Leone (Sheriff 2006). List of other species reported to have been cultured in brackish water environments are listed in Table 2.

Table 1: *Fish production statistics for capture and aquaculture per country in 2014*

Country	Capture (MT)	Aquaculture (MT)	Total (MT)
Benin	42 416	667	40 210
Burkina Faso	10 600	405	11 005
Côte D'Ivoire	77 985	3720	81 705
Cape Verde	23 606	-	23 606
Gambia	43 726	33	43 759
Ghana	297912	32 513	330 425
Guinea	127 000	250	127 250
Guinea Bissau	6550	-	6 550
Liberia	9 500	30	9 530
Mali	99 353	2 205	101 526
Mauritania	292 624	-	292 624
Niger	45 000	200	45 200
Nigeria	721 355	278 706	1000 061
Senegal	469 636	705	470 341
Sierra Leone	200 000	80	200 080
St. Helena	574	-	574
Togo	20 015	20	20 035

Source: ftp://ftp.fao.org/FI/STAT/summary/a-0a.pdf

Table 2: *List of fish and shrimp species cultivated in West African brackish waters*

Species Cultured	Côte d'Ivoire	Benin	Ghana	Nigeria	Senegal
Tilapia zillii	X		X		
T.rendalli	X			X	
T. nilotica	X		X	X	
T. galilaea	X		X		
T. guineensis	X	X	X		
T. melanotheron		X			
T. heudelotii	X				
S. m. heudelotii					X*
Mugil cephalus			X	X	
L. falcipinnis	X	X			
L. grandisquamis	X				
Chrysichthys walkeri	X			X	
C. nigrodigitatus	X	X		X	
Clarias lazera	X			X	
Penaeus duorarum	X	X	X	X	

Source: Coche, A.G. (ed) 1982
** Source: Wilde and Gilles (2009)*

3.3 Potential for Aquaculture Development in West Africa

By virtue of its tropical climate and rich natural water resources, the sub-region has a huge potential for aquaculture development but this potential is largely untapped. Studies by FAO and others have shown considerable physical potential for aquaculture in the sub-Saharan Africa (Muir et al 2005). Anguilar Manjarrez and Nath (1998) estimated that 9.2 million km2 (31 % of land area) were suitable for small holder fish farming and 3.8 million km2 (9.1 % of land area) were suitable for commercial farming. These projections as stated were based on land-based aquaculture. Land-based aquaculture potential for just the West African region was, however, not estimated but countries such as Nigeria were ranked top 10 in Sub-Sahara Africa as having potential to grow two crops of tilapia, carp and catfish in a year. The potential for water-based systems in the region is yet to be estimated.

3.4 Existing Policies and Regulations Governing Aquaculture in Member Countries

Policies, regulations and governance measures are enacted to ensure environmental sustainability, without destroying entrepreneurial initiatives and social harmony. Without effective governance, there will be misallocation of resources or stagnation which will affect all economic activities, whether aquaculture or any other (FAO 2014). All the countries in the sub-region have some form of legislations that relate to aquaculture directly or indirectly. Presented below in Table 3 are existing Environmental Acts and legislations governing aquaculture development in the West Africa Countries.

Table 3: *Summary of Environmental Laws and EIA regulations affecting aquaculture in West Africa*

Country	Environmental Law	EIA regulations	Explicit mention of aquaculture in EIA	EIA oversight institution	Guidelines published for EIA: general or aquaculture
Benin	1999 Framework Law on Environment 98-030	2001	Simplified EIA mandatory for aquaculture / fish culture	ABE/BEA	General guidelines
Burkina Faso	1997 Law on Environmental Code 005/97	2001	Category A (requires EIA): dams over 10m height Category B (requires a notice of impact): - small dams between 3m and 10m height - construction of ponds for aquaculture	CONAGESE	
Cape Verde	Act No. 86/ IV/93 of 26 June 1993 defining environmental policy	2006		CAN	
Côte d'Ivoire	1996 Code on the Environment	1996		BEI/MLCVE, ANDE	
Gambia	1994 National Environment Management Act 94/13	1999	EIA required: for storage dams, barrages, weirs; fisheries especially large scale commercial projects;		General guidelines
Ghana	1994 Environment Protection Act 490/94	1999	EIA regulations: EIA mandatory for aquaculture Required to accompany any application for a licence for aquaculture; Fisheries Impact Assessments required for any activity impacting on a fishery (as well as EIA)	EPA	General guidelines

Country	Environmental Law	EIA regulations	Explicit mention of aquaculture in EIA	EIA oversight institution	Guidelines published for EIA: general or aquaculture
Guinea	1987 Code on the Environment	1990	EIA required: Aquaculture installations	Ministry	
Guinea-Bissau	1993 National Environmental Action Plan	1993			
Liberia	Environment Protection and Management Law	2002	Mandatory for: 'artificial' fisheries (aquaculture for fish, algae, crustaceans, shrimps, lobster or crabs)	EPA	
Mali	1991 Protection of Environment and Life Framework 91-47	1999	EIA required: for dams and other permanent installations intended to retain or to stock water	Ministry	General guidelines
Mauritania		2004			
Niger	1998	2000	Indirect: EIA required for dams and reservoir	BEEEI	
Nigeria	Decree 58 of 1998 and Decree 86 of 1992	1992	EIA required: Land based aquaculture projects accompanied by clearing of mangrove swamp forests covering an area of 50 hectares or more; dams and man-made lakes and artificial enlargement of lakes > 200 ha	FEPA	General guidelines
Saint Helena	National Environmental Management Plan	2012	Indirect: Safeguard St. Helena's environment both terrestrial and marine for future generations through effective environmental management including through improving the status of biodiversity by safeguarding ecosystems, species and genetic diversity.	Environmental Management Directorate, St. Helena Government	General guidelines
Sao Tome and Principe	Decree No. 37/99. The Environmental Framework Law	1999	Indirect: The Environmental Framework Law, spells out basic principles for the use of the environment, its impacts and of environmental protection.	Environment Cabinet, Ministry of Natural Resource and Environment	General guidelines
Senegal	1983 Code on the environment	1983	Indirect: preliminary review for irrigation and small and medium agri-business.	Ministry	General guidelines
Sierra Leone	2000 Environmental protection Act	2008	EIA required: substantial changes in farming and fisheries practices e.g. introduction of new crops...; dams, drainage or irrigation projects…;	Ministry of Fisheries and Marine Resources	

Country	Environmental Law	EIA regulations	Explicit mention of aquaculture in EIA	EIA oversight institution	Guidelines published for EIA: general or aquaculture
Togo	1988 Code on the Environment		Require EIA: dams and reservoirs (> 5ha < 10 ha: Simplified EIA, > 10 ha: In-depth EIA); Aquaculture/Fish culture (< 300 ha: Simplified EIA, > 300 ha In-depth EIA). Extraction of water from rivers, underground, lakes, lagoons and the sea… for aquaculture, requires authorisation from the Ministry of Environment	Ministry	

Source: Modified from Nugent, 2009

3.5 SWOT analysis to identify gaps

The strengths, weaknesses, opportunities and threats to aquaculture development in the sub-region are presented in Table 4.

Table 4: *SWOT analyses of aquaculture in West Africa*

Strengths	• Several water resources in most countries of the region • Good water quality • Suitable climate • Sheltered bays suitable for marine aquaculture production • Established production techniques • Technically advanced systems
Weaknesses	• Lack of quality inputs (notably; poor quality brood stock, slow growing fingerlings and quality feed) • Insufficient investment in research and development • High cost of production • Bureaucracies and delays in aquaculture permitting process in some countries • Inadequate private investment • Poor management practices • Lack of support services and ancillary industries • Limited technical capabilities
Opportunities	• Employment for rural and riparian communities • High demand for fish locally • Shortfall in domestic fish demand • Decline in capture fisheries • Land and sea based sheltered sites • Market demands not met (e.g. oysters, seaweeds) • New species and niche products.
Threats	• Fish diseases and parasites • Climatic change and variability - possible flooding and/or water shortage in some areas • Lack of access to finance • Potential conflicts over water access • High costs of production • Impact on biodiversity from alien species • Pollution and poor sanitation

4. FRAMEWORK FOR SUSTAINABLE AQUACULTURE DEVELOPMENT

The framework for sustainable aquaculture development is discussed under the following sub-headings:

1. Identification of suitable sites for aquaculture
2. Tools for aquaculture site section
3. Transboundary context for shared resources

4. Outline for conduction of Strategic Environmental Assessments
5. Environment Safety and Occupational Health Associated with Aquaculture
6. Stakeholder consultations

Specific objectives for the framework are:
1. Sustainable production of culture fish
2. Expansion and growth of the sector
3. Enhanced Social and economic benefits

4.1 Identification of suitable sites for aquaculture

Selection of suitable areas or sites for aquaculture development are among the most important considerations for the success of aquaculture and need to be carried out in accordance with sustainability and best practice guidelines (FAO/World Bank 2015; FAO 2010). It being a resource based activity, it competes for economic, social, physical and ecological resources with other industries and can have negative impacts on industries such as fisheries, agriculture and tourism (Ross et al. 2013). Also use of environmental goods and services could leads to impacts that can have both social and economic implications (FAO, 2008). As a result, it is imperative that the carrying capacity of these systems is considered a necessary tool for the development and site selection process for aquaculture activities, and is inherent in the adoption of good practices and sound environmental regulations to ensure the sustainability of aquaculture-based food production (Ross et al. 2013).

The ecosystem approach to aquaculture is one of the benchmark guidelines designed for sustainable development of aquaculture. It proposes three main considerations in aquaculture site selection; (i) ecological; (ii) socio-economic; and (iii) governance. Adopting such an approach will help ensure that sites selected for aquaculture fall within the ecosystem's functional limits, are socially acceptable and are economically feasible.

One of the considerations in aquaculture site selection is the concept of carrying capacity. It has been defined as. McKindsey et al (2006) proposed four categories; the physical carrying capacity, production carrying capacity, ecological carrying capacity and social carrying capacity (McKindsey et al 2006).

i. *Physical Carrying Capacity* — the total area which is geographically available and physically adequate for a certain type of aquaculture. This is determined based on available natural conditions.
ii. *Production Carrying Capacity* — describes the optimum level of production of the targeted species and is estimated based on modelling effort – e.g. TROPOMOD which is suited for tropical environments but its development is still in progress.
iii. *Ecological Carrying Capacity* — the stocking or farm density which causes unacceptable ecological impacts. This is mostly driven by public perception of negative consequences of aquaculture (Stickney 2003). It is determined by modelling efforts by determining the range of possible outcomes of production e.g. the mass balance approach model.
iv. *Social Carrying Capacity* — the level of farm development that causes unacceptable social impacts.

4.1.1 Tools for aquaculture site selection

Aquaculture site selection involves both technical and administrative procedures (IUCN 2009). Tools are available to facilitate these procedures; these include Geographic Information System (GIS), TROPOMOD and the Dillon and Rigler model for estimation of carrying capacity. GIS compared to existing aquaculture site selection procedures is considered one of the fastest and less expensive tools in site selection particularly in estimation of the physical carrying capacity. Although site selection depends on the culture system to be adopted and the species to be cultured there are factors such as agro-climatic conditions, hydrology/water availability, land-use patterns, access to markets, suitable communications, protection from disasters, availability of skilled and unskilled labour, public utilities, security etc. which affect all systems. With an adequate database however, Geographic Information Systems (GIS), serves as a powerful analytic and decision-making tool (Aguilar-Manjarrez and Ross, 1995). Considerations for aquaculture site selection for different production systems are presented in Table 6. The range of values for the various parameters suitable for a farm will depend on the species of interest.

Site selection issues and proposed mitigation strategies for land-based and water based operations as well the use of inputs are presented in Table 6 and 7.

TROPOMOD, a dispersion model is also useful in estimating the production and ecological carrying capacity. The model predicts footprint of waste feed and faeces on sea bed and associated benthic impact for tilapia and milkfish in tropical environments. Data requirements for the model whose development is still in progress are presented in Table 8.

A tool for the ecological carrying capacity is the Dillon and Rigler model. It uses a phosphorus budget model to determine the carrying capacity. The steps are described as follows:

1. Measure the steady-state total-P concentration. In tropical lakes and reservoirs, [P] should be taken as the annual mean total P concentration of surface waters and should be based on a number of samples taken during the year.
2. The development capacity of lake or reservoir for intensive cage culture is the difference between the productivity of the water body prior to exploitation and the final desired/acceptable level of productivity.
3. The capacity of the water body for intensive cage fish culture is the difference, [P], between Δ[P] prior to exploitation, $[P]_i$, and the acceptable [P] once fish culture is established, $[P]_f$.

$$[P] = [P]_f - [P]_i \qquad (1)$$

P is related to P loadings from the fish cages, Lfish, the size of the lake, A, its flushing rate and the ability of the water body to handle the loadings.

$$\Delta P = L_{fish} (1 - R_{fish}) / z\square \qquad (2)$$

$$L_{fish} = \Delta [P] z\square / (1 - R_{fish}) \qquad (3)$$

The acceptable/desirable change in [P], Δ[P] (mgm^{-3}) is determined as described in Step 2 above, and z can be calculated from hydrographic data obtained either from the literature or from survey work.
Z = V/A

Where V = volume of water body (m3) and A = surface area (m^2). The flushing rate, □ (per year), is equal to QoV, where Qo is the average total volume (m3) flowing out of the lake/reservoir each year.

Rfish is the most difficult parameter to estimate. At least 45-55% of the total-P wastes from cage rainbow trout are likely to be permanently lost to sediments as a result of solids deposition. In the absence of any other data, these values are also used for cage tilapia and carp, and calculated as

$R_{fish} = x + [(1 - x) R]$ (4)

Where x is the net proportion of total-P lost permanently to the sediments as a result of solids deposition (0.45-0.55) and R is proportion of dissolved total-P lost to the sediments i.e. Phosphorus retention coefficient

$R = 1/1 + 0.747\square^{0.507}$ (5)

$\square$= Flushing rate (y-1)

4. Acceptable total-P loading, La is estimated by multiplying Lfish and lake surface area.
5. Intensive cage fish production (t y--1) can be estimated by dividing La by the average total-P wastes per tonne of fish production.

Finally, a tool for estimating the production carrying capacity the mass-balance approach which according to Beveridge (2004) can be defined as.

$Nut_{env} = Nut_{food} - Nut_{fish}$

Where

Nut env, is the total nutrient losses to the environment (computed as being equivalent to the difference between the nutrients added in the food)

Nut food is that assimilated by the fish and which were subsequently harvested

Nut fish is determined by analysed data on N, P and C (nutrient) content of feeds, FCR (Food conversion ratio) values and N, P, C content of fish. Accordingly, the equations for N, P and C loadings into the environment are expressed as follows:

$N_{env} = N_{feed} - N_{fish}$ (4)

$P_{env} = P_{feed} - P_{fish}$ (5)

$C_{env} = C_{feed} - C_{fish}$ (6)

Where N_{env}, P_{env} and C_{env} are N, P, C losses to the environment. N_{feed}, P_{feed} and C_{feed} are N, P, C content in $_{feed}$. N_{fish}, P_{fish} and C_{fish} are N, P, C content in fish.

Table 5: *Key considerations in aquaculture site selection*

Type of Production System	Climate	Water quality	Environment	Hydrography	Socio-economics	Infrastructure
Cages (Fresh-water and marine)	Average Temperature Average wind speed and direction	• Dissolved Oxygen • pH • Turbidity • Salinity • Nutrients • Chlorophyll a • Alkalinity • Total Hardness • Microbial quality	• Perennial/Reliable water sources: lakes, reservoirs, lagoons, estuaries and the sea • Land topography • Sensitive ecological niches • Pollution	• • Bathymetry • • Current velocity and direction • • Significant wave height	• Occupational uses of the water bodies • Landuse activities in project area • Activities of riparian communities • Navigational routes	• Roads • Services • Access • Communication • Electricity grid
Earthen Ponds	Average Temperature	• Dissolved Oxygen • pH • Turbidity • Salinity • Nutrients • Chlorophyll a • Alkalinity • Total Hardness • Microbial quality	• Perennial/Reliable water sources: • rivers, streams, lakes, reservoirs, the sea and groundwater • Soil type • Topography and elevation	• River/stream discharge • Water sources and supply Pond water budgets	• Occupational uses of the water bodies • Landuse activities in project area • Activities of riparian communities	• Roads • Services • Access • Communication • Electricity grid
Concrete tanks	Average Temperature	• Dissolved Oxygen • pH • Turbidity • Salinity • Nutrients • Chlorophyll a • Alkalinity • Total Hardness • Microbial quality	• Perennial/Reliable water sources: • rivers, streams, lakes, reservoirs, the sea and groundwater • Topography and elevation	• River/stream discharge Water sources and supply Water budgets	• Occupational uses of the water bodies • Landuse activities in project area • Activities of riparian communities • Navigational routes	• Roads • Services • Access • Communication • Electricity grid

Table 6: *Site selection issues and strategic actions*

	Elements	Identified Issues		Strategic Actions	
	Production Systems	**Environmental / Technical**	**Socio-Economic Issues**	**Environmental/ Technical Actions**	**Socio-Economic Actions**
1.	**EARTHEN PONDS**				
a.	Site selection	Sitting of ponds to obstruct reserves and socio-cultural sites Water availability	Ponds pose risk of drowning to community members	Sitting of ponds should not adversely obstruct water to reserves and socio-cultural sites (sacred groves and forest reserves)	Negotiation for peaceful settlement Public involvement guidelines
		Soil type changes and erosion	Loss of land to alternative uses Potential loss of rent and social status to land owners	Avoid deforestation which will cause soil-type changes and erosion by seepage, erosion and drying.	Reasonable compensation for use of land for aquaculture should be requested and made. Allocation of employment opportunities to community members in negotiations with prospective fish farmers
		Water availability to areas downstream of ponds Flood-prone area ecological and cultural sensitivity of site	Potential Conflict of water –use between downstream communities members aquaculture operator, particularly in water stressed areas – possibility of limited water supply for aquaculture	Water budget – loss of water availability to areas downstream of ponds should be avoided Flood-prone areas should be avoided as pond sites for fish culture	Establish water balance to ensure availability of water for downstream communities. Efficient utilisation of water for aquaculture Restriction of access of pond area to the general public.
		Water availability for aquaculture and to areas downstream of ponds Flood-prone area ecological and cultural sensitivity of site	Potential Conflict of water –use between downstream communities members aquaculture operator, particularly in water stressed areas	Water budget – loss of water availability to areas downstream of ponds should be avoided Flood-prone and drought-prone areas should be avoided as pond sites for fish culture	Establish water balance to ensure availability of water for downstream communities. Restriction of access of pond area to the general public.
			Escalation of communicable diseases and STDs as a result of aggregation of people for economic activity	Improve health service delivery in related communities, and monitoring of impact of treatment	Education and Awareness creation, Reduce stigmatization.

	Elements	Identified Issues		Strategic Actions	
	Production Systems	**Environmental / Technical**	**Socio-Economic Issues**	**Environmental/ Technical Actions**	**Socio-Economic Actions**
			Escalation of water-borne diseases	Improve health service delivery in related communities, and monitoring of impact of treatment by working on risk factors such as drainage, bush control and other aspects of environmental public health, etc	Education and Awareness creation, Reduce stigmatization Social-responsibility of the enterprise be made clear to the community
b.	Land clearing	Deforestation, loss of biodiversity, soil erosion, habitat alteration	Habitat alteration and changes in micro environment results in loss of ecosystem services such as soil fertility as a result of soil erosion and soil water retention capacity and potential for cultivation of vegetables	Land –use planning	Alternative commodities that withstand new micro environment should be promoted
c.	Pollution	Effluent discharge – potential for nutrient enrichment in receiving water bodies	Contamination of source of community water supply Contamination being potential source of conflict between farmers and community	Prescribe treatment of effluent before release into open waters; Pond water could be utilized for irrigation of crops in irrigated fields	*Evidence of treatment of effluent before discharge demonstrated*
		Pollution of ground water through seepage	Contamination of source of community water supply Contamination being potential source of conflict between farmers and community	Avoid construction of ponds in porous soils;	Evidence of treatment of effluent before discharge demonstrated
		Use of antibiotic and hormones	Drug resistant species	Use of feed additives such as hormones, steroids and others should be regulated	
d.	Flooding	*Climatic change and variability –flooding, water shortage*	Vulnerability of community livelihood systems to climate change increased	Climate adaption strategies for aquaculture eg. Reduction of water tables Use of aerosols and similar chemicals should be avoided	Develop vulnerability adaptation strategies
e.	Fish escape	Genetic introgression and biodiversity changes	Loss of income by local fishermen	Zonation to identify areas where certain genetic materials may be restricted to.	Loss of livelihood

	Elements	Identified Issues		Strategic Actions	
	Production Systems	Environmental / Technical	Socio-Economic Issues	Environmental/ Technical Actions	Socio-Economic Actions
				Provide guidelines to allow new genetic material into a regions, Develop guidelines to assist in traceability of genetic identity resources Develop bio-security approaches to control fish escapes netting materials for cages to limit escape of fish	
		Use of antibiotic and hormones	Drug resistant species	Use of feed additives such as hormones, steroids and others should be regulated	
2.	**CAGES AQUACULTURE**				
a.	Site selection		Navigational rights of communities close to cage operations restricted Proximity of cages to community water abstraction points lead to degradation of community portable water Limited access to near shore areas by riparian communities		Right of access to near shore areas of water bodies by communities should be guaranteed Establish minimum distance from community water points to minimize impact on community water quality
b.	Fish escape	Genetic introgression and biodiversity changes	Loss of income by local fishermen	Zonation to identify areas where certain genetic materials may be restricted to. Provide guidelines to allow new genetic material into a regions, Develop guidelines to assist in traceability of genetic identity resources develop bio-security approaches to control fish escapes	Loss of livelihood
c.	Pollution	Feed and feed management		Quality of feed with respect to floating period should be emphasized to give opportunity for fish to feed before it sinks	

	Elements	Identified Issues		Strategic Actions	
	Production Systems	**Environmental / Technical**	**Socio-Economic Issues**	**Environmental/ Technical Actions**	**Socio-Economic Actions**
				High digestibility of feed should be prescribed to allow most of feed to be used by fish to avoid pollution; Enhance capacity fish farmers in feed management. Regulate additives (steroids, hormones) in feed.	
		Cage net clogging		Exclude anti-fouling agent for cleaning cage nets	
		Predators		Develop predator exclusion devices (fencing, scaring off)	
		Water Current and depth		Limits for depth below the cages and current speed should be set to allow for dispersion of cage effluent and excess feed before they reach the floor of water.	
		Use of antibiotic and hormones		Use of feed additives such as hormones, steroids and others should be regulated	
			Cage farms located near water intake point can lead to conflict between farm operators and water companies	Regulatory measures to ensure compliance to environmental quality standards	Cage farmers should comply with minimum distance from water intake points
		Use of anti-fouling agents to clean cages.		Cleaning agents should be regulated.	
				Regulatory system identifying certified hatcheries with periodic assessment of performance. Introduction of new species of fish seed should be done cautiously.	
		Materials for cage construction		Non-corrosive material to be used	

Table 7: *Farming Inputs Use Issues and strategic actions*

	Elements	Identified Issues		Strategic Actions	
	Production Systems	**Environmental / Technical**	**Socio-Economic Issues**	**Environmental/ Technical Actions**	**Socio-Economic Actions**
	INPUTS				
a.	Feed	• Pollution and waste • Loss of biodiversity	• Water pollution and use • Diseases • Low incomes • Livelihoods	• Capacity building of farmers in feed management and use. • Certification of feeds and quality assurance • Regulations and enforcement • Monitoring	• Alternative water sources • Alternative livelihoods • Health facility
b.	Seed	Loss of Biodiversity	• Loss of livelihoods • Social vices	• Use of indigenous species • Certification hatcheries • Legislations and enforcement	• Alternative livelihoods
c.	Brood stock	Poor quality brood stock		Recruitment/ adoption of quality brood stocks, Capacity building of hatchery operators Only certified brood stocks of approved fish should be used Hatcheries should be certified	
d.	Additives and probiotics	misuse of hormones and antibiotics which become available to non-target species	Conflict resulting from uncertainty of actions of different countries	Hormones, additives and probiotics should be approved materials should be approved materials and where they can be used should be guided.	Negotiations for agreement on type of additives to use.
e.	Organic and inorganic fertilizers in pond aquaculture	*Unacceptable rate of application and contaminated animal droppings.*	Social acceptance of different manures by different countries as source of conflict and delay of actions	Capacity building of farmers for appropriate use, Extension to farmers.	Negotiations for agreement on use of organic manure
f.	Nets and cage materials and pond liners	Poor quality liner material		Material quality should be prescribed and the rate of change determined	

Table 8: *Data requirements and costs for TROPOMOD*

Data to run model,	Farmer has to collect these data as part of consent
Hydrographic data	15 days, 3 depths
Bathymetry	Survey or chart
Cage dimensions	Yes
Cage layout specified	Yes
Feed returns so feed input is known?	Yes, but always hard to get information, from survey
Accurate position cages	Yes
Benthic fauna monitoring	Yes
Required Cost of running model	Depends

Source: http://www.ecasa.org.uk/Documents/Depo-MeraandTropomod.pdf

4.2 Transboundary context for shared resources

About 40 per cent of the world's population lives in river and lake basins that comprise two or more countries, and more than 90 per cent lives in countries that share basins (Kalinin 2008). Climate change is expected to add to pressures on transboundary water resources in many areas with fluctuations in water availability and water quality. It will magnify regional differences in the world's natural resources and assets and lead to an increased risk of inland flash floods and more frequent coastal flooding, droughts, etc. All transboundary water bodies create hydrological, social and economic interdependencies between societies. They are vital for economic development, reducing poverty and contributing to the attainment of the Millennium Development Goals. The 1997 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses is the only treaty governing shared freshwater resources that is of universal applicability (UN 2008).

Issues and strategic guidelines for sustainable use of shared water bodies in relation to aquaculture are presented in Table 6.

Table 9: *Issues related to shared waterbodies*

	Issues	Strategic Action
SHARED WATER BODIES	Availability of water in sufficient quantities for aquaculture activities as well as downstream requirements (Communities and ecosystems)	• Collaboration in managing shared water resources • Negotiations to allocate abstraction quotas
WATER SYSTEMS	Introduction of non-native species	• Regulation to control movement of genetic material
	Alteration of river flow	• Catchment protection
	Spread of invasive species	• Develop integrated management approaches
	Sediment and nutrient loading	• Pollution control
PUBLIC HEALTH ISSUES	Increased incidence of communicable diseases and water borne diseases due to aggregation of population around water fish enterprise	• Education and awareness creation • Improve health service delivery • Reduce stigmatization

4.3 Outline for conduction of Strategic Ecological and Environmental Assessments

Among the tools recommended for sustainable development of aquaculture in the region is the institution of Strategic Environmental Assessments (SEA) by member countries. SEA is the process of evaluating the environmental impacts of any proposed plan/programme likely to have significant effects on the environment. The process, which involves preparation of the Environmental Report, is thought to very effective when done at an early stage; during the preparation of the plan or programme. SEA will often involve a repetitive process of collecting information, defining alternatives, identifying environmental effects, developing mitigation measures and revising proposals in the light of expected environmental effects. It will be important to identify an end-point where further iterations are unlikely to bring further significant improvements in predicting the environmental effects of the plan or programme.

It plays an important role in improving the integration of environmental concerns in policy and planning processes for sustainable development.

SEA has three major objectives (Partidário (2012);

1. Encourage environmental and sustainability integration (including biophysical, social, institutional and economic aspects), setting enabling conditions to nest future development proposals;

2. Add-value to decision-making, discussing opportunities and risks of development options and turning problems into opportunities;
3. Change minds and create a strategic culture in decision-making, promoting institutional cooperation and dialogues, avoiding conflicts.

Stages in the SEA process and requirements for each stage are provided in Table 9.

Table 10: *Stages in the SEA Process*

Stages in the SEA process	Details of process required
Screening	Screening is required to determine whether the proposed plan/programme is likely to have significant environmental effects and whether an SEA is required.
Scooping	Scooping is the stage of the SEA that ensures that all key environmental issues are identified so that they can be addressed appropriately in the Environmental Report. It is important at this stage that the appropriate Environmental Authorities are consulted when deciding on the scope and level of detail to be included in the Environmental Report.
Environmental Report	The Environmental Report details the likely significant effects of the programme on the environment and the proposed alternatives of the programme to mitigate its effects. The public and the environmental authorities are informed and consulted on the draft plan.
Adoption	The Adoption Report details the results of consultation; how comments have been incorporated into the programme; the final programme; and the proposals for monitoring the environmental impacts of the programme.
Monitoring	The Monitoring stage is undertaken during implementation of the programme and serves to identify the level of monitoring required and, should adverse impacts be identified, any remediation proposals

4.4 Categories of directly and indirectly affected stakeholders both at regional and national level who should be consulted

Stakeholders in the aquaculture sector may include individuals, groups or institutions with an interest in the science, use and management of fisheries and the aquatic resource to be managed (World Bank 1996; Sen 2001). Directly affected stakeholders are the primary stakeholders immediately influenced by proposed interventions or policies. Indirectly affected stakeholders are those who have technical expertise and/or links to the primary stakeholders such as NGOs, representative organisations and technical and professional bodies. Lists of directly and indirectly affected stakeholders in the aquaculture sector in relation to strategic frameworks for sustainable aquaculture development are presented in Table 10.

The involvement of stakeholders in aquaculture policy making, planning and management ensures more realistic and effective policies and is a key aspect of successful implementation of ecosystem based management. It lends the opportunity to deepen mutual understanding about the issues at hand, explore and integrate ideas together, generate new options and solutions, that may not have been considered individually (Pomeroy and Douvere 2008; Sen 2001). Such involvements are based on pluralistic structures, political legitimacy and consensus.

Table 11: *List of directly and indirectly affected stakeholders in the strategic framework for sustainable aquaculture development*

Directly affected stakeholders

a. Grow-out operators
b. Hatchery operators
c. Feed manufacturing companies and feed importers
d. Other water resource users (Upstream and downstream, including the watershed)
e. Regulatory bodies in aquaculture, agriculture, fisheries, coastal zone management
f. Aquaculture Institutions, researchers and technicians,
g. Other watershed users in the catchment area such as Commercial crop and livestock farmers
h. Extension officers
i. Riparian Communities
j. Fish processors and traders
k. Arable farmers

Indirectly affected stakeholders

a. Consumer groups
b. Public interest represented by environmental groups and agencies
c. Quarantine and customs officers
d. Adjacent land owners
e. Tourism organizations
f. Fishers (Where juveniles for aquaculture are sourced from the wild or where there is market competition between wild-caught and farmed species)
g. Local Government
h. Development Agencies
i. Financial Institutions
j. Health workers

4.5 Environment Safety and Occupational Health Associated with Aquaculture

With the intensification of aquaculture, a number of aquaculture facilities across the world depend a lot on the input of formulated feeds and the application of agrochemicals, antibiotics and other inputs, resulting in the presence of many chemical and biological contaminants in aquaculture facilities (Sapkota et al 2008). These can lead to high levels of antibiotic residues, antibiotic-resistant bacteria, persistent organic pollutants, metals, parasites and viruses in aquaculture finfish and shellfish.

The occupational hazards, safety concerns, and risks to health in the aquaculture industry can vary considerably based on the types of operation, scale of production, and even the specific species of interest (EFSA, 2005).

Five categories of hazards according to Moreau and Neis (2009) are associated with the industry's activities. Myers and Robert (2012) summarised these as follows: physiological (work design), physical, chemical, biological, and psychological. Details are provided in Table 12.

Table 12: *Categories of health and safety issues associated with aquaculture*

Categories	Exposures	Potential Consequences
Physiological (work design)	Heavy lifting, prolonged standing, awkward postures, repetitive motion, overexertion, lack of visibility	Low back pain, neck and shoulder pain, bursitis, tendonitis, tenosynovitis, carpal tunnel syndrome
Physical	Slips and trips, falls from height, falls overboard, transport and trucking, machinery, electricity, fire, heat and cold, diving, noise, vibration, confined spaces, entanglement, underwater entrapment, solar radiation	Injuries, cuts, burns, broken bones, amputation, hypothermia, hyperthermia, drowning, electrocution, injuryrelated death, asphyxiation, decompression illness, sprains and strains

Categories	Exposures	Potential Consequences
Chemical (toxic, flammable, corrosive, explosive)	Disinfectants, parasiticides, piscicides, fungicides, antifoulants, anesthetics, antibiotics, radon gas from water sources, hydrogen sulfide, carbon monoxide, sulfites, dusts, fumes, styrene, needle-sticks, flammabilities, battery explosion	Respiratory illness, burns, cancer, central nervous system effects, birth defects, reproductive effects, poisoning, hematopoietic effects, and lung, eye, or skin irritations
Biological	Sharp teeth, spines, aerosolized proteins, bacteria, parasites, skin contact with shellfish and finfish tissues and fluids, enzymes, airborne proteins and endotoxins, fish feed dust	Bites, cuts, punctures and related infections; allergy, asthma, eczema, urticaria (hives), chapped skin, itching
Psychological	High demand and low control situations, remote locations away from family, potential for large fish kills, abusive social environment	Work-related stress

Source: Myers and Robert (2012)

To mitigate these incidences, there is a need for the documentation of a health and safety plan which ensures that practical steps are taken to prevent an incident from occurring. A good health and safety plan would normally include the following:

- A method of identifying hazard
- Safe work procedure
- A programme of training workers in safe work procedures
- Method of monitoring workers for safe work procedures
- A progressive disciplinary policy to ensure compliance with safety policies
- Documentation of the steps of the health and safety plan as proof of due diligence

The plan should propose the designation of the Health Safety and Environment Manager (HSE) by every commercial farm.

The duties and responsibilities of the HSE would be as follows:

- Liaising with all regulatory and enforcement agencies on coordination of environmental and safety-related activities
- Ensuring that environmental and safety policies are rightly transmitted to all levels, and bring all breach of the rules and regulations to the attention of the Environment Manager, together with recommendations for mitigation measures.
- Responsible for the timely preparation and submission of EMPs and all documents necessary for the realization of the environment, safety and health objectives of the Company.

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