



Governing the Environmental Impact of Dredging: Consequences for Marine Biodiversity in the Niger Delta Region of Nigeria



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Abstract

The attention of most scholars and stakeholders is far drawn from the devastation of the environmental consequences caused by dredging related activities, which has necessitated sand filling and pilling including skewed national government policies, which has resulted to fundamental concern to halt species extinction, a situation which ecologist are not at ease with. Emphasis has been focused on alterations in the chemistry of the environment. They are worried with the numerous vanished creatures and saddened, often angered by their extinction. Man has directly or indirectly been the cause of the extinction, including the issues of depletion and degradation impact on the environment, thereby, leading to restrictions in the size, density, and distribution of organisms that threaten the biodiversity, resilience, or provision of ecosystem services. As soon as the functionally significant components of an ecosystem are missing, it is extremely challenging to identify and understand ecological thresholds. The extent and intensity of human disturbance to oceanic ecosystems is a significant threat to both structural and functional biodiversity and in many cases this has virtually eliminated natural systems that might serve as baselines to appraise these impacts. It is therefore recommended that effective management of dredging problems in the Niger delta will require enforcement of relevant environmental laws, environmental monitoring, as it help limits the huge expenses on habitat clean-up exercises and restoration programs and critical habitats should be banned or carried out in such a manner as to protect the area or limit dredging to the lowest ecological damage. This should be pressure on all oil companies and relevant stakeholders to discontinue with dredging related activities. Petrochemical such as oils and other hydrocarbon should not be present in the aquatic environment in concentration that can cause tainting of edible aquatic organism, form visible deposits on shoreline and bottom sediment or be detected as a visible film/sheen or discoloration.

Keywords: Dredging; Environmental impact; Ecological damage; Critical habitats; Bio-complexity; Bioturbation; Niger Delta

Introduction

The Niger Delta is the life wire of the Nigerian economy, an important region that has been very seriously affected by oil exploration and production. Large channels have been dredged in many places to float oil rigs and lay pipelines. While the Niger Delta is located in the Gulf of Guinea in the Atlantic Coast of southern Nigeria precisely where River Niger divides into numerous tributaries (Figure 1). Regarded as the second largest delta in the world with a coastline spanning about 450 kilometres terminating at the Imo River entrance, the region span over 20,000 square kilometers and it has been described as the largest wetlands in Africa and among the three largest in the world. About 2,370 square kilometres of the Niger Delta area consist of rivers, creeks and estuaries and while stagnant swamp covers

about 8,600 square kilometers [1-6]. In the last two decades, the Niger Delta has enjoyed rare spotlight in the Nigerian political discourse. The reasons for this are not connected to its being the second largest delta in the world or because it consists of rivers, creeks and stagnant swamp, but because the Niger Delta has been a victim of its resources.

The oil wealth and the politics of its exploration and exploitation, make the Niger Delta a study on paradox. The Niger Deltas resource oil production makes Nigeria the seventh largest producer in the world and the fifth exporter of oil in the United State. However, the region account for nearly 95% of Nigeria's foreign exchange earnings, 40% of gross domestic product (GDP), and 84 percent of government expenditure is undeniably a victim

of “oil resources curse” [7]. It is the most underdeveloped region in Nigeria with widespread and entrenched poverty. The people are not only poor, but their environment has also become the most environmentally assaulted area with major impact as a result of dredging activities. With over 5200 oil wells drilled in the areas, and about 2 million barrels of crude oil per day that passed through about 275 flow station and exported through

ten terminals [1,8-10], the region has been subjected to the most environmental abuse recorded in sub-Saharan Africa. Hence, human activity is having a significant and escalating impact on the global environment, they also reduce the resilience and capacity of ecosystems for delivery of vital ecosystem services, including food and water provision and protection from natural disasters.

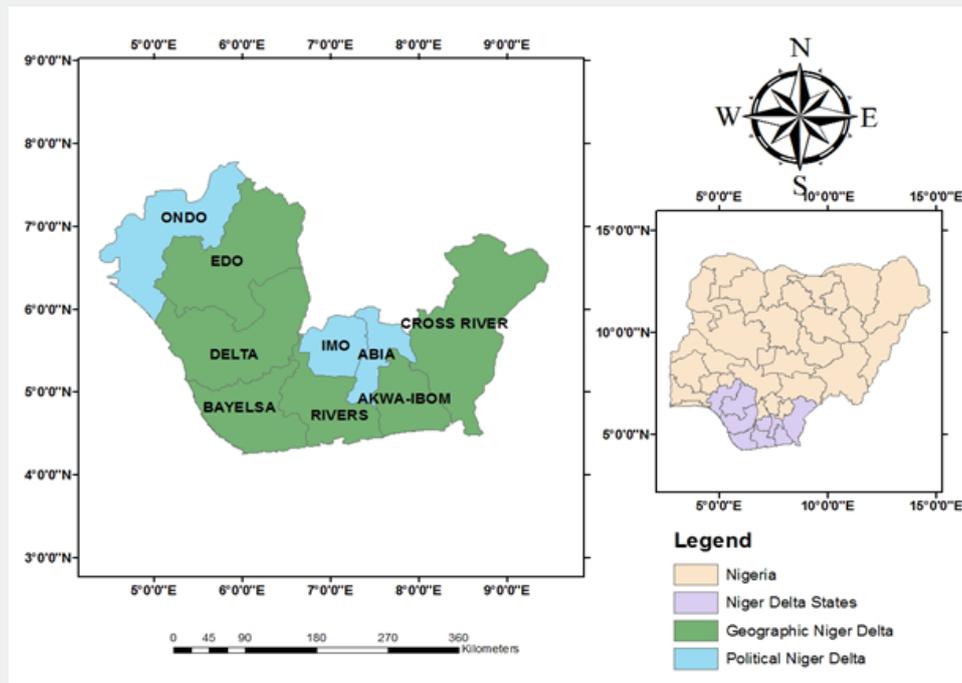


Figure 1: Map of Nigeria numerically showing states typically considered to be part the Niger Delta, including: Abia, Akwa Ibom, Bayelsa, Cross Rivers, Edo, Delta, Imo, Ondo and Rivers.

Often times, environmental degradation is a major cause of productivity losses and poor human health in the Niger Delta, and environmental degradation issues are of topical concern to communities in the area. While, human altered these aquatic systems and ruin the life histories of many species, even those that he finds desirable interest. Because of their partially enclosed nature, estuaries seem especially vulnerable to this anthropogenic perturbation. As many currently experience remarkable rates of qualitative and quantitative degradation, environmental threats and impacts are associated with growing human populations; as population dynamics are key drivers of local and global environmental change. The resulting growing populations leads to increased consumption of land use natural resources, posing additional environmental pressures in terms of uses and misuses of aquatic systems that have caused considerable increase in their degradation (Table 1) [11-14]. Consequently, their importance has continually diminished and there is an overall alteration in ecological integrity. Very often, the duration, magnitude and

extent of undetected anthropogenic perturbations may be so enormous that there is limited opportunity for natural recovery of impacted aquatic systems without serious restoration efforts. Moreover, species and whole communities are being lost in an alarming rate in some cases even before they can be identified and long before they can be studied (Stiassny, 1996). There is thus an obvious need for organized environmental monitoring exercises if aquatic systems and their resources are to be protected from the adverse effects of human-induced perturbations.

The aquatic ecosystem parameters that are commonly affected by anthropogenic perturbations are summarized in Table 2. The integrated impacts of these human mediated factors cause considerable perturbations of a minimum of eight major components of aquatic systems viz: ecohydrological regime, habitat area, habitat quality, water quality, substrate quality, energy source, biotic interactions and resources exploitation. These variables play critical roles in determining the ecological integrity of aquatic systems (Figure 2).



Figure 2: Primary variables that affect the ecological integrity of aquatic systems.

Table 1: Major anthropogenic perturbations of aquatic systems.

Human Factors	Perturbation Processes
Water Utilization	Hydroelectric power generation/reservoir construction
	Water abstraction for agricultural, domestic and industrial purposes
	Extraction of common salt
	Navigation and associated harbor/port activities
	Dredging of navigational routes
	Channelization
	Levee construction
	Subsurface oil pipeline construction
	Constructions of the oil rigs/platforms
	Sundry military operations
	Fisheries: subsistence, artisanal, industrial and recreational fisheries sub-sectors
	Aquaculture: cage/pen culture, rice field culture, mariculture
	Solid waste disposal: municipal/industrial wastes
	Industrial/municipal/domestic effluents inputs
Oil spillage/other liquid contaminants	
Marginal Land	Unintentional introduction of exotic species
	Wildlife hunting
Utilization	Deforestation, resulting from irrational extraction of forest products
	Conversion for crop agriculture
	Conversion for aquaculture ponds
	Pasture land for grazing livestock
	Villagization: creation of village centers
	Urbanization/industrialization
	Infrastructure development
	Canalization
	Substrate extraction –limestone, peat, clay, sand and gravel
	Surface oil pipeline construction
	Construction of oil rigs/platforms
Mineral extraction: petroleum and associated natural gas; gold mining	

Socioeconomic	Demographic changes e.g. increased population
Pressures	Standard of living/sanitation
	Housing conditions/human health
	Demand for food/better living conditions
	Employment
	Outdoor recreation
	Tourism
	Intentional introduction of exotic species

Sources: Adapted from Richard and Goodluck [39].

Table 2: Parameters affected by various anthropogenic perturbations of aquatic systems.

Aquatic Parameters	Anthropogenic Perturbation
Ecohydrological Regime	Impoundments: - hydroelectric power generation
	Irrigation
	Interbasin water transfer
	Surface/ground water abstraction
	Urbanization/villagization: infilling/land reclamation
	Industrialization: Infilling/land reclamation
	Agriculture: Infilling/land degradation
	Dredging of navigational routes
	Channelization: channel straightening, widening and deepening
	Canalization: Land fragmentation; interbasin water transfer
Habitat Area/Habitat	Loss and/or fragmentation of habitat due to:
Destruction	a) Urbanization/villagization: Infilling/reclamation
	b) Industrialization: Infilling/reclamation
	c) Road and rail construction
	d) Oil pipeline construction
	e) Crop agriculture: conversion of wetland into arable land; expansion of cultivated land
	f) Aquaculture: conversion of wetland into fish ponds
Habitat Quality	Channelization: channel straightening, widening and deepening
	Embankments: bank stabilization e.g. levees, dikes, wing dams
Water Quality	Urbanization: input of municipal surface runoff; input of solid wastes; input of microbial pathogens from human sewage
	Industrialization: input of fertilizers and agrochemicals; thermal/cold water; heavy metals
	Aquaculture: input of fertilizers, growth hormones, chemicals and waste water
	Agriculture: input of fertilizers from cultivated lands and animal manure
	Disposal of dredging spoils (sludge)
	Dumping of radio-active wastes
	Oil pollution: petroleum hydrocarbons
Substrate Quality	Dredging: decrease in the stability and diversity of the benthic substrate; sedimentation
	Pollution: accumulation of heavy metals and toxicants
Energy Source	Removal of riparian vegetation results in a decline in allochthonous energy input
	Dredging adversely affects the microbenthic invertebrates
	Anthropogenic eutrophication results in algal blooms
	Pollution: destruction of both primary and secondary food sources

Biotic Interactions	Removal of riparian vegetation, dredging, anthropogenic eutrophication, pollution (see energy source above) and introduction of exotic species
Resources Exploitation	Overexploitation of living resources via finfish fishing, octopus fishing, shellfish collection, sea-cucumber collection, seaweed collection, coral mining, curio collection, hunting, grazing and tourism

Sources: Adapted from Richard and Goodluck [39].

While, changes in wealth and age structure also alter lifestyle, consumption habits and diet, all of which can have environmental consequences [7, 15-18]. The world's population has grown from less than 4 billion in 1970 to 7 billion today. By 2050, the United Nations estimates that the global population will reach almost 9.2 billion people, an additional 2.2 billion people [19]. The world's population is now over seven billion people and is tracking toward nine billion come 2050 [19]. Many environmental problems arise from human-induced habitat modification, resource use, and disposal of waste. Examples comprise air and water pollution, impacts on biodiversity as a result of direct influences (e.g., hunting and fishing) or indirect activities (habitat clearing, pesticide use), and reduction of freshwater flows as a result of diversion (irrigation) or storage (dams) for human use [13,16,20-22].

Although great emphasis has been paid to the decline in species diversity in terrestrial ecosystems, it is apparent that there have also been substantial changes in the diversity of aquatic systems, albeit changes that may not be so readily detected. A common perception of marine seafloor biodiversity reflects a disproportionate interest in hard bottoms such as coral reefs, kelp forests, and the rocky intertidal. This bias is understandable because these hard-bottom communities lend themselves to terrestrial comparisons and ecological studies. However, nearly 70% of the earth's seafloor is composed of marine soft sediments [23,24]. These soft-sediment habitats can be highly heterogeneous due to the interactions between broad-scale factors (e.g., hydrodynamic and nutrient regimes) and smaller-scale physical and biological features; nonetheless, the apparent three-dimensional habitat structure imposed by this heterogeneity may not be as obvious as that observed on hard-bottom habitats. Although these habitats are not always appearing as highly structured as some terrestrial or marine reef habitats, they support an extremely high species diversity [24-26]. Additionally, organisms that inhabit the sediments create much of the structure in soft-sediment habitats, ranging from the micro-scale changes around individual animal burrows to the formation of extensive biogenic reefs. As well as adding substantively to the variety of species found on earth, soft sediment marine organisms have functional roles crucial to many ecosystem processes. However, the disturbance regimes play an important role in influencing biodiversity [27].

In marine benthic habitats small-scale natural disturbance plays a remarkable role in influencing communities by generating patchiness [28,29]. Many of the small-scale disturbances that impact benthic communities and generate heterogeneity result from the biological activities of organisms that live in or feed on the seafloor. The spatial heterogeneity created by local disturbance events can account for resource patchiness [30], and ubiquity of opportunistic species in soft-sediment habitats. This heterogeneity is an important component of the functioning of ecological systems [31] and has consequences for diversity maintenance and population stability for community, and ecosystem levels [32]. The natural disturbance factor is important to soft-sediment communities that has led to the suggestion that fishing disturbance can positively affect biodiversity.

Dredging is a critical operation that is regularly carried out to preserve safe passage for boats and ships at ports and harbors [33,34]. In other words, dredging is significant for maintaining and performance of harbor operations, i.e., For the import and export of goods. However, the removal of dredged spoil at sea can potentially affect the marine environment and its ecosystems [35,36]. The dredging and dumping of spoils at sea will inevitably increase turbidity levels and settlement of fine sediment over an extended area. This can propagate to a large area around the dumped location. The impacts of this loss of land and fisheries potential has been studied at Louisiana State University [37]. It is estimated that nearly 1-2.6% of Barataria Basin (around 5,700 km² or 2,200 square miles) has been directly removed by dredging. If the dredged spoils area is combined (as this land also is lost from marsh production), perhaps 10% of the area could be lost due to biotic production.

The total area adversely affected is almost 20% in combination with secondary adverse effects, such as loss of sheet flow, are included. Once the canals are dug, they tend to expand each year from erosion [38] thus the effects persist even after dredging or extraction ceases. Also, dredging results in the direct removal of intact benthic sediments, the habitat upon which the survival of many species of animals, plants, and bacteria depends. A similar effect from dredging was observed on shallow-water benthos in a tropical estuary and the loss in benthic algae biomass (i.e. standing crop) was attributed to dredging. The main sources of environmental stress from dredging activities are the formation

of airborne dust, solid waste, noise, and chemical discharges released into nearby bodies of waters. A well comprehensive review will cover all these impacts associated with dredging activities in other areas of the Niger Delta region of Nigeria. It also, interferes with physiological processes, suggesting that temperature is very significant in determining the rates, and in some cases even the presence of significant biological functions such as photosynthesis, respiration, enzyme activity, feeding, and reproduction. Hence, any change in water temperature affects the metabolism of aquatic plants, bacteria, and cold-blooded animals since they cannot perform their internal heat balance actively.

Henceforth, the continuous dumping of spoils can interfere with the smothering of the seabed environment, coral reefs, egg-laying nests of fish and can disturb their navigations. Finally, dredging and dumping alter the topography of the seabed during dredging and dumping locations and can therefore change the local flow patterns. The impact of the dumped spoils on water quality is also affected by the concentration of suspended material. The chemical, physical, physiological, and behavioral changes can be combined to change and affect entire aquatic ecosystems through changing primary and secondary production, community respiration, species composition, biomass, and nutrient flows. As a result, dredging and its related activities should be monitored, controlled and their impacts on the marine environments should be assessed, maintained and safeguarded through appropriate and effective management strategies.

Impacts are summarized as follows:

- a) Introduction of hard substrata into soft-sediment ecosystems (shipwrecks, clinkers, trash, cables, pipelines, submarine structures).
- b) Organic enrichment (sewage dumping, organic cargo on sunken vessels, dumping of by catch).
- c) Chemical pollution (oil, drilling muds and other oil/gas production chemicals, industrial chemicals, pharmaceuticals, munitions including chemical weapons).
- d) The introduction of heavy metals and other toxins into the environment during the dredging operations.
- e) Excessive sediment disruption with sometimes heavy increases in turbidity-associated with the dredging of channels for tankers and drill rigs.
- f) Radiochemical pollution.
- g) Biomass removal (fishing, bioprospecting, scientific research).
- h) Mechanical disturbance (bottom fishing, cable laying, submarine pipelines, scientific research).
- i) Light pollution (industrial activity, scientific research).

j) Acoustic disturbance (oil and gas exploration, military activity, scientific research).

k) The provision of protein for human consumption and the ecosystems that sustain fisheries are clear examples of the products and functions of marine ecosystems that benefit humankind. Other processes in which marine benthos play important roles include their influence on sediment stability, water column turbidity, nutrient and carbon processing, and contaminant sequestering, as well as the provision of pharmaceuticals and nutraceuticals and recreational and amenity values.

l) Suspended sediments reduce primary productivity by limiting light penetration into the water column. However, many nearshore coastal sediments are also badly polluted with a variety of hydrocarbons, metals, pesticides, etc. and the suspension and movement of such polluted sediments can pose a significant threat to biological communities [8-10,12,22].

m) The disposal of polluted dredge spoil alone is also a significant problem. Poorly planned and managed dredging has resulted in the death of many miles of coral reefs.

n) This loss to the ecosystem occurs when there are restrictions in the size, density, and distribution of organisms that threaten the biodiversity, resilience, or provision of ecosystem services. Once the functionally important components of an ecosystem are missing, it is extremely difficult to identify and understand ecological thresholds. The extent and intensity of human disturbance to oceanic ecosystems is a significant threat to both structural and functional biodiversity and in many cases, this has virtually eliminated natural systems that might serve as baselines to evaluate these impacts [39].

Addressing the Issues

Most of these changes have arisen as a result of the quest of man to improve his socioeconomic and technological status. Because of the fact that mankind will always continue to improve on these endeavors so as to make life meaningful and the world better to live in, the aquatic environment will for a long time be under intense pressure. Of these, the most serious present impacts arise from deep-sea bottom fisheries that target low species productivity. Low species productivity are those considered by slow growth rates, high longevity, and sporadic reproduction when they have accumulated enough energy for offspring production. Undisturbed coastal regions are uniquely rich biotic resources that are valued highly by society. They are also areas that is important and often necessary industries must be maintained and utilized. Some of these are large-scale systems for the production, processing, and distribution of commercial energy. Since dredging-related activities have been known to generate severe and persistent environmental impacts, it is important to understand how and why they affect the integrity of coastal ecosystems as they do and to determine the adequacy of

attempting to mitigate their effects. This is especially imperative when the aquatic and semiaquatic systems is to continue to provide us with the various aesthetic, recreational, and fishery resources they have given us in the past. These benefits confirm some legitimate uses of the coastal zone that should be protected or safeguarded by appropriate management strategies. Much of the current negative impact connected with dredging activities in the coastal zone is unwarranted and could have been avoided by more thoughtful planning. This is a condition that has resulted from man's inability to measure or characterize ecological stress, mismanagement of our technical resources, and/or from the inadequacy of appropriate decision-making.

Likewise, the ecological consequences of human activity on marine environment require an understanding of the broad scale forcing functions as well as knowledge of the natural and life history characteristics of each individual species. There are winners and losers in responding to the ecological disturbance, but the big question is understanding the ecological heterogeneity and its role in transforming the consequences of habitat disturbance to ecosystem processes. It is necessary to better understand the implications of natural and anthropogenic habitat fragmentation and how it relates to the intensity and frequency of disturbance. Interesting empirical and theoretical studies that solves this problem should integrate biogeochemistry, hydrodynamics, and ecology. Site history and the effect of multiple stresses will be predominantly remarkable in many areas in order to address the role of the resident species assemblage and environmental context in affecting disturbance-recovery dynamics in fragmented habitats. Once the functionally important components of an ecosystem are missing, it is extremely difficult to identify and understand ecological thresholds that are violated beyond the point of recovery, at which point the anthropogenic disturbances are less evident. Some knowledge of these issues is necessary to resolve this more important question. Also, environmental impact assessment should be conducted as detailed and specified by the regulatory authority.

The study if well executed will serve all concern stakeholders in no small measure. The document will serve as a management tool to guide decision making during start up and decommissioning of dredging project. Similarly, there is need for the development of an integrated monitoring framework from dredging related activities to provide the fundamental implement for decision making through integrated multidisciplinary approach such as environmental scientists, planners and managers. Consequently, a monitoring scheme should be expedient and uncomplicated. It should involve the use of a standard monitoring team that has the expertise to investigate and evaluate the apparent or potential effects of dredging related activities. The team should be acceptable to government authorities, community stakeholders, property owners, developers and other interest groups. The team membership should include inter alia experts in the fields of ecology, geography, biology, geology, fisheries,

hydrochemistry, hydrology, engineering, sociology, economics, tourism, environmental laws and policies, including hydro-informatics. Ancillary team members may perhaps include public relations officers, policymakers, representatives of affected local communities, stakeholders, coast guards, wildlife rangers and police. The selection of the team members should be based strictly on qualification and experience. Very often unqualified and inexperienced personnel are appointed in order to limit operational cost. This should be strongly discouraged. Moreover, the composition of the team should be gender biased.

As many more effort is urgently needed to save the 100 species scientist fear are being extinguished every single day as humans deliberately or inadvertently destroy the natural system that sustain life on earth. Like any inheritance, biodiversity can flourish if well managed, or it can be squandered and lost. Today massive loss of species and habitat will be slowed only when the human community understand that nature is not an inferior to be exploited or an enemy to be destroyed but an ally requiring respect and replenishment. Hence, to reduce vulnerability, there is need for collective action on environmental protection and ecosystem balance, henceforth the collective drive for environmentalism. This is because every human society depends to a large extent on the biodiversity that are within its immediate environment. Hence, an effective weighing and aggregating system of environmental evaluation could be devised.

Competing Interests

We affirm that we have no conflict of interest that may be alleged as prejudicing the impartiality of the study reported. This researcher did not receive special assistance from government, not-for-profit sectors or commercial institutions.

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