Mangroves of the Niger Delta: Their Importance, Threats, and Possible Restoration

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INTRODUCTION

Mangroves are among the most important ecosystems in the world. Mangroves has social, economic and ecological functions, hence are true agents of sustainable development. Mangroves are made up a unique group of trees and shrubs that grow in the intertidal zones of tropical and subtropical estuaries, creeks and sheltered bay across the world (Osborne and Berjak 1997; Ukpong 2000). Mangroves ecosystems are found approximately between 30°N and 30°S (Gilbert and Janssen 1998). They are variously described as coastal woodland, tidal forest and are still regarded as wastelands in some uninformed communities. Mangrove trees can grow up to 40 meters high or as shrubs below the high-water level of spring tides (Corcoran et al. 2007). Blasco et al. (1996) refers to mangrove as ecological term referring to the taxonomically diverse assemblages of trees and shrubs that form the dominant plant communities in tidal, saline wetlands along sheltered tropical and subtropical coasts. Tomlinson (1986) include the taxonomically diverse group of species that are restricted to and do play a major role in the intertidal environment as 'true' mangroves. Mangrove species exhibit a range of adaptations for coping with flooding, anaerobic conditions and high salinities, which fluctuates daily and seasonally depending on tidal movement. The term mangrove has been used in a broad sense to include species that are restricted to and those that occur in, but not necessarily restricted to the intertidal environment. Due to the dynamic nature of the swamp landscape, several physiographic habitats have evolved within mangrove ecosystems. Habitat differences relate to several factors including swamp gradient, hydrology and topography, salinity, substrate texture and carbonate content of the soil (Ukpong 1997). Mangrove is an ecosystem complex consisting not just mangrove vegetation, but also mangrove soils, brackish water, fisheries, wildlife and even microbes. Human populations live in and around mangrove ecosystems forming part of the complex because of their activities such as resources extraction that affect the survival of mangroves, both existing stands and newly revegetated mangroves (Walter 1997). Anthropogenic activities in the current century are fast impacting on mangrove ecosystems globally.

Despite the importance of mangroves, the ecosystem is under threat due to human exploitation. The unsustainable exploitation of mangrove trees for fuel wood has led to the destruction of mangrove ecosystems globally. Mangroves are also destroyed by expanding coastal cities with mangrove ecosystems filled with sand for construction purposes. Sewage, solid wastes and other kinds of wastes including non-biodegradable plastics are freely dumped into mangrove forests. The exploitation of petroleum resources located in mangrove ecosystems has impacted the ecosystems. Oil exploration activities that impact on mangroves include dredging, seismic exploration, pipeline construction, and well drilling. In addition, oil spills arising from oil production and transportation have detrimental effects on mangroves. Due to the activities of illegal bunkering, oil spills are becoming a regular occurrence in the Niger Delta. The impacts on mangrove from multiple sources are now overwhelming the ecosystem and starting to threaten the ecological functions and integrity of the wetlands. For instance, the role of mangroves in the control of coastal erosion, which is now more relevant owing to the observed climate change, is threatened. Hence, the aim of this paper is therefore to present the importance of mangroves, threats facing mangroves and possibility of mangrove restoration.

MANGROVE ECOSYSTEM OF NIGERIA

The size of mangrove ecosystem in the World was estimated as 150,000 – 182, 000 km^2 (Spalding et al. 1997; Lewis 2001; Blasco et al. 1996; Dodd et al. 1998). Nigeria has the largest mangrove stand in Africa and the third largest in the world after India and Indonesia (Corcoran et al. 2007). The authors estimated the current size of Nigerian mangrove to be 7,386km^2 having lost 26% since 1980. While many authors estimated the size of mangrove ecosystem in Nigeria as 10,000 km^2 (Jackson and Lewis 2000; Lewis and Jackson 2000), but Spalding et al. (1997) in the Mangrove Atlas of the World estimated 11,134 km^2 of mangrove in Nigeria. Estimates by Wilkie and Fortuna (2003) also show

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that Nigeria has over 10,000 km^2 of mangrove ecosystem. Nigeria mangroves occupy the area from Calabar estuary in the east to Badagery in the West. Mangroves are present in the entire Nigeria coastline, with the largest width of 30-40 km in the Niger Delta and 7-9 km in the other coastlines. Hence, the majority of Nigerian mangrove is located in the Niger Delta region. Moffat and Linden (1995) and World Bank (1995) estimated the size of mangroves found in the Niger Delta to be 6000 km^2.

The development and composition of mangrove communities depend largely on temperature, soil type, salinity, duration and frequency of inundation, accretion of silt, tidal and wave energy (Hutchings and Saeger 1987; Blasco et al. 1996; Ukpong 1997). Plants of the mangrove community belong to many different genera and families, most of which are not closely related phylogenetically. What they do have in common is a variety of morphological, physiological and reproductive adaptations that enable them to grow in a particular kind of rather unstable, harsh and salty environment (Saeger 1982; Tomilinson 1986; Blasco et al. 1996). Mangrove vegetation is typically classified as true mangroves and mangrove associ-

FIGURE 1. Healthy *Concocarpus erectus* with *Rhizophora racemosa* mangrove (in the background, with prop roots evident) in the Niger Delta

TABLE 1. Mangroves of Nigeria. (Modified from Ukpong 1997; Lewis and Jackson 2000)

	Scientific name	Common name in Nigeria	Remarks
True mangrove	*Rhizophora racemosa*	Tall red mangrove	Occurs on mostly recently deposited inceptisols
	Rhizophora mangle	Short (dwarf) red mangrove	Often located behind the tall red mangroves
	Rhizophora harrisonii	Short (dwarf) red mangrove	Regarded as a putative hybrid of *R. Racemosa and R. mngle*
	Avicennia germinans (A. africana)	White mangrove	Regarded as blank mangrove in the USA
	Laguncularia racemosa	Black mangrove	Regarded as white mangrove in the USA
	*Conocarpus erectus**	Buttonwood tree	Localized near Kidney Island , Rivers State
Mangrove associates	*Acrostichum aureum*	Leather fern (mangrove fern)	
	Hibiscus tiliaceus	Hibiscus	
	Thespesia populnea	-	
	Drepanocarpus lanatus	-	
	Chrsobalanus spp.	-	
	Pandanus candelabum	Screw pine	Occurs at transition zones between freshwater and mangrove ecosystems
	Nypa fruticans	Nipa palm (mangrove palm)	Was imported into Nigeria in 1901 and is fast replacing true mangroves in the country and along the Atlantic coast of West Africa

* C*onocarpus erectus* is referred to as true mangrove in some literature and as mangrove associate in others.

ates (Tomlinson 1985; Dodd et al. 1998; Lewis and Jackson 2000). There are approximately 80 species of mangrove plants (with about 60 in the Indo-Pacific region and 20 in the Western Hemisphere) belonging to about 30 genera in 20 families (Blasco et al. 1996), of which 17 species exist in 26 countries of Sub-Saharan Africa. African mangroves are widespread along the west coast from Senegal to the Congo, and occur locally in East Africa, interlinked with highly productive coastal lagoons, tidal estuaries and deltas (Corcoran et al. 2007). Of the 17 mangrove species in Africa, only 6 species of true mangroves and about 7 species of mangrove associates are found in Nigeria (Ukpong 1997; Lewis and Jackson 2000) listed in Table 1. *Rhizophora harrisonii* is often referred to as a putative hybrid of *R. racemosa* (Figure 1) and *R. mangle* (Dodd et al. 1998; Sanger and Bellan 1995).

IMPORTANCE OF MANGROVE ECOSYSTEMS

Mangroves are true agents of sustainable development because they posses environmental, social and economic relevance. There are over 70 documented uses of mangrove ecosystem (IUCN 1993). Generally, wetlands provide human with a wide range of goods and services including staple food plants, fertile grazing land, support for coastal and inland fisheries, flood control, breeding and foraging grounds for birds and source of fuel wood (Tri et al. 1998). Food items include finfish (many species), crustaceans (prawns, shrimps, and crabs) and mollusks (oysters, mussels, and cockles). Honey bees reside and produce honey in the mangrove ecosystem. However, in Nigeria and many other African countries, wild animals including various mammals, birds and reptiles are unsustainably hunted in the mangroves for food, skin and traditional practices. Forestry products particularly wood are obtained from mangrove ecosystems. Mangrove woods are used for civil construction activities (boat construction, buildings and bridges) and due to their high energy content are also used as fuel woods. The organic matter and nutrient flow from the mangrove ecosystem to a great extent support the benthic population of the sea (Das et al. 1997). Sylla et al. (1995) reported the use of mangrove ecosystems for rice farming in West Africa. Apart from the disused rice farm in Diebu Creek (Peremabiri, Bayelsa State), mangrove rice farming is not a common practice in Nigeria. However, mangrove ecosystems are commonly used for fish farming in the Niger Delta (Dublin- Green 1987; Dublin-Green et al. 2003). Bandaranayake (1998) reviewed the various traditional and medicinal uses of Nigeria's mangrove species (Table 2). The environmental/ecological use of mangroves includes hydrological cycle, carbon fixation, sediment control, and buffering of storms (Gilbert and Janssen 1998). One of the notable functions of mangroves is the treatment of wastewater containing heavy metals. Mangrove soil has the capacity to retain heavy metals in non-available forms (Tam and Wong 1996). Blasco et al. (1996) reported the economic values of mangroves to include

TABLE 2. Medicinal uses of mangrove plants. (Sources: Gordon 2005; Bandaranayake 1998.)

Botanical name	Mangrove type	Uses (tissues)
Acrostichum aureum	Mangrove associate	Boils and wounds, (rhizome), rheumatism (L)
Avicennia germinans	True Mangrove	Incontinence, rheumatism, (B). throat pains, ulcers of the mouth, (L, B); ashes used as salt substitutes (L); powdered bark mixed with palm oil for treatment of lice, ring worm and mangles (B); germinating seeds used as a poison (S). Cure of thrush, cancer, gangrenous wounds, skin parasites, tumors (B), and ulcers (B).
Concocarpus erectus	True Mangrove	Catarrh (R), febrifuge (L), gonorrhoea, malaria, and stops bleeding (B).
Hibiscus tiliaceus	Mangroves associate	Ear infections (flowers)
Nypa fruiticans	Mangroves associate	Asthma, diabetes, leprosy, rheumatism, and snake bite (L, F).
Rhizophora mangle	True Mangrove	Angia, boils and fungal infections (B), antiseptic, diarrhoea, dysentery, elephantiasis, fever, malaria, leprosy (B, L), minor bruises (B), plaster for fractured bones (B), and tuberculosis (B, L).
Rhizophora racemosa	True Mangrove	Stops bleeding (L); used with palm oil as an ointment for boil (R); extract used for fungal infections of the skin (B); treatment of diarrhoea and dysentery in children (B), leprosy (B), Sore throat (B).

(B-bark; L-leaves; F-fruits; R-roots, S-seed) source of timber, poles, tanning material, food, and medicine. Readers are directed to IUCN (1993) report for a detailed review on the uses of mangroves.

THREATS TO MANGROVES

Table 3 presents legal framework pertaining to mangrove and wetlands conservation in Nigeria. Some of the regulations are international and regional to which Nigeria is a signatory, while the rest are national. The policies though many are inadequate to effectively prevent mangrove destruction. For instance, there is no no-net-loss of wetland policy in Nigeria. Therefore, wetland best management practices like wetland banking are not practiced in Nigeria. Moreover, due to institutional weakness, policy enforcement in the country is generally poor. Hence, mangroves continue to decline in Nigeria and globally due to anthropogenic impacts. In many countries, including Nigeria, many people still regard wetlands as wastelands, hence they are freely destroyed (Figure 2) or converted to other uses (Adekola et al. 2012). In most cases, losses of mangrove are due to over-exploitation, clearing and pollution (Saenger et al. 1983), whereas in other areas losses are due to natural causes such as coastal erosion, permanent inundation and increased salinization, all linked to sea-level rise (Saenger et al. 1983; Blasco et al. 1996). In Senegal, the change in hydrological regime causing rainfall deficit, triggered ecological processes resulting in increased evaporation, low humidity, higher frequency of dry winds, increased salinity and acidification; all cause a decline in mangroves (Diop et al. 1997). Reports from other countries also indicate that mangrove ecosystems are fast disappearing. For instance, the size of the mangrove ecosystem in Puerto Rico has declined from 24,310 ha to 6,410 ha. Similar losses have been reported in other countries such as Philippines (60%), Thailand (55%), Vietnam (37%) and Malaysia (12%) (Lewis 2001). In Nigeria, mangroves loss of 26% has been reported (Corcoran et al. 2007).

FIGURE 2. Impacted *Rhizophora racemosa* mangrove forest in the Niger Delta

The causes of mangrove decline in Nigeria are many but could be classified broadly into two namely anthropogenic and natural. The anthropogenic factors include increasing population pressure, rapid urbanization, mining oil, industrial waste pollution, uncontrolled tilling for crop production, overgrazing, logging, land reclamation, road and dam construction, and other infrastructural developments (Uluocha and Okeke 2004). Increases in waterfront residences together with an increasing population and land shortages has induced unprecedented wetland reclamation projects in the southern areas of Lagos and the Niger Delta (Adekola et al. 2012). Other anthropogenic impacts on mangrove are waste disposal, reclamation and sand filling. Ecological factors (which could also be induced by human activities) include climate change, marine and coastal erosion, subsidence, ocean water intrusion, invasion by non-native biota, desertification, and droughts.

Oil and gas exploration activities affecting mangrove ecosystems include seismic operations, drilling, pipeline installation, dredging, and oil spills. Seismic operations cause one of the most devastating impacts on mangrove. Seismic lines criss-cross the entire Niger Delta (Figure 3); seismic lines cut in the mangrove ecosystem over five decades ago are still quite visible. Crude oil is toxic in nature and when plant and animals are covered by these products results to suffocation, starvation and other inference with physiological functions (Hoff 2002). Studies have shown that mangroves are affected by lethal and sub-lethal effects associated with oil spills. During oil spills, oil soaks into sediment and coat exposed trunks, prop roots and pneumatophore causing high mortality of mangroves and fauna. Long-term

TABLE 3. Legal framework pertaining to mangrove management in Nigeria.

Legislation	Coverage/ spread	Implications
The Ramsar Convention, 1971	International	Provides a framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.
Convention on Biological Diversity (CBD), 1992	International	The three main goals of CBD are the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from utilization of genetic resources.
International Union for Conservation of Nature and Natural Resources (IUCN) Guidelines	International	Guidelines for oil and gas exploration and production in mangrove areas, conservation of mangroves and enhancing the protection of marine ecosystems.
The Convention on International Trade In Endangered Species Of Wild Flora and Fauna, 1975 (CITES)	International	CITES represents a cooperative effort between countries to prevent loss of species resulting from international wildlife trade.
Convention on the conservation of Migratory Species of wildlife animals, 1979 (Bonn Convention)	International	Aims to "conserve terrestrial, marine and avian migratory species throughout their range."
Convention for cooperation in the protection and Development of the Marine and Coastal Environment of the West and Central African Region, 1981	Regional	The convention provides an important framework through which national policy-makers and resource managers implement national control measures in the protection and development of the marine and coastal environment of the Region.
Nigerian Legislation Guiding Biodiversity Protection National Environmental (Wetlands, River Banks and Lake Shores Protection) Regulations, 2009 (S. 1. 26 of 2009)	National	Contained regulations pertaining to the protection of Wetlands, River Banks and Lake Shores
National Environmental (Control of Bush/Forest Fire and Open Burning) Regulations, 2011 (S.I. No 15)	National	Regulation for the control of forest fire
National Environmental (Protection of Endangered Species in International Trade) Regulations, 2011 (S. I. No 16)	National	Protection of Endangered Species in International Trade
The Natural Resources Conservation Act 1989	National	The Act establishes the Natural Resources Conservation Council, which is empowered to address soil, water, forestry, fisheries and wildlife conservation by formulating and implementing policies, programmes and projects on conservation of the country's natural resources
Federal Environmental Protection Agency Act (Chapter 131, Laws of the Federation, 1990)	National	The Federal Environmental Protection Act was promulgated to protect the country's environment from degradation. The functions of FEPA have been subsumed by the Federal Ministry of Environment
Environmental Impact Assessment Act (No 86 of 1992)	National	This Act requires that environmental impact assessment must first be carried out before any project likely to impact the natural environment could be undertaken.
National Parks Decree (Decree No 36 of 1991)/ National Parks Act of 1999	National	The Act was promulgated to provide a protective sanctuary for wildlife species as well as to promote and preserve the beauty and conservation of the country's natural vegetation.

TABLE 3, Continued.

Legislation	Coverage/ spread	Implications
Forestry Law CAP 52, 1994	National	The law prohibits any act that may lead to the destruction of or cause injuries to any forest produce, forest growth or forest property.
The Navigable Waterways Declaration Act, 1985	National	This act prohibits the taking of such natural resources as sand, gravel or stone from rivers, creeks, lakes, lagoons and intra-coastal water ways. It also bans the erection of permanent structures within the right of way or the diversion of water from wetlands.
River Basin Development Authority, 1986	National	Established River Basin Authorities which will ensure that surface and underground water resources are used for agriculture, irrigation, forestry and fisheries with utmost environmental care.
Niger Delta Development Commission Act, 2000	National	This established the NDDC with the aim, amongst other things, of tackling ecological and environmental problems that arise from the exploration of oil mineral in the Niger Delta region.
National Environmental Standard and Regulation Enforcement Agency Act, 2004	National	Established NESREA to regulate and enforce environmental standards through protecting and developing strategies for quality environment, biodiversity conservation and sustainable development of Nigeria's natural resources.
National Oil Spill Detection and Response Agency Act, 2006	National	Established NOSDRA which is expected to restore and preserve Nigeria's environment by ensuring the best oil field, storage and transmission practices in exploration, production and use of oil in the quest to achieve sustainable development in Nigeria.

chronic oiling or oil spills that produce elevated concentrations of polynuclear aromatic hydrocarbons in the sediment are capable of producing chlorophyll-deficient mutations in *Rhizophora mangle* (Proffitt et al. 1995). When spills occur, oil gets washed into the mangrove back swamp at high tide and gets stranded there when the water retreats at low tide, where the spilled oil becomes persistent due to the anaerobic nature of mangrove sediments. However, mangroves have physiological mechanisms that enable them to adapt and survive in a low-oxygen (compounded by oil spill) and high salinity habitat. For instance pneumatophores with their hypertrophied lenticels aid gaseous exchange (Boer 1993), while the leaves and submerged roots help in the excretion of salts. Studies have shown that 96% of *Avicennia marina* that are exposed to an oil spill usually die-off (Grant et al. 1993). During oil spill, symptoms like leaf staining, chlorosis, leaf death, defoliation and tree death occurs (Duke et al. 2000). Study of an oil spill in Panama in 1986 suggests that after clean-up, the remaining oil in the mangrove sediments continues to affect root survival, canopy conditions and growth rate of mangrove seedlings as 6 years later, the surviving forests fringing deforested areas continued to deteriorate (Burn et al. 1993). Wardrop et al. (1996) showed that the 1992 Era spills in Australia failed to recover even 4 years after the spill.

According to the official estimates of the Nigerian National Petroleum Corporation, a total of approximately 2300m^3 of oil was spilled in 300 separate incidences annually. Since the oil companies frequently underestimate the quantity of oil spilt and a large number of other spills go unreported, the total volume of oil spilt may be 10 times higher than the official figure (http://www.stakeholderdemocracy.org/massive-nigerian-oil-spill-goes-unreported/, https://therawreport.org/2012/10/25/the-oil-spills-that-went-largely-unreported/). Nigerian oil is a very light crude oil which might indicate an evaporation loss close to 50% within 48 hours (Moffat and Linden 1995).

Other activities of the oil industry that kill mangrove are dredging, spoil disposal, and sand filling (Fagbami et al. 1988; Ohimain, 2004; Ohimain et al. 2004). Since the mangrove ecosystem, because of its several shallow and meandering creeks, is largely inaccessible for most oil and gas related activities (IUCN 1993), dredging is performed to provide access to drilling sites, pipeline installation, production facilities, and logistic base (camp) accommodation (Ohimain 2008a, 2008b). Dredging could involve the following activities including clearing of mangrove vegetation, straightening, widening and deepening of existing creeks, and creating new canals. In the process of dredging, the dredged spoils (soil, sediment and vegetation) are typically discharged at creek banks and abandoned (Ohimain 2002, 2003a, 2003b, 2003c). Besides the mangroves killed via direct removal (dredging) and smothering (spoil disposal), changes in the topography, hydrology and salinity result in mangrove mortality beyond the immediate impact area (Ohimain 2004, 2008a, 2004b; Ohimain et al. 2004, 2010). Both permanent flooding and lack of tidal inundation kill mangroves on a large scale (Ohimain 2003a), whereas the abandoned dredged spoil soon becomes acidic and drains into the mangrove back swamps killing more mangroves (Ohimain et al. 2004; Ohimain 2001, 2004). The environmental impacts of acidification can be overwhelming, affecting virtually all components of the ecosystem including phytoplankton (Ohimain and Imoobe 2003), zooplankton (Ohimain et al. 2002), benthic invertebrates (Ohimain et al. 2005), and vertebrates especially fishes (Fagbami et al. 1998; Ohimain 2003a). Dredging and spoil abandonment has also been implicated in widespread hydrological changes (Ohimain 2003a), topography changes (Ohimain et al. 2010), water quality changes (Ohimain et al. 2008b), heavy metal pollution (Ohimain et al. 2008a, 2008c), shift in vegetation types (Ohimain, 2005; Ohimain et al. 2004, 2005), increased erosion and siltation (Ohimain et al. 2004), excessive flooding of the back swamp (Ohimain et al. 2004) and coastal retreat (Eedy et al. 1994).

Nipa palm, which is often referred to as mangrove palm is of immense benefit in Southern East Africa, and was introduced to Nigeria in 1901. It is now replacing mangroves in the Niger Delta (Bioresources Development and Conservation Programme 2010; Moffat and Linden 1995) and poses a serious threat to the entire mangrove ecosystem of the Niger Delta. The government of Nigeria is at a loss on how to control nipa palm that is rapidly expanding along the entire West African coastline at the expense of indigenous mangroves.

MANGROVE RESTORATION

There have been various attempts at mangrove restoration in Nigeria (Figures 4 and 5) and all over the tropical world. The success of most of these efforts especially in Nigeria is not verifiable. Many of the failures are often unreported. Possible causes of mangrove restoration failures are presented in Table 4. In most of the reported successes, it is uncertain if they became fully established because of the short time of post re-vegetation monitoring, which is less than one year in most cases. Mangrove can present

FIGURE 3. Seismic lines across mangrove swamp in the Niger Delta. (Note freshwater swamps beside the mangrove swamp)

FIGURE 4. Re-established mangroves in the Niger Delta

FIGURE 5. Restored site with *Rhizophora* (with *Avicennia* in the background)

TABLE 4. Reasons for failures of mangrove restoration projects in Nigeria

Causes of failures	Explanation	References
Community disturbance	Due to limited farming lands in the mangrove swamp, indigenous people use abandoned spoils for farming. Hence, they resist mangrove restoration on abandoned spoils.	Ohimain et al. 2004; Ohimain 2004
Acidification	Acidification typically results following the exposure of mangrove spoils containing pyrites	Ohimain 2003a, 2003b, 2004, 2008a, 2008b
Physicochemical changes and heavy metal pollution	Physicochemical changes follows dredging and exposure of pyritic dredged materials resulting in physicochemical changes such as extreme acidity and heavy metal pollution	Ohimain et al. 2003a, 2008a, b, c
Maintenance dredging	Maintenance dredging result in the deposition of dredged spoils upon fringing mangroves, thus killing them	Ohimain 2002, 2004
Topographic and hydrological deficiencies	Changes in topography often results in altered hydrology, which do not favour mangrove recruitment, establishment and growth	Ohimain et al. 2010
Competition by alien species	Due to altered hydrology, abandoned spoils are becoming less saline after years of weathering, which favours invasive species over mangroves	Ohimain et al. 2010
Gardening effect	Plant of mangroves without due regards to hydrology, resulting in mangrove failures	Lewis 2001; Lewis and Streever 2000
Poor site preparation	Planting mangrove without effective site preparation or poorly designed site preparation often results in failures	Lewis 1999; Lewis 2001
Oil spills	Oil spills upon new recruits is devastating and often results in failures	Hoff 2002
Stressor unaddressed	Mangrove restoration in areas where the original cause of mangrove death have not been effectively addressed such as oil spill, alteration in salinity, topography and hydrological changes	Lewis 2001; Lewis and Streever 2000; Hoff 2002; Ohimain et al. 2010, 2014

initial success and later die due to unfavorable conditions that even existing at the time of planting. Mangroves are not known to be good competitors except under special hydrological conditions, which prevent other competitors from establishing. The four major aims for rehabilitating mangroves are for conservation, landscaping, sustainable production and coastal protection (Field 1999).

SITES SELECTION AND PREPARATION

Elster (2000) reported that mangrove success depends largely on site selection and preparation. Particular attention must be paid to topography, hydrology (flooding regimes and fresh water runoff), water chemistry, tidal and wave energy, natural propagule availability and regeneration, re-vegetation techniques (natural, transplanting, and nursery stock), adequate monitoring and maintenance (spacing, thinning and weeding), and budget. Planting without due consideration to these factors could lead to failures. Unfortunately, most of the mangrove re-vegetation projects reported in Nigeria fall short of most of these considerations. Some were even planted on dredged spoils without due consideration to the topography and hydrology. This poor practice is often regarded as the gardening effect (Lewis 2001; Lewis and Streever 2000). Many mangrove-restoration projects move immediately into planting of mangroves without determining why natural recovery has not occurred. Identification of the underlining causes of mangrove death is very important to their restoration. Sanyal (1998) reported that between 1989 and 1995 about 9,050 ha of mangroves were planted in West Bengal, India with only a 1.52% success rate. A study in Philippines attempted to restore 22,723 ha of mangrove primarily by direct planting on mudflats but recorded 0 to 66% success with average of 17% (Lewis 1999, 2001). Site preparation is critical to the success of any mangrove restoration project.

TABLE 5. Mangrove propagation methods.

Macro-propagation methods	Micro-propagation method
Direct planting of propagules, seedlings and saplings	Tissue culture
Planting nursery-raised seedlings and saplings	
Enhanced natural restoration	
Air layering techniques	

MANGROVE RESTORATION TECHNIQUES

There are both macro- and micro-propagation (tissue culture) methods for mangroves (Table 5; Saenger 2002). Mangrove can also be propagated through air layering techniques (Kathiresan and Ravikumar 1995; Saenger 2002). This article focuses only on macro-propagation methods because these methods have been successfully demonstrated in many countries including Nigeria. Approaches for macro-propagation of mangrove include direct planting of propagules, seedlings and saplings collected from the wild and planting nursery-raised seedlings and saplings. Another method of mangrove re-vegetation and restoration is enhanced natural restoration. Each of these techniques is further discussed below with application to Nigeria mangroves species.

Enhanced natural restoration. Degraded mangrove forest may self repair within 15-30 years provided there exist adequate seeds/seedlings under normal wetland hydrology (Lewis 2000, 2001; Lewis and Streever 2000). Enhanced natural restoration involves removal of the underlining causes of mangrove death by, for example, oil spill clean-up and restoring topography and normal hydrology, which could promote natural recruitment of volunteer propagules and their establishment at the site. This method is relatively cheap and applicable for mass propagation of all the three genera of Nigerian mangroves (*Rhizophora, Avicennia* and *Laguncularia*). Of the three genera *Rhizophora* is the slowest to recover naturally within 10-110 years (Jackson and Lewis 2000), yet this time could be shortened if the correct site topography and hydrology is restored. Hydrologic restoration is also critical because, without it other restoration measures could fail.

Direct planting of propagules, seedlings and saplings. Collecting and planting of propagules from local mangrove swamps is the next restoration method to consider if natural recruitment is shown to be inadequate. In

FIGURE 6. Mangrove seedling established in the intertidal zone in the Niger Delta

this method, planting materials such as propagules (fruits/seeds), seedlings (young plants 30-60 cm tall) and saplings (shrubs 1-2 m tall) are collected from the wild and planted in a site. For most mangrove species, matured propagules are only available 2-4 months of the year, so direct planting of propagules needs to be scheduled accordingly (Saenger 2002). Propagules, generally from *Rhizophora,* are young plants with no roots or open leaves that develop while still attached to the parent tree. When mature, the propagules drop from the parent plant and becomes establish in the mud. Propagules can be harvested directly from the tree when mature, or collected from litter under the tree if they have not already rooted into the ground. Direct planting of propagules is recommended for *Rhizophora*. *Avicennia*, and *Laguncularia* seeds can be collected from the wild and broadcasted to restore mangroves, but their survival rate and establishment are typically less than 30% (Jackson and Lewis 2000).

Nursery techniques. In nursery techniques, mangrove propagules and seedlings are obtained from the wild and raised in nurseries before transplanting to the site of interest. Propagules are typically collected during the fruiting season, raised in nurseries and grown to 0.50-1 m before transplanting. Mangrove nurseries are typically established in intertidal areas (Figure 6). Establishing mangrove plants in a nursery can be practical as plants are ready for restoration planting when needed, but it can be costly (Jackson and Lewis 2000). Notwithstanding, nursery-grown plants can demonstrate high-survival rates. Seedlings can be transplanted within 6-12 months of growth in the nursery. *Rhizophora*, *Avicennia* and *Laguncularia* trees 0.5 to 1.5 tall have been successfully used as transplant stock (Jackson and Lewis 2000).

CONCLUSION

In recent years, mangrove restoration and conservation practices have increased all over the world with support from several international organizations. Mangrove restoration techniques that have been demonstrated in Nigeria include enhanced natural restoration, transplanting of propagules/seeds/saplings obtained from the wild or raised in nurseries. In spite of the increased attention to the mangrove ecosystem, various anthropogenic activities such as logging, dredging and dredged spoil disposal, oil and gas activities, and rising population along the coastal communities, failures in public policy have hampered efforts to both conserve and restore mangrove ecosystems. Despite the array of legislations and policies, wetlands continue to be overexploited due to the preference for short-term economic gain rather than long-term sustainable use of the ecosystem (Saenger et al. 1983). An integrated approach to coastal area management through coherent policy development, enforcement of environmental policies, and concerted action through restoration and environmental education is increasingly being regarded as the best way to achieve conservation and sustainable use of mangrove and other coastal resources (Chua and Scura 1992). ■

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Women's Role in Managing International Wetlands

Mariam Kenza Ali and Ania Grobicki have written an article about the role that women play in conserving wetlands around the globe. Using examples from Burkina Faso, Greece, and Iraq the authors demonstrate how women serve as guardians of wetland and water resources, while recognizing that the nature of women's role is heavily dependent on local culture and environmental conditions. Consequently, what works to empower women in one country will not necessarily work in other countries. The article proposes five principles for enhancing women's participation in wetland and water management:

1. Recognize women's central role in providing, managing, and safeguarding wetland and water resources;
2. Actively support women's full participation in the governance of these resources at all levels;
3. Mainstream gender issues across wetland, water, and cross-sectoral policies and plans;
4. Value the economic, cultural, and social benefits of women's wetland-based livelihoods; and,
5. Ensure that solutions to enhance gender equality are adapted to local cultural contexts."

For more information on the three case studies, read the online article at https://www.thesolutionsjournal.com/article/womens-roles-managing-wetlands/. ■