Aquaculture site selection and carrying capacity estimates for inland and coastal aquaculture in West Africa

Ruby Asmah
CSIR Water Research Institute, P. O. Box M.32 Accra, the Republic of Ghana.

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Abstract

This article reviews aquaculture site selection and carrying capacity estimates for the West African region. Site selection within the sub-region varied was based on the type of production system employed. For water-based culture systems main considerations included physico-chemical properties of the waterbody, weather, shelter and depth. Considerations for land based systems included topography, soil type, availability of water and water quality. Legal issues, access, land-based facilities, security, economic and social considerations cut across both land and water based system

To ensure sustainable development of aquaculture, each of the countries had instituted some form of national legislation relating to environmental assessment and, which were undertaken following Environmental Impact Assessment (EIA) procedures. For some of the countries, however, these legislations applied to only large commercial farms.

Site assessment were undertaken using the traditional methods of resolving aquaculture site selection which are length, intensive and subjective, and cannot be efficient if site selection is to be based on the Ecological Approach to Aquaculture.

Introduction

In view of virtual stagnation in capture fish production, and as nations strive to meet the Millennium Development Goal of reducing poverty and hunger by half by 2015 (www.unicef.org/mdg/poverty.html), the importance of aquaculture to food security, income generation and indirect benefits of employment cannot be over emphasized, particularly when the role of aquaculture as a food producing sector is considered in combination with the importance of fish in the diets of many of the worlds' poorest nations. The aquaculture sector thus continues to grow worldwide at an average compounded rate of 8.1 percent per year (Lazard *et al.,* 2010), making it the fastest food growing sector.

Aquaculture growth involves the expansion of cultivated areas, higher density of aquaculture installations and increased use of feeds and other inputs. Being a resource-

based activity, which competes for economic, social, physical and ecological resources with other industries, its development could have negative impacts on other industries such as fisheries, agriculture, and tourism with environmental impacts, which can have social and economic implications (FAO, 2008). Site selection and carrying capacity estimates are believed to play key roles in the success of such projects.

Presented in the report is a review of aquaculture site selection and carrying capacity estimates in West Africa and it forms part of a global review of the subject. It provides a brief description of the West African region, the state of aquaculture development in the region and current criteria and approaches for site selection within the region considering current legislation, regulations and actual compliance, main carrying capacity and site selection issues, gaps in information and local needs. As well as key elements to be included (or improved) to bring existing site selection requirements in line with the ecosystem approach to aquaculture (EAA).

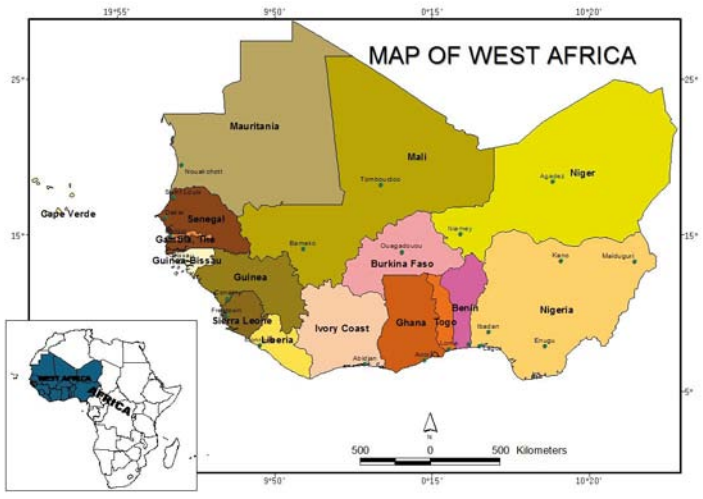
Aquaculture in West Africa

The West African Region comprises sixteen countries namely the Republic of Benin, Burkina Faso, the Republic of Cape Verde, the Republic of Côte d'Ivoire, the Republic of the Gambia, the Republic of Ghana, the Republic of Guinea, the Republic of Guinea-Bissau, the Republic of Liberia, the Republic of Mali, the Islamic Republic of Mauritania, the Republic of the Niger, the Federal Republic of Nigeria, the Republic of Senegal, the Republic of Sierra Leone and the Togolese Republic (Figure 1). It has a tropical climate with a population of around 300 million representing 4.6 percent of the world population.

Status of Aquaculture in West Africa

Aquaculture activities in the region are wide spread and have been practiced in the various countries for periods ranging from 40 to about 60 years. Levels of development and growth are quite varied. Production levels range from subsistence in rural communities to commercial in peri-urban centres. Countries with relatively strong aquaculture activities within the sub-region are the Federal Republic of Nigeria, the Republic of the Niger, the Republic of Ghana and the Republic of Côte d'Ivoire. Africa as a whole accounts for less than one percent of the world's aquaculture production (www.oecd.org/dataoecd/56/31/38523223.pdf). West Africa should therefore account for much less considering the fact that the Arab Republic of Egypt is the largest farmed fish producer in Africa. Fish production data for the study area in 2008 from capture and aquaculture are presented (Table 1).

FIGURE 1
Map of West Africa
(Inset - Map of Africa showing the location of the West African Region)



Source: http://wn.com/ECOWAS.

Aquaculture in the sub-region is largely undertaken in the freshwater environment, employing land-based and water-based facilities. Existing production systems include cages, pens, earthen ponds and concrete/fibre/plastic tanks. The most commonly cultured species are *Oreochromis niloticus* (Tilapia) and *Carias gariepinus* (Catfish). Others are trial productions of *Heterobranchus* and *Notopterus* sp, in the Republic of Sierra Leone (Sheriff, 2006).

TABLE 1
Fish production statistics for capture and aquaculture per country.

Country	Capture	Aquaculture	Total
Benin	37 495	180	37 675
Burkina Faso	10 600	405	11 005
Côte D Ivoire	58 000	1290	
Cape Verde	21 910	-	21 910
The Gambia	42 645	0	42 645
Ghana	34 9831	5594	355 425
Guinea	74 000	0	74 000
Guinea Bissau	6 750	0	6 750
Liberia	7 890	0	7 890
Mali	100 000	821	100 821
Mauritania	195 328	-	195 328
Niger	29 810	16078	45 888
Nigeria	541 368	143207	684 575
Senegal	447 754	200	447 954
Sierra Leone	203 582	0	203 582
Togo	20 000	126	20 126

Source: ftp://ftp.fao.org/fi/stat/summary/a-0a.pdf

Coastal aquaculture activities in the region are relatively few. Existing production activities include intensive production of *Chrysichthys nigrodigitatus* (Bagrid catfish) in lagoons in the Republic of Côte d'Ivoire (Sanogo, 2008), commercial production of *Peneaus monodon* (Black Tiger Prawns) in the Republic of the Gambia (FAO, 2007), and trial production of *Mugil* sp in the Republic of Sierra Leone (Sheriff, 2006) and a pilot project culturing *Epinephelus aeneus* (White grouper) has been reported in the Republic of Senegal. The Republic of the Gambia and the Republic of Côte d'Ivoire are also reported to have potentials for oyster production. While potential market for the product is yet to be identified in the Republic of the Gambia (www.accessgambia.com/information/aquaculture.html), production in the Republic of Côte d'Ivoire could not be continued because the product could not compete in price with wild stocks which are easily gathered from mangroves (Sanogo, 2008). Table 2 shows a list of other species reported to have been cultured in brackish water environments in the sub-region.

TABLE 2
List of Fish and shrimp species cultivated in 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		

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

Species Cultured	Côte d'Ivoire	Benin	Ghana	Nigeria	Senegal
T. melanotheron		X			
T. heudelotii	X				
S. m. heudelotti					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	

Aquaculture site selection

Aquaculture sites selection is very important as it determines economic viability of a project by determining capital expenditure, running costs of production, mortality and ultimately, the success of the operation (Pillay and Kutty, 2005). Site selection is, however, complex involving identification of areas that are economically, socially and environmentally available, and offer the prospect to be commercially viable (McLeod, Pantus and Preston, 2002).

Site selection considerations vary based on the production system employed. For water-based culture systems (cages, pens, inshore and off shore culture systems) general site selection considerations include physico-chemical properties of the waterbody (temperature, salinity, oxygen, currents, pollution, algal blooms, exchange); weather, shelter, depth and substrate conditions, which ensure successful siting of cages. Other considerations are legal issues, access, land-based facilities, security economic and social considerations which relate to the establishment of the farm and profitability.

Basic site selection considerations for land based aquaculture (ponds, raceways, hatcheries, tanks etc.) include access, topography of the area, soil type, quality and quantity of available water as well legal issues. Sites for coastal pond farms should be tidal and intertidal mudflats in protected areas near river estuaries, bays, creeks, lagoons and salt marshes including mangrove swamps (Pillay and Kutty, 2005).

Regional and national factors relevant to site selection for aquaculture

Site selection considerations within the sub-region are based on the production system employed and are the same as those mentioned above for water-based and land-based systems. All the countries have, however, instituted some form of national legislation relating to environmental assessment and, which are based largely on general Environmental Impact Assessment (EIA) procedures. Although a number of these do not contain references to aquaculture, there is always the prospect of an aquaculture project being required to conduct some form of environmental assessment as part of site selection procedures (Nugent, 2009).

A summary of environmental law and EIA regulations likely to affect aquaculture site selection or practice in the sub-region are presented (Table 3).

In the Republic of Ghana the main legislative act governing site selection and the practise of aquaculture are: Fisheries Acts 625 of 2002 section 60 which requires licensing of aquaculture and recreational fishing projects, the Environmental Protection Agency (EPA) Act 490 of 1994 and the Environmental Assessment Regulations, 1999 (LI 1652) which gives mandate to the Agency to ensure compliance

TABLE 3
Summary of environmental law and EIA regulations affecting aquaculture in Africa (to 2006)

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	
The 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 landbased aquaculture EIA for construction of dams/reservoirs Fisheries Act: EIA 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
Guinea	1987 Code on the Environment	1990	EIA required: Aquaculture installations	Ministry	
Guinea-Bissau	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	

Country	Environmental Law	EIA regulations	Explicit mention of aquaculture in EIA	EIA oversight institution	Guidelines published for EIA: general or aquaculture
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
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...;	EPA	
Togo	1988 Code on the Environment	2006	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: Nugent, 2009.

of all investments and undertaking with all laid down Environmental Assessment (EA) procedures in the planning and execution of development projects, including compliance in respect of existing ones.

The WRC Act 1996 (Act 522) which established the Commission, empowers it as the sole agent responsible for the regulation and management of the utilization of water resources in the country. The Commission does this through the granting of Water Rights, which has to be applied by an operator with an approved EIA document.

The principal legislation in the Federal Republic of Nigeria which probably makes EIA requirements for Aquaculture Projects necessary is Decree 86 of 1992, and for the Republic of Côte d'Ivoire Framework Act No. 96/766 of 3 October 1996 of the Code of the Environment. The EIA details the minimum content of any environmental study which covers; screening, mandatory study, mediation or review panel assessment; information required across the countries include:

- Description of proposed project area
- Description of existing environment
- Potential environmental impacts and alternatives
- Possible mitigation measures
- Environmental monitoring plans
- Provisional environmental management plans

- Consultations (Discussions with stakeholder)
- Decommissioning

One of the things these laws are intended to ensure is that aquaculture operations are located at sites where unacceptable ecological impacts such as low DO, high nutrients, destruction of biodiversity and important habitats would not occur or where they are likely to occur there are mitigation measures. Many of the EIAs so far carried out for aquaculture projects in the sub-region have, however, been for large commercial farms and this according to Nugent (2009) is because these have often received investment from private sources overseas or support from international agencies or banks and it is the expectation of their partners that EIA is part of the project installation, even where there may not have been comprehensive national legislation. Beside this for countries like the Republic of Ghana and the Federal Republic of Nigeria detailed EIA is limited to large commercial farms. In the Republic of Ghana fish farms considered to be small (no particular size defined) are only expected to register their operations with the EPA without the need for the submission of an EIA report and in the Federal Republic of Nigeria, only farms sizes larger than 50 ha are expected to submit EIAs prior to commencement and this virtually eliminates all existing farms (Nugent, 2009). Reasons for this practice probably being that small farms are assumed to have minimal impacts.

Use of models and Decision Support tools in aquaculture Site Selection

Geographic Information System (GIS) compared to existing aquaculture site selection procedures is considered one of the fastest and less expensive tools in aquaculture site selection, its use within the subregion for this purpose is, however, minimal. Available information on its use for this purpose are from studies carried out by Kapetsky (1994) and Aguilar-Manjarrez and Nath (1998) for the entire Sub-Saharan African area i.e. countries south of the Sahara Dessert. Both studies undertook an assessment of areas and locations with suitable to optimum potential for subsistence and commercial fish farming. The main difference between the two studies was in the resolution of data used; the later study using data of better resolution, making its outcomes more functional in assessing fish farming potential at the national level (Aguilar-Manjarrez and Nath, 1998). And more recently Asmah (2008) and Sankoh (2009) as part of doctoral research studies at the University of Stirling used GIS to determine aquaculture development potentials for the Republic of Ghana and the Republic of Sierra Leone respectively. All the studies so far undertaken focused mainly on development potential for freshwater pond culture. Asmah (2008) in her study briefly considered the potential for cage aquaculture development in the Republic of Ghana but the assessment was only based on the availability of a waterbody such as a lake or reservoir

The applications and relevance of GIS and remote sensing within the subregion must, however, be well appreciated as each of the countries had well established National Centres for Remote Sensing and Geographic Information Systems (http://nma.agirn.org/index.php/agencies/registered_agencies). The objectives of some of these institutions are to use GIS to maximize efficiency of decision-making and planning as well as training to individuals and other government institutions for a fee.

Carrying capacity estimates

Aquaculture growth involves the expansion of cultivated areas, higher density of aquaculture installations, increased feeds and other inputs. Being a resource-based activity, which competes for economic, social, physical and ecological resources with other industries, its development could have negative impacts on other industries such as fisheries, agriculture, and tourism with environmental impacts, which can have social and economic implications (FAO, 2008). Aquaculture ironically is sensitive to poor environmental conditions created by surrounding activities which can occur

as a result of natural and anthropogenic activities. The extent of the anthropogenic influences on the culture operations from without and within is dependent on what may be described as the carrying capacity of the ecosystem within which the aquaculture operation is located.

IUCN (2009) defined Environmental carrying capacity as the maximum number of animals or amount of biomass that can be supported by a given ecosystem for a given period of time. The term 'carrying capacity' according to the publication is often used in the context of coastal management or planning, with regard to human activities such as industry or aquaculture and is thought to be more appropriate for shell fish extraction. For other forms of aquaculture, the term 'holding capacity' is thought to be more appropriate as the concern in such cases is on the ability of the environment to efficiently absorb and assimilate excess loading of organic compounds and nutrients without any negative effects (IUCN, 2009).

Main tool for estimating carrying capacity is models and Decision Support tools.

Within the West African sub-region, no research on what constitutes carrying capacity, and how this relates to specific developments or sectors was found.

Main gaps and improvement needs according to the EAA

The Ecosystem Approach to Aquaculture is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems (FAO, 2010).

An important step in implementing the ecosystem approach to aquaculture (EAA) is the ability to work across administrative and ecosystem boundaries. The traditional methods of resolving aquaculture site selection by individual site assessment are length, intensive and subjective, and cannot be efficient if site selection is to be based on EAA.

Basic requirement for implementation of the EAA are spatial planning tools, including geographic information systems (GIS), remote sensing and mapping for data management, analysis, modelling and decision-making (FAO, 2010). Geographic Information System has the potential to incorporate and present information at different spatial scales and allows for effective management planning. GIS also makes it possible to assess multiple sites in a rapid and systematic way.

A first step needed to bring aquaculture site selection in the sub-region in line with the EAA principles is to create awareness of these principles, train stakeholders and relevant regulatory bodies on requirements of these principles and to equip relevant institutions with the necessary tools to be able to implement them. There may also be a need for enhanced coalition and development of institutional mechanisms to facilitate coordination among the various sectors with interests in the ecosystems where aquaculture operates.

Current site selection procedures in the sub-region are based on individual site assessment and which as indicated above could be lengthy and subjective. Although the environmental and social impacts of a single farm might seem unimportant, more attention must be paid to the potentially cumulative ecosystem effects of groups of farms at particular sites. This requires an ability to address the cumulative impacts of many small-scale developments probably through monitoring which is basic to effective environmental management of aquaculture.

Finally carrying capacity estimates is an important factor in sustainable aquaculture development and countries within the region should be educated to incorporate.

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