Articles

The role and work of African Mangrove Network (AMN) in conservation and sustainable use of mangroves in Africa

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Introduction

Mangroves cover most of the coastal areas of Africa. They are salt-tolerant inter-tidal forest communities and are restricted to tropical and sub-tropical areas in the world. The total mangrove area in Africa is estimated at 3.2 million ha (about 19% of global coverage) distributed as follows: 63% on the Atlantic coast; and 37% on the Indian Ocean and Red Sea coasts. There are 9 species of mangroves in the Indian Ocean coast, compared to 6 species on the Atlantic coast and 4-5 species in the Red Sea Coast.

Like other mangrove areas in the world, mangroves of Africa play quite significant ecological, socioeconomic and climate amelioration functions: supporting high flora and fauna diversity; providing direct wood and non-wood products and services to the people in terms of building poles, charcoal, tannins, firewood; shoreline protection and also serving as reliable carbon sink. An old-growth mangrove forest in the north coast of Kenya has been estimated to contain up to 500tC/ha, for both above and below ground components. Despite these roles and functions, mangroves have been severely impacted over the years, with West Africa reporting a 20-30% loss and Eastern Africa an 8% loss within the past 25 years. Major causes of mangrove degradation and loss in Africa have been over-exploitation of resources, conversion of mangrove area for other land uses such as, pond aquaculture, agriculture, coastal landfill, urbanization as well as indirect effects of pollution and upstream land use. National and international efforts through a variety of projects and programmes on mangrove conservation have been initiated throughout Africa with organisations such as the FAO, WWF, EU, the Guinea Current Large Marine Ecosystem (GCLME) project and UNEP. These organizations work with mainstream government departments to conserve mangroves.

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With the view to fostering regional collaboration to save African mangroves from further destruction and to collectively work to bring the mangrove agenda to the fore in national and international arenas, the African Mangrove Network (AMN) was established in Cameroon in May 2003. Current membership comprise 22 countries, including; Mauritania, Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Liberia, Cote d'Ivoire, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Gabon, Sao Tome& Principe, Congo, Democratic Republic of Congo, Angola, Kenya, Somalia and Tanzania (Figure 1).

Figure 1: Map showing current member countries of the African Mangrove Network (AMN)

Vision and mission of AMN

AMN's main vision and mission is to create and animate a framework for exchange and concerted actions of NGOs and CBOs on mangroves. The network further aims at promoting cooperation with African decision makers, development partners and counterpart networks in Asia and America towards the emergence of a "mangrove civil society**".** Specific objectives of the network include:

- strengthening operational capacities (material, technical and financial) of mangrove ecosystem conservation actors;
- promoting and strengthening the participation of local populations in the formulation and execution of programmes or projects towards the protection, safeguard and sustainable management of mangrove ecosystems ;
- undertaking active lobbying and advocacy against local, national or international policies and projects which adversely affects the functional integrity of the mangrove ecosystems;
- developing partnership with research institutions, governments and all initiatives geared towards sustainable management of mangrove ecosystems;
- participating in the implementation of different national, regional and international programmes related to the protection, safeguard and sustainable management of mangrove areas.

Organisational Structure

AMN has a clearly defined constitution which was recently modified during the second General Assembly (GA) in Ghana (27-30 April 2009). The GA is the highest decision making body and comprises all members of the Executive (Bureau) and Country Focal Points; the Executive Board (EB) is headed by the Board Chairman (BC) from the NGO Resource and Environment Development (REDO) based in Ghana; the Secretariat is based in Senegal and hosted by the NGO West African Association for Marine Environment (WAAME). It is headed by the Executive Secretary (ES) who manages the day-to-day activities of the network with assistance from an Accountant, Secretary, Communication and Webmaster. A Technical Advisory Group (TAG) gives technical advice and strategic guidance while the Country Focal Points (CFP) coordinate the implementation of decisions at country level. The AMN, through its website (www.mangrove-africa.net), regularly briefs members and the world at large on its programmes, current mangrove conservation and sustainable management issues.

Activities

AMN has been playing quite a unique pan-African coordinating role on rehabilitation, conservation and sustainable utilisation of mangrove resources by undertaking programmes ranging from capacity building, advocacy, awareness creation, promoting the use of improved smoke ovens, mangrove reforestation, promoting alternative income generation opportunities to management plan developments in different countries. The following are some of the key accomplishments of the network.

- Capacity building in mangrove management plan development in Cameroon and Benin.
- Supporting mangrove reforestation and evaluation in Congo, Guinea, Senegal, Benin, Nigeria and Ghana.
- Supporting mangrove protected area establishment in Liberia.
- Advocacy campaign on shrimp farming impacts in Nigeria.
- Enhancing mangrove nursery and plantation establishment in Kenya.

Future perspectives

AMN strategic orientations have been clearly stated in the 2009-2014 Action Plan developed during the Ghana General Assembly. It has an overall objective of promoting the conservation and ecologically sustainable development of mangroves and associated coastal habitats in Africa for the benefit of present and future generations and for the preservation of its intrinsic biodiversity, ecological, aesthetic and other values. The Action Plan has six priority areas as follows:

	Priority Areas	Priority Objectives
1.	Integrated Coastal Zone Management	Promote the conservation, restoration and sustainable utilisation of African mangroves within the context of integrated coastal area management
2	Mangroves and Climate change	Promote mitigation and adaptation of climate change
3	Information, Education and Awareness Creation	Strengthen information, education and sensitisation campaigns
4	Policy advocacy and development	Advocate and support development of national and regional mangrove forest policies
5	Fund-raising	Promote fund raising initiatives
6	Governance	Strengthen the Governance mechanism within the AMN

Despite the above efforts, the AMN has challenges in mobilising funds to accomplish its activities. The AMN is concerned about the grave consequences of mangrove loss to mankind and recognises the time to conserve, protect and restore degraded mangrove lands is now! The international community is therefore called upon to support AMN efforts in addressing the impacts of climate change on mangrove ecosystems including its vulnerability on human communities through research and advocacy. We invite you to join us save the mangroves of Africa and the world to ensure that future generations also benefit from the goods and services mangrove ecosystems provide.

Acknowledgement
AMN has received financial support from the International Union for Conservation of Nature – Netherlands (IUCN-NL), Swedish Society for Nature Conservation, Friends of the Earth (FoE) and World Wildlife Fund for Nature (WWF). Food and Agriculture Organization of the Unties Nations (FAO) remains one of the main technical partners of AMN.

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The Application of the Ecosystem Approach to Mangrove management: Lessons for Ghana

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Summary
The area of mangrove in Ghana has suffered significant depletion in the last 30 years. Causes of loss are based on anthropogenic pressures which will increase with population rise and the climate variability. The impact of this loss of mangrove cover reduces ecosystem services such as fish breeding and nursery as well as erosion control. These losses have a negative effect on marginalised coastal populations, especially women and the elderly. The FAO and CBD ecosystem approach to natural resource management provides a tool for government to revisit the issue of mangrove management in Ghana using adaptive management, participatory engagement with local communities and a holistic approach involving various disciplines. The immediate assessment of frameworks such as the ITTO Action Plan for Mangroves; the World Bank Code of Conduct for Mangrove Ecosystems for their implementation in the Ghanaian context should be carried out by Government. Capacity to apply the FAO system of ecosystem management needs to be built in Ghana.

Introduction

Ghanaian coastal ecosystems provide unique services and are habitats for important coastal species such as waterfowl, crabs, shrimps, marine turtles and juvenile stages of commercial fisheries (Dankwa & Gordon, 2002; EPA/UNOPS 2004; Tweneboah, 2009). Mangroves are trees and shrubs that grow in saline coastal habitats in the tropics and subtropics – mainly between latitudes 25° N and 25° S. The term mangrove is also applied to the mangrove swamp forest ecosystems as a whole. Mangroves are closely related to the forestry and fisheries sectors, and other coastal wetland ecosystems (Clark, 1992; Lawson, 1986; Sackey *et al.*, 1993). They are severely under threat and have lost much of their area in Ghana (Coleman *et al.* 2005; Gordon, 1998; Rubin *et al.*, 1998) partly due to the fact that they are seen as "commons (Hardin, 1968). They are important links in the coastal ecological chain, providing the basis for livelihoods for many marginalized coastal communities (Diop *et al.* 2001; Porter & Young 1998). Ghana has built a strategy for management and protection of nature reserves as well as a strategy for wetland management; however there have been no specific legal rules and regulations for mangrove management (Agyepong *et al.* 1990). The great value of Ghana's mangroves, the current and potential pressures placed on them as well as their management status are the issues of growing concerns, especially to managers, planners and policy makers at

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central and particularly local levels (Gordon & Ibe, 2006). A plan for protection and development of mangrove forests in Ghana is necessary since increasing pressures on the resource and the threat of sea level rise and associated climate change phenomena will exacerbate the situation in future. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change predicts with high confidence that Climate variability and change could result in low-lying lands being inundated, with resultant impacts on coastal settlements (Boko et al. 2007). Climate variability and change, coupled with human-induced changes, would affect ecosystems such as mangroves with additional consequences for fisheries and tourism. Boko et al (2007) state that not only would the projection that sea-level rise could increase flooding, have implications for health, sea-level rise will also potentially increase the high socio-economic and physical vulnerability of coastal cities. The cost of adaptation to sea-level rise could amount to at least 5-10% of gross domestic product. It should be noted that this figure is in the same range as the planned annual growth rate of the Ghanaian economy over the next 50 years (MOFEP, 2007).

The aim of this review is to assess how Ghana has managed its mangroves to date. We also wish to explore how the use of frameworks such as the Driver-Pressure-State-Impact-Response (DPSIR); and use of the principles of the ecosystem approach as espoused by FAO (FAO 2003; De Young *et al*. 2008) as well as the Convention on Biological Diversity (CBD) can be applied in mangrove management.

The Driver-Pressure-State-Impact-Response framework

Arthurton *et al*. (2002) used the Driver-Pressure-State-Impact-Response framework to illustrate the linkage between the dual drivers/pressures of deforestation and cultivation and their impact on the coast. The latter includes the degradation of wetland habitats, which results from reduced water retention in the catchment and greater severity of flooding (Finlayson *et al.*1998; Gordon 1998, 2000). Mensah (2009) points out that DPSIR and related frameworks have been criticized for over simplifying reality, ignoring other linkages within the socio-ecological system, not incorporating the relations between the elements where responses to one pressure can become pressure on another part of the system, and not addressing the fact that some elements may be more relevant than others (Berger *et al.*, 1998; Rekolainen *et al.*, 2003). Other comments suggest that DPSIR has shortcomings in its function as a neutral tool and is biased when it was designed to establish proper communication between researchers and stakeholders/policy makers; with the need to research into effective incorporation of the social and economic concerns of *all* stakeholders (Svarstad *et al.*, 2008).

The Ecosystem Approach to management

The ecosystem approach (EA) proposed under the CBD is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (Christensen et al., 1996; Smith & Maltby, 2003). That is *"the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity"*. It encourages community involvement in the effective management of species and habitats (UNEP, 2000). Ecosystem Management (EM) emphasises ecological interactions within an ecosystem, rather than human activities, and implies that it is possible to understand, control and manage entire ecosystems (Brodziak & Link, 2002; Kappel et al. 2006). On the other hand, Ecosystem-Based Management (EBM) is an integrated, science-based approach to the management of natural resources that aims to "sustain the health, resilience and diversity of ecosystems while allowing for sustainable use by humans of the goods and services they provide" (Kappel et al. 2006). The ecosystem approach has two main dimensions, vertical within a sector, e.g., forestry or fisheries and horizontal, i.e., cross sectoral/integrated management. EBM's goals include learning how these biophysical and socio-economic spheres interact. It also includes understanding of the linkages among activities and social and ecological system components by using institutional and scientific ways of managing multiple human activities within entire ecosystems (Kappel et al. 2006). Understanding how humans interact with ecosystems is important because decisions on natural resource use and management are made in a social context (Savory, 1988).

The FAO Technical Guidelines on the ecosystem approach to fisheries (EAF) (FAO 2003) define EAF as follows: "An ecosystem approach to fisheries strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries." The FAO views the EA as being based on three pillars; societal well-being, ecosystem well-being and the "ability to achieve" which refers to the governance and policy framework needed to deliver the first two pillars.

Despite the clear definition given by both the FAO and the CBD, there is still an element of uncertainty at the level of implementation of the ecosystem approach. Much of the confusion that surrounds the ecosystem approach is that the EA is an approach to management not to science – but as a management approach it has implications for science. For mangroves, this situation is compounded by the ambiguous position that mangrove ecosystems have for managers – do they belong to administrative units that manage the land or the sea, should they be managed by government departments that deal with fisheries or forestry?

Discussion: The Ecosystem Approach as Applied to Mangrove Management in Ghana

Ecosystem Well-being

The following summary on the state of mangrove ecosystems of Ghana is based on the account given by Gordon & Ayivor (2003) and Diop *et al*. (2001). Out of the 81,342 km^2 of total forest area in Ghana, mangroves cover about 140 km^2.They are limited to a very narrow, non-continuous coastal area around lagoons on the west of the country; and to the east, on the fringes of the lower reaches and delta of the Volta River (UNEP, 2007). They are most extensive to the west in the stretch between Cape Three Points and Côte d' Ivoire, especially, areas around Half Assini, Amanzure lagoon, Axim, Princes Town and Shama, among others. To the east of the country, they are best developed at Apam, Muni lagoon, Winneba, Sakumo-1 lagoon, Bortiano, Korle lagoon, Teshie, Sakumo-2 lagoon, Ada, Sroegbe and Keta lagoon. Six species of mangroves found in Ghana are *Acrostichum aureum*, *Avicennia germinans*, *Conocarpus erectus*, *Laguncularia racemosa*, *Rhizophora harrisonii*, and *Rhizophora racemosa* (Table 1). The open lagoons tend to be dominated by *Rhizophora racemosa*, whilst closed lagoons with an elevated salinity contain *Avicennia germinans*, *Conocarpus erectus*, *Laguncularia racemosa* and *Acrostichum aureum* (UNEP, 2007).

Table 1. Mangrove area estimates for Ghana

Year	1980	1990	1997	2000	2005	2006
Area (km^2)	181	168	214	138	124	137

Source: UNEP, 2007

Wetlands and mangrove in Ghana provide a number of vital ecosystem functions (World Bank, 1996). In addition the products they provide can be for human use at the subsistence, commercial, recreational levels (Amatekpor, 1997). The primary causes of wetlands and mangrove degradation can be linked to activities such as exploitation of fish, crabs and oysters, fuel wood gathering (See Figure 1), salt extraction, urban pollution and urban encroachment. The local populations who live in the mangrove areas have traditionally used mangrove products and the mangrove environment over the years. They have mainly exploited it for wood, fish, crabs and oysters. Nevertheless, mangrove areas in the country have received virtually no attention in terms of conservation and sustainable management.

Mangrove ecosystems support a wide array of biodiversity in Ghana. The ecosystems and their associated wetlands provide habitat for high concentrations of birds, mammals, reptiles, amphibians, fish and invertebrate species (Marquette *et al*., 2002). Thousands of waterfowl, many of them migratory, visit Ghana during the northern winter (Ntiamoa-Baidu & Hepburn 1988; Ntiamoa-Baidu & Gordon 1991). Mangroves serve as sanctuaries and nestling grounds for several of these birds.

Figure 1. Clear cut mangrove

Gordon and Ibe (2006) note that physical alteration and destruction of habitats along the West African coast is very common, especially near river mouths and lagoons. This is evident in shoreline erosion, changing hydrological patterns, and water abstraction and impoundment by the opening of channels to the sea or by physical structures such as ports and harbours. Tweneboah (2009) gives the issues directly affecting the coastal zone of Ghana to include: population increases and poverty; loss of habitat and land through coastal erosion; wetland and mangrove degradation; fisheries degradation; poor access to safe drinking water; poor sanitation; industrial pollution of land; and water pollution.

Despite the ecological and economic (See Box 1) importance of mangroves, they continue to be over exploited on a daily basis with little or no control. In most coastal communities in Ghana, mangrove ecosystems are used in a variety of ways such as fishponds, salt pans, sugarcane fields, human settlements and other agricultural uses. The mangrove stands from the forest are felled for firewood which serves variety of purposes, including domestic fuel, fish smoking and distillation of *akpeteshie* (local gin). A large quantity of the mangrove wood is also used for constructional purposes and for fishing (Lawson, 1986; Singh, 1987; Amatekpor, 1998). Mangrove exploitation intensified, particularly in the Volta Basin, following the construction of the Volta dam in 1964 and the consequential loss of fishing and farming opportunities for downstream communities. Many of the small creeks silted up due to the loss of the annual floods, necessitating the dredging of channels to maintain water access to some communities (See Figure 2).

Between 1980 and 2005 the mangrove area fell from 181 km2 to 137 km2 representing a loss of 24% (FAO 2007).

Box 1. Economic returns from mangrove in the Lower Volta

Mangrove related economic activities such as fuel wood, fish smoking, *akpeteshi* distilling, construction of houses, harvesting of crabs, fish and black snails are significant. The net return per person to fish smoking is about US $30 per week while the contribution to roofing a house is estimated to be US $ 85. The total returns to mangrove related harvesting to the study area comes to US $ 340 per hectare per year. Mangroves benefit marine fisheries by increasing the yield. The increase in fisheries as a result of the presence of mangroves was estimated to be US $ 165 per hectare. Based on these figures from the lower Volta, The total value for just mangrove related harvesting and contribution to marine fisheries is over US $ 500 per hectare. Using an estimated 12,000 ha. as the area of mangrove in Ghana, gives the value of mangrove as well over US $ 6,000,000 per year as this does not include all the other ecosystem services that mangroves provide such as erosion control, trapping of pollutants provision of biomass for the detritivore food chain etc.

Source: Lower Volta Mangrove Project

Figure 2. Dredging in mangrove areas of Lower Volta to maintain water access to communities

Societal Well-being

The local communities are well aware of the importance of mangroves to their lives but due to lack of options they have no choice but to keep destroying them. Tweneboah (2003) notes that in most cases, it is women, children and the elderly who are impacted most by the loss of mangroves as these marginalized groups have limited alternatives.

The land tenure system and the ownership and sale of mangrove as currently practiced do not promote sustainable use. Mangrove plots are leased for ten years. The new owners of the mangrove (not the land) clear cut as soon as possible wait five years clear cut again and then just before handing the mangrove back to the owners, clear cut again.

Donors are now more aware of the need to have integrated projects when dealing with mangroves. An example of such a project is the "Regeneration, Sustainable use and Management of Mangrove in the Keta Lagoon Complex Ramsar Site". This project funded by a Ramsar Small Grant, is based in a Ramsar site which has become degraded due to mangrove over-harvesting, with subsequent negative impacts on fishing resources and the turtles' breeding grounds. There are two main components: awareness creation and capacity building among local communities to enable mangrove restoration and sustainable use, and creation of alternative income-generating activities. Mangrove plantations and woodlots will be established and workshops on goat, crab and grass-cutter rearing, as well as fish farming will be run.

Ability to Achieve

Ministries and agencies whose activities border on mangroves and biodiversity in general include: National Development Planning Commission, Ministries of Environment and Science, Lands and Forestry, Food and Agriculture, Justice, Local Government and Rural Development, Environmental Protection Agency, Fisheries Commission, Water Resources Commission and Wildlife Division of the Forestry Commission. In spite of the existence of these institutions and departments, mangrove management and conservation has been far from satisfactory. A major constraint has been the lack of coordination, collaboration and networking among the policy developing institutions on one side and policy-implementing institutions on the other. There is also the problem of lack of capacities of some institutions. This results in lack of baseline data and deficiencies in information management.

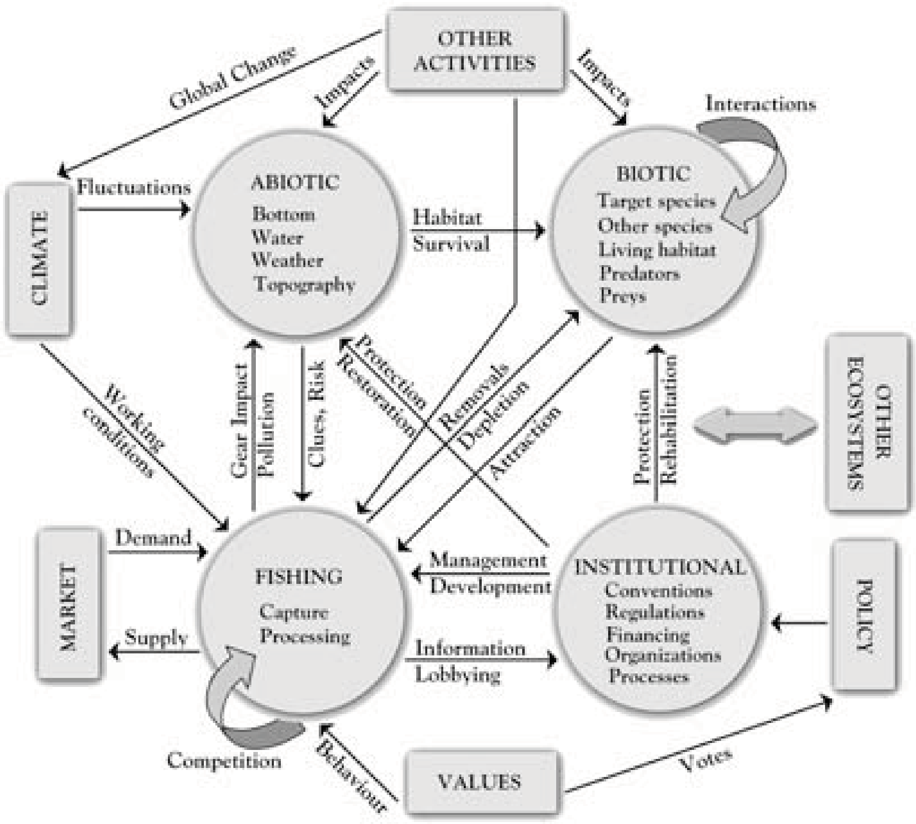
There are a number of legislation governing management, development and conservation of specific natural resources (Hens & Boon 1999). Most of the legislation tends to be sector-based; they may be conflicting, obsolete, deficient and unenforceable. More so, there is no single comprehensive legislation in the country that handles all natural resources in totality. Neither is there a specific elaborate legislation on biological diversity. However, there is legislation of relevance to biodiversity use and conservation. Despite the existence of various legislations, the conservation and management of the country's biological resources still leaves a lot to be desired. While legislation on the use of resources of the terrestrial systems abound, there are only a few national laws that deal with the protection of the marine environment. Mangrove is one of the habitats that is deemed sensitive and any development in an area with mangroves requires and Environmental Impact Study by Ghanaian law. Even though Ghana is signatory to and has ratified a number of international conventions and agreements relating to the marine and coastal environment in general and biological resources in particular, she has failed to translate many of them into national legislation for implementation purposes.

Conclusions

Clearly mangroves in Ghana and their management have been given a low priority in practical terms. The mangroves are now in a serious situation, and the "business as usual" approach will not correct the situation. There are a number of institutional and operational bottlenecks in the system which precludes progress in developing a comprehensive mangrove management plan.

The first is a severe lack of the information needed to evaluate and, where possible, enhance the different tools for assessing indirect interactions and their impacts on mangroves. Each of the arrows in Figure 3 below represents a data set or information required for the understanding of the system for its management. For the most part mangrove managers in Ghana operate in an environment of severely limited data availability. Part of this problem is linked to lack of trained personnel so there is a need to develop training tools for capacity building in EA as applied to mangroves, with an emphasis on identifying and reconciling operational objectives in the mangrove ecosystem, with particular emphasis on biological and ecological objectives and indicators.

Though many models and systems are available both the Ecosystem Approach and the DPSIR framework have been well proven in coastal environments and there is no need to "reinvent the wheel". Use of EA and DPSIR will offer opportunities for mangrove mangers in Ghana to streamline their operations. The use of a more holistic approach with the needed participation from all stakeholders, coupled with the political will to implement management prescriptions may be the key to saving Ghana's mangroves.



Source: Garcia, et al. 2003

Figure 3. Simplified diagram of an ecosystem and its components

Recommendations

The actions needed to save Ghana's mangroves are varied and include best forestry practice such as:

- Replanting of both *Rhizophora* and *Avicennia* and thinning of areas of dense mangrove seedlings;
- Removal of the noxious weeds *Acrostichum* within mangrove, removal of *Typha* and the dredging of waterways;
- Control of the felling of undersized and under aged trees and a leaving a buffer zone or green belt of mature trees beside waterways;

Alternative income generating activities are another initiative that could reduce pressure on mangroves such as:

- Poverty reduction measures (e.g., cottage industries), assisting with credit facilities in expanding crop and other farming activities

- Developing low impact tourism in the area
- Development of woodlots to supplement mangrove as a source of fuel wood and aid rainwater infiltration

There is a need for more information and data to feed management, while the "precautionary approach" given in the EA is adhered to, these include:

- Assessing the capacity of mangroves to produce tannins as well as the tannin quality
- Provision of observation wells for groundwater monitoring for hypersaline water
- Monitoring programme for hydrological data collection, i.e., discharge, surface run-off, water level variation
- Demarcation and detailed soil mapping of the areal extent of acid sulphate soils in mangrove area.
- Field trials by participatory approach, of the efficacy of liming acid sulphate soils with locally available raw materials.

An improved management system is needed that would address the incentives for both owners and contractors to yield maximum benefits. This could be achieved through:

- Greater interaction between the District Assembly and the stake-holders by the promotion of community based mangrove management strategies; local political structures and traditional stakeholders must be involved.
- Educate local people of the current situation on the ground on measures that must be taken to check un planned cutting of mangrove;
- Creation of environmental awareness is imperative if the above recommendations are to be successfully implemented.

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FAO REGIONAL OFFICE FOR AFRICA

Ecology and Restoration of Mangrove Forests in Kenya

James Gitundu Kairo[1] and Jared Bosire[2]

Summary
Conservation status of mangrove forests along the Kenyan coast was assessed by means of aerial photographs, intensive ground-truthing and GIS. Old growth mangrove stands in the north coast of Kenya at Kiunga had stocking rates and standing biomass of 2142.0 and 497.1 ton/ha respectively. In the south coast of Kenya, however, mangroves are more degraded through wood extraction pressure. The stocking rates of degraded mangrove stands at Gazi was 678 stems/ha with a standing biomass of 43.5 ton/ha. Natural regeneration of the secondary mangrove forests in Mida was found to be adequate thus requiring no re-stocking.

The structural development and productivity of replanted mangrove plantations was investigated at Gazi bay. A 12 years old Rhizophora mucronata plantation had a stand density of 5132 stems/ha; with a mean canopy height and stem diameter of 8.4 ± 1.1 m (range: 3.0–11.0 m) and 6.2 ± 1.87 cm (range: 2.5–12.4 cm), respectively. The standing biomass for the 12-year-old replanted forest was 106.7 ± 24.0 t/ha, giving a biomass accumulation rate of 8.9 t/ha/year.

Mangrove forestry in Kenya suffers from an inadequate knowledge of silviculture of indigenous species, of multiple-use potential of resources, and of techniques and economics of natural regeneration and reforestation. Consequently, the information generated in this study has an important role to play in gathering basic information based on field trials as a necessary input towards sustainable management of mangroves in Kenya.

Introduction

Mangroves are forests growing at the edge of tropical seas (Spalding, et al., 1997). In addition to providing a range of products that people need, including building materials, firewood, tannins, fodder and herbal medicines, mangroves are of invaluable local and global ecologic, economic and social importance (FAO, 1994). Mangroves serve as breeding and feeding grounds for many species of fish, mollusks, crustaceans and birds (Saenger, 2002). Being at the edge of the seas mangroves control coastal erosion and sea-level rise (FAO, 1994).

Kenya has over 53,000 ha of mangrove forests along her 574 km coastline (Doute *et al.*, 1981). The highest concentration of these forests occurs in the area north of the Tana river, in Lamu district. There are 9 recorded mangrove species in Kenya; the principal species being *Ceriops tagal* (Perr.) and *Rhizophora mucronata* Lam., which form more than 70% of the forests (Ferguson, 1993; Kairo, 2001). Recent surveys indicate

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considerable loss of mangrove resources through over-exploitation (Ferguson 1993; FAO, 1993a, FAO, 2005) and conversion of mangrove area to other land uses such as fishponds and solar salt works (Yap and Landoy, 1986). Losses of mangrove through oil pollution have also been witnessed (Abuodha & Kairo, 2001). Degradation of mangroves is directly reflected in the increased coastal erosion (Kairo *et al.,* 2001), shortage of building material and firewood (Dahdouh-Guebas *et al.,* 2000), and reduction in fishery (Tiesongrusmee, 1991).

The present study aimed at sustaining the supply of mangrove goods and services without negatively affecting the forest ecosystem resilience. More specifically, the objectives were:

1. To conduct mapping and quantitative analysis of mangrove forests in the pilot areas,
2. To examine natural regeneration patterns of commercial mangrove species and timber potential of mangroves forests in the pilot areas,
3. To assess recovery processes, in terms of biomass increment, of mangrove plantations established since 1991.

Description of the study area

This study was carried out in three sites, containing all together five distinctive mangrove populations. The sites span the entire Kenyan coastline from the northern limit (Kiunga, 1°37'S, 41°30'E), the middle region (Mida creek, 3°20'S, 40°00'E), to the southern limit at Gazi bay (4°25'S, 39°32'E) – Fig. 1. The sites were selected in such a way that they represented different mangrove formation in Kenya ranging from fringing, riverine and basin. Based on the definition by Lugo and Snedaker (1974), fringing mangroves are those forests that occur along shoreline with elevations that are higher than mean high tide levels. Fringe forests reach a maximum height of 12m. Riverine mangroves, on the other hand, are tall forests along tidal rivers and creeks frequently influenced by freshwater input. Riverine forests can attain stand height of more than 18m. The basin mangroves occur in depressions normally receiving terrestrial run-offs and without direct influence of tidal waves. Trees in tidal forest may reach 15m tall or more (FAO, 1994).

Mangroves in the north of Kenya at Kiunga represent pristine to semi-pristine forests (Kairo *et al*., 2002a). These forests are mostly fringing mangrove formation and are located in area of low human density. Mida creek represents disturbed forest undergoing rapid natural regeneration (Kairo *et al*., 2002b); whereas Gazi mangroves area are degraded forests that would never recover naturally without human intervention (Kairo, 1995, Kairo *et al.,* 2001, Kairo *et al.,* 2008). Casual observation of mangroves in the study sites suggests that they differ in structure (physiognomy), hence quantitative description of the populations were made to give baseline information and provide a better understanding of their natural ecological patterns.

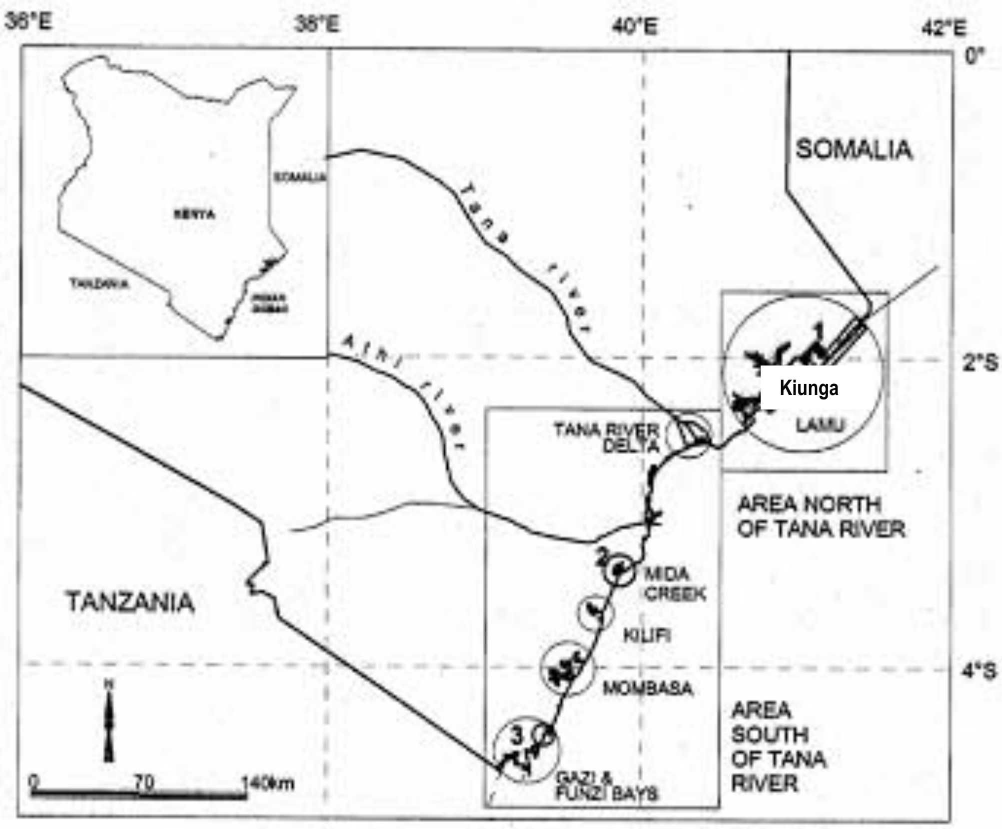


Figure1. The Kenya coastline showing major mangrove areas. In the present study mangroves of Kenya have been divided into two broad regions; area north and south of the Tana River delta. The numerical values represent pilot areas: 1- Kiunga 2 – Mida creek, 3 – Gazi bay.

Study approach and methodology

Mapping of mangroves in the pilot areas was carried out using medium scale (1:25000) aerial photographs and Geographic Information System (GIS). Stratified sampling technique was used to generate vegetation data. Measured parameters included tree height, stem diameter at breast height (dbh), crown diameter and biomass, from which were derived tree basal area, species density and frequency. The ecological importance of each species was calculated by summing its relative density, relative frequency and relative dominance (Cintron and Schaeffer-Novelli, 1984). Complexity index was obtained as the product of number of species, basal area (m^2/0.1 ha), maximum tree height (m) and number of stems/0.1 ha, times 10^{-3} in a 0.1ha plot (Holdridge *et al*., 1971). Lineral regeneration sampling (FAO, 1994) was used to assess the composition and distribution pattern of natural regeneration.

Results and Discussions

a. Survey and mapping of the mangrove resources in Kiunga

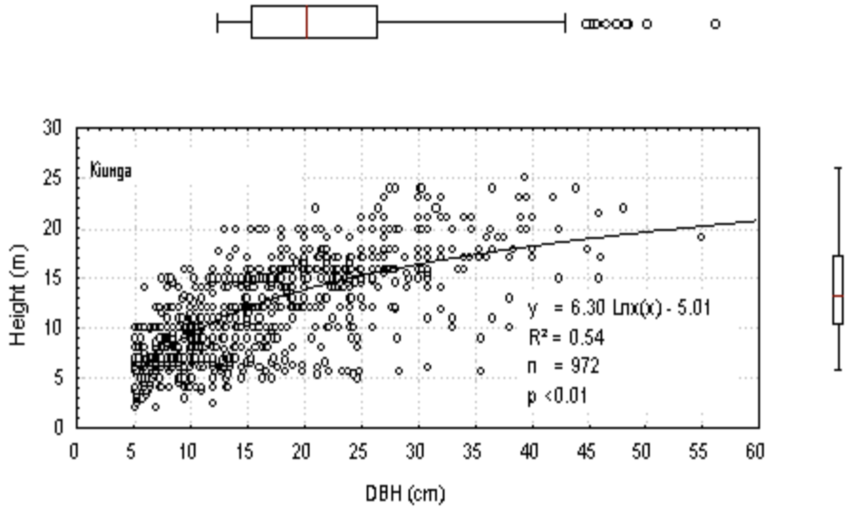
The present study revealed that the existing mangrove forests within and adjacent to Kiunga Marine Protected Area occupied a surface area of 16,035.94ha, with a standing volume of 2,354,004.85 m^3 (Kairo *et al.,* 2002a). The dominant species of mangrove in Kiunga are *Ceriops tagal* and *Rhizophora mucronata.* The average standing volume for stems above 5.0cm diameter was 145.88 m^3/ha (range: 6.85 - 710.0 m^3/ha); corresponding to 1736 stems/ha. Given its high potential productivity and natural regeneration, mangroves of Kiunga have excellent prospects for sustainable exploitation.

b. Structural characteristics

Table 1 is a summary result of the vegetation inventories of mangrove of the pilot areas. The high complexity indices (C.I.) recorded in the mangrove forests north of Tana river especially the high basal area and canopy height in Kiunga (C.I. = 62.81), as compared to the southern mangroves at Mida creek (6.97) and Gazi bay (0.35) – Table 1. In Kiunga, 50% of trees had a dbh of 16 – 27 cm (height: 9 – 17 m) while in Mida, 50% of the stems had a dbh of 14 – 25 cm (height 6 – 12 m) –Fig 2. Compared to the mangroves north of Tana river, the forests south of Tana River are highly degraded due to dense human population in the area (Kairo *et al.,* 2002a, 2002b, Dahdouh-Guebas *et al*., 2004).

Table 1. Structural characteristics of mangroves in the study areas (Source: Kairo et al., 2002a, 2002b)

Species	**Kiunga**	**Mida**	*Gazi bay*
Basal area (m^2/ha)	46.97	23.62	3.19
Stand density (stems/ha)	2142.0	1192.0	678.0
Biomass (ton/ha)	497.10	104.73	43.15
Complexity Index	62.81	6.97	0.35



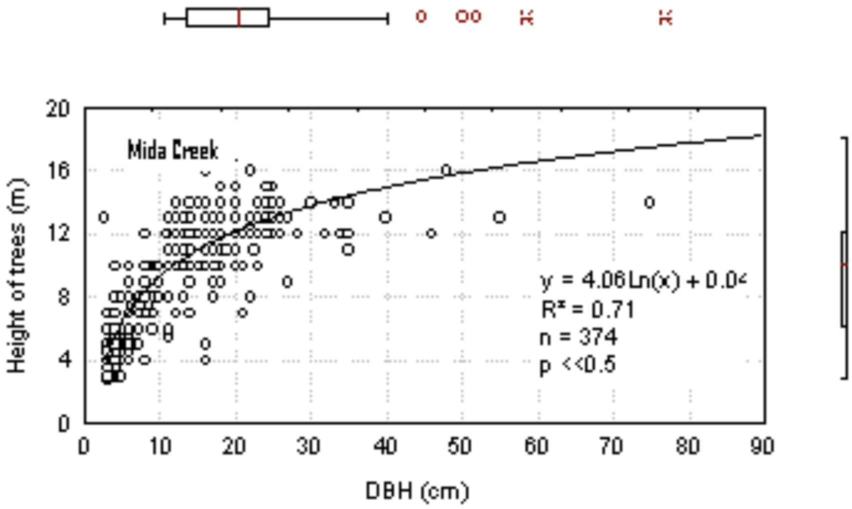


Fig. 2. Height-Diameter distribution of mangrove forests in the study areas. The box-plots display percentile distribution in each case (Source: Kairo et al., 2002a, 2002b).

c. Structural development and productivity of replanted forests

The above ground biomass was determined for 12 year old *Rhizophora mucronata* plantation at Gazi bay that were established since 1991 (Figure 3). Trees with stem diameter greater than 2.5 cm inside 100 m² were harvested, and then separated into trunks, branches, leaves and prop roots. The replanted forest had a stand density of 5132 stems/ha; with a mean canopy height and stem diameter of 8.4 ± 1.1 m (range: 3.0 - 11.0 m) and 6.2 ± 1.87 cm (range: 2.5 – 12.4 cm), respectively (Kairo *et al.,* 2008, Table 2). This is much higher than the 3330 and 3100 stems/ha that were recorded when the plantation was 5- and 8-year-old, respectively (Kairo *et al.,* 2009). The stocking rate for the 12-year-old plantation compares well with those reported for *Rhizophora apiculata* at similar age in Vietnam (FAO, 1993b). However, compared to stocking rates of natural mangrove stands in Kenya, the current stocking rate in replanted forests can be said to be excellent. The standing biomass for the 12-year-old *Rhizophora* plantation was 106.7 ± 24.0 t/ha, giving a biomass accumulation rate of 8.9tons/ha/yr.

Table 2. Yield table data for replanted R. mucronata plantation at Gazi. Source: Kairo et al., 2008).

Parameters	Utilization classes (cm)				
	Fito < 4.0	*Pau* 4.1-6.0	*Mazio* 6.1-9.0	*Boriti* 9.1-13	total
Stems/ha	559	1586	2392	327	4864
Standing biomass (t/ha)[a]	2.35	18.55	66.36	19.39	106.66 - 24
Below ground biomass (t/ha)					24.89 – 11.4

[a]*Equation used was: $y_i = 0.000016\,(D_{130}{}^2H_i)^2 + 0.0454\,D_{130}{}^2H_i + 0.495$; where y_i = biomass of the ith tree, D_{130} = diameter at 130 cm above the ground and H = height.*

Figure 3. A 12- year old Rhizophora mucronata plantation at Gazi bay, Kenya. The net value of such a replanted stand has been estimated at US$3000/ha/yr (Kairo et al., 2009b).

Conclusions

Recent assessments of global forest resources indicate that about 50% of the mangroves in world have been lost in the last 50 years and many mangroves worldwide risk to disappear in the following decades (FAO, 2005, Duke *et al*., 2007). The underlying root causes of the loss and modification of mangroves in Kenya are associated with the population growth in the coastal areas that leads to over-exploitation of resources, conversion of mangrove areas to other land uses such as pond aquaculture; diversion of fresh water flow, heavy siltation associated with poor land-use, and pollution. Losses of mangroves have affected local and national economies as indicated by shortage of firewood and building poles, increased coastal erosion and reduction in fishery (Dahdouh-Guebas *et al.,* 2000; Abuodha and Kairo, 2001). There is an urgent need to reforest degraded areas in order to achieve the objectives of sustainable forest management.

The quantitative findings from the present study indicate the presence of both pristine and degraded mangroves in Kenya. The pristine stands of mangrove in Kiunga are of similar structural complexity to healthy mangroves in the world undergoing sustainable exploitation e.g. Matang Forests in Peninsula Malaysia. The data generated from this study (and from other recent works) can be used in the preparations of management plans of the mangroves in Kenya. Currently Kenya lacks management plan to guide exploitation of mangrove resources. This is unfortunate, considering that mangroves provide 70% of wood requirement along the Kenya coast (Wass, 1995).

The results of this study demonstrate, as well, the potential use of reforestation as tool in returning the lost forests and thereby sustain supply of mangrove goods and services. Major goods and services from replanted mangrove plantation include: firewood and building poles, coastal protection, ecotourism, research and education, carbon sequestration and on-site fisheries. The total economic value of a 12-year-old *Rhizophora mucronata* plantation in Kenya has been estimated at $3000/ha/yr (Kairo *et al*., 2009b); most of this being accounted for by the coastal protection functions of the forest.

Acknowledgement
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Management challenges of mangrove forests in Africa: a critical appraisal of the coastal mangrove ecosystem of Nigeria

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Summary

Mangroves in Africa have played significant ecological, economical and socio-cultural roles in the lives of coastal communities in the continent. This paper presents the management challenges confronting the mangrove ecosystem of a typical tropical mangrove ecosystem - the Niger delta area of maritime Nigeria. With a coastline of over 970km, Nigeria is a coastal-oriented continental nation having a coastal resource base and a concentration of population along the coast. The paper shows that the Niger delta consists of a tropical rain forest zone and a coastal area of mangrove vegetation transversed by many rivers, tributaries, creeks and lagoons. It lies at the centre of oil productive sites (off-shore and in-shore) and is a sensitive ecosystem vital to the fishing industry and local economy of the citizenry. With a view to highlighting the importance of this ecosystem to the fishing industry, this paper presents the results of investigations carried out in three coastal mangrove systems of Nigeria (Ondo, Ogun and Cross River). All the commercially important fin and shell fish assessed are shown to be either temporary or permanent residents of the mangrove area. The beneficial effects on marine fisheries are at risk from anthropogenic influences such as pollution or destruction of the mangrove ecosystem. The paper calls for a sound marine area protection programme in Nigeria, most especially due to the negative environmental impact of oil production activities in the area.

Introduction

Mangrove forests, which in West Africa cover an area of over 27 000 km^2 in deltas, estuaries and lagoons, is part of the offshore coastal ecosystem. They are regularly influenced and disturbed by seasonal freshwater and diurnal tidal flooding, thus they often exhibit features of an under-utilised ecosystem namely low species diversity and high productivity. African mangroves are very diverse morphologically and in flora and fauna. A total of 17 mangrove tree species are found in Africa with eight species unique for west and central Africa while nine species are unique to the eastern African costs. Nigeria has the largest mangrove forest in Africa. It covers an area of about 9 723 km^2, forming a vegetative band of 15 - 45 km wide above the barrier islands and running parallel to the coastline. About 305 km^2 of the mangrove forest are in reserves. The Nigerian mangrove resource is dominated by the red mangroves (Rhizophoraceae), in association with white mangroves (Avicenneaceae). The mangroves provide breeding and nursery grounds for many commercially important species of fish and shell fish. The stilt

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roots of the mangroves and the mud surface usually support a varied fauna of oysters, crabs and other invertebrates.

The Niger Delta mangroves are today threatened by various human activities such as over logging, clearance for the passage of oil pipes and seismic lines, swamp reclamation for urban development, etc. This paper presents the management challenges confronting the mangrove ecosystem of a typical tropical mangrove ecosystem - the Niger delta area of maritime Nigeria. This paper looks at the economic (fishing) and social (livelihood) importance of the mangrove ecosystem in the Niger Delta. The need for a defined and sustainable management programme of the entire coastal region of Nigeria is recommended.

The Niger Delta of Nigeria

The Niger Delta region of Nigeria covers an area of about 70 000km^2 and is inhabited by about 7 million people (NDES, 1997). Data shows that it is Africa's largest and the world's third largest delta and West and Central Africa's most extensive freshwater swamp forest. This region is a mosaic of diverse and sensitive ecosystems that traverse four vegetation zones, *viz*. freshwater swamps, mangroves, creeks, estuaries and barrier islands. The overlapping and inter-active freshwater, brackish and marine ecological zones are biologically significant for the fisheries of the Niger Delta. The brackish water zone of the Niger Delta is delimited upstream by freshwater swamps and downstream by sandy beach ridges. The mangrove swamps, where the salinity changes with each tide, contribute significantly to the high production of zooplankton thus providing sustenance for the stocks that spawn and "nursery" for fish and crustaceans there. As a result the brackish water zone appears to be the most valuable part of the Niger Delta in terms of the fisheries population.

Data analysis and Results of studies

Between 1990 and 2009, various investigations have been carried out by the staff of the Department of Aquaculture and Fisheries Management, University of Agriculture, Abeokuta. Three different studies were carried out in three coastal states of Nigeria with a view to investigate the diversity and distribution of fish species occurring along the coastal zone of the study areas. Findings from the three mangrove systems of Ondo, Ogun and Cross river estuary are summarized in this paper.

In Nigeria, over 90% of the fish catch is derived from the coastal zone (Moses, 2006). This zone has a high diversity of fish species which are of economic value to the people of Nigeria. The Niger Delta consists of many distinct ecological zones that have a diversity of finfish and shell fish of about 120 species belonging to 78 families in the brackish and marine environments. It has wetland vegetation that are comprised of taxonomically diverse, salt-tolerant tree and other plant species which thrive in inter-tidal zones of sheltered tropical shores and estuaries. Throughout the brackish water areas, crabs and mud skippers (*Periopthalmus hoelferi)* are targets of numerous subsistence operators mainly women (Ajayi,1990). Before the advent of the oil industry, in the late 1950s, the importance of the coastal zone was as a base for much of the country's artisanal fisheries. In the 1970s, yields from catches ranged from 128 000 to 170 000 metric tons per year. According to the survey, (Ibe, 1990), the following species were prominent among catches from the zone: bonga, (*Ethmalosa finmbriata), s*ardines

(*Sardinella madarensis, S. eba, S. cameornensis)* and shad (*Ilisha africana),* which were the principal targets of the pelagic and semi pelagic coastal artisanal fishery activities. Shell fish harvested by artisanal fishermen included white shrimp *(Nematopalaemon machrobrachion),* river prawn (*Macrabrachium vollenhovenii)* and juvenile pink shrimp (*Penaeus notialis, P. duorarum).* The mangrove oyster, (C*rassostra gasar)* and other molluscs were delicacies in high demand.

Mangrove forests are vital for a healthy coastal ecosystem. The forest detritus, consisting mainly of fallen leaves and branches from the mangroves, provides nutrients for marine species and supports a large variety of life in intricate food webs, associated directly through detritus or indirectly through the planktonic and epiphytic algal food chains with the trees.

Fish resources and associated biota: Ondo state coastal mangrove system

Ondo state is one of the eight coastal states of Nigeria that shares a common boundary with the Atlantic ocean. It is characterised by extensive lagoons and river delta system. It lies between latitude 6^0 N and 7^0N and longitude 4^0E and 5^0E. The state is divided into 18 local government areas (LGAs) with only 2 of the LGAs reachable and explored by boats and canoes. Investigation on the fish resources of the area was conducted between 1991 and 1995. Over 32 fish species were encountered and assessed. From the studies, the Bonga, Cichlids and the Catfish family were found to be the most abundant ones in the study area. Apart from the fish resources, the mangrove ecosystem of this area supports other associated organisms which sometimes occur in inter-tidal habitats. While some of these organisms depend upon the mangrove trees for only part of their life cycles, some are associated with them on a permanent basis. In addition, *Rhizophora racemosa, Raphia spp* and *Avicennia africana* was abundantly present in the mangrove ecosystem of the Ondo state coastal area (Akegbejo-Samsons, 1995).

Cross River coastal area

The Cross River is located at the south eastern part of Nigeria (Latitude 4^0, 25^1 – 7^0. 00^1N; Longitude 7^0, 15^1 – 90.30^1E). It is bounded in the south by the Atlantic Ocean and in the east by the Republic of Cameroon. Fish was sampled for 2 years, between May 2004 and March 2006, in 3 zones of the river. Zone I represented the upper part of Cross River characterized by dry climate with grassland floodplains. Zone II was the middle part of the river with moderate climate and mixture of forest-savannah flood plains. Zone III represented the mangrove forest area of the River which is covered by rain forest canopy. Results show that the cichlids, especially *Oreochromis niloticus* and *Tilapia* spp were more numerous in the mangrove forest ecosystem than in the other two zones. *Heterotis niloticus* dominated the zone in percentage, and was more common than in the other zones. The mangrove forest ecosystem was found to be the major habitat for all the Mormyridae, while the catfish family, especially *Clarias anguillaris, Heterobranchus longfilis, Chrysichthys nigrodigitatus* and *C.auratus,* were major commercial species in both weight and number (Offem, 2006).

Ogun state mangrove area

Ogun state is one of the maritime states of Nigeria with a short coastline of about 15 km. It is endowed with an extensive brackish water lagoon system extending from Lagos state in the west and to Ondo state in the east. It is covered by aquatic biotope that reflects its large area of wetlands. The estuarine biotopes include Yewa lagoon, Omu Moha, Makun creek etc, with a total surface area of 767 3 km^2. In addition, Ogun state coastal wetlands have about seven 'special tidal depressions, with a total surface area of about 24.4 ha. The vegetation of the area is mangrove forest characterised by coastal swamps. There are open-tide flats, popularly known as marine beels. The study was carried out between January 2003 and December 2004 in the coastal area of Ogun Waterside local government area of Ogun state. 38 fish species belonging to 25 families were identified, out which 34 were finfish and 4 shellfish. The results are presented in Table 1.

Table 1: Relative composition and distribution of some commercially important fish species in Ogun state coastal area, Nigeria

Specie	Family	Total fish abundance	Relative abundance (%)
Ethmalosa fimbriata	Clupeidae	101524	28.87
Sardinella spp	,,	93097	26.47
Ilisha Africana	,,	62941	17.90
Pentanemus quinqurius	Polynemidae	30920	8.79
Chloroscombrus chrysurus	Carangidae	16241	4.62
Parapenaeopsis atlanticus	Penaeidae	3303	0.94
Penaeus notialis	,,	2247	0.64

The results showed that *Ethmalosa fimbriata, Ilisha aficana, Sardinella* spp*, Pentanemus quinquarius* and *Chloroscombrus chrysurus* were the most abundant of finfish, contributing 86.6% of the total fish catch. Among these, Clupeids (*Ethmalosa fimbriata, Ilisha africana* and *Sardinella* spp*)* contributed 73.2% of the total catch. The fish species richness varied from one sampled location to another, with the mangrove forest ecosystem contributing the largest (Odulate, 2004).

Discussion

Mangrove forests provide a number of ecological services, including habitat and nursery ground for a productive range of fish, crustaceans, and mollusk species that are harvested locally and in off-shore fisheries. Local residents also use mangrove trees for firewood and for dying of fishing nets. The coastal area is heavily populated, with about 20 percent of Nigeria's residents living in one of the nine coastal states. The mangroves found here are the largest remaining tract of these ecosystems in Africa and the third largest in the world — covering an area of about 9,723 km2. The mangrove forest ecosystem provides a nursery and breeding ground for many of the commercial fishery species caught in the Gulf of Guinea. Nigeria's coast is estimated to have about 199 species of finfish and shellfish, a number of which are used commercially. In general, artisanal fisher folk harvest a large variety of fish, crustaceans, and molluscs from the estuaries and channels and utilize mangrove and swamp forest products for a variety of domestic uses. It is evident that most of the coastal areas in Nigeria depend on the mangroves for survival, sustenance and income, in one way or the other. However many marine resources are today harvested unsustainably, both on a commercial scale and by local fisher folks with virtually no controls.

Conclusion

The major problem facing the management of mangrove forests in Nigeria is the lack of baseline data and information for the development of a comprehensive management plan and limited community participation in mangrove management. Unlike the terrestrial forestry little attention has been given to mangrove forestry. As human populations in the coastal zones of Africa continue to grow, and pressures on the environment from land-based and marine human activities increase, coastal and marine resources and their habitats will continue to be dissipated, lost or damaged. This will result to loss in biodiversity and decreasing livelihood opportunities and will further aggravate poverty in these regions. Arresting further losses of coastal and marine resources, and building on opportunities to manage the resources that remain in a sustainable way, are urgent objectives. There is limited monitoring of harvesting system used by mangrove cutters in the entire stretch of the mangrove coastline. Therefore, there is a need to step up sustainable management of this vital coastal ecosystem. This could be achieved by participatory management approach where all stakeholders, especially the local communities, are involved. Studies suggest that the Niger Delta provides an excellent case study in the effects of pollution; there are all conceivable types of pollution in the Niger Delta. There are hundreds of gas flares throughout the Niger Delta. These adversely affect plant life, pollute the air and the surface water; and as they burn they change to other gases which are harmful to the people in the environment. They also cause acid rain. Many fisheries-dependent communities already live a precarious and vulnerable existence because of poverty, lack of social services and lack of essential infrastructure. The fragility of these communities is further undermined by overexploited fishery resources and degraded ecosystems.

Recommendations

There is need to embark on major ways to stem mangrove destruction not only in Nigeria but in the entire sub-Saharan Africa. Some of the recommendations include: (a) Conduct local workshops particularly with involved NGOs, other stakeholders and government agencies to adopt and adapt various management strategies as well as make further adjustments to its context; (b) Collaborate with international NGOs, national, and multilateral organizations to gain endorsement or adoption of the Principles of adopted strategies and management options; (c) Sustained monitoring of the conversion of mangroves to other forms of land use, including agriculture, oil and gas production and mining, most of which cause significant localized damage to mangrove ecosystems; (d) Acquisition of skills, information and opportunities which are available worldwide through collaboration with international players such as FAO, UNESCO etc for more effective mangrove management and (e) Capacity development for mangrove ecosystem management, and awareness raising about mangroves in general are needed at all levels from decision makers in government, to district and municipal officials, community leaders and educational institutions (teachers, students and school children).

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