International Journal of Multidisciplinary Research and Growth Evaluation.

An overview of the effects of oil theft on the mangrove and wildlife ecosystems in the Niger Delta Zone

Gbuvboro Anthonia Ejiroghene
Department of Environmental Management and Pollution, Faculty of Environmental Management, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria

* Corresponding Author: **Gbuvboro Anthonia Ejiroghene**

Article Info

ISSN (online): 2582-7138
Impact Factor: 5.307 (SJIF)
Volume: 05
Issue: 02
March-April 2024
Received: 18-01-2024;
Accepted: 20-02-2024
Page No: 195-201

Abstract
Mangroves have a positive ecological impact that supports the way of life for people who live along coastlines everywhere. They provide food and shelter to a number of animal populations, including wading birds and seabirds. Aside from that, many Nigerians, particularly those who reside along the coast, rely heavily on mangroves as a source of housing, fuel, and medicine. Constructed from a network of many creeks, the heart of the Niger Delta holds the largest mangrove swamp in Africa and the third largest in the world. Mangroves are important to the local economy and ecology wherever they are located in the Niger Delta. Mangroves provide such important purposes, yet they are losing vegetation at a rate of 1.7% per year on average; this issue is made worse by poor administration and fish smoking-related tree chopping. Even though the Niger Delta is home to a wide variety of natural species, the prestigious International Union for the Conservation of Nature (IUCN) does not yet recognize this area of exceptional ecology. Oil is crucial to the advancement of modern societies, due to its widespread usage in manufacturing, transportation, and energy across the globe. However, oil leaks from drilling rigs, shipwrecks, and crude oil theft cause extensive, uncontrollable ecological harm in addition to destroying the functions that aquatic ecosystems serve. Coastal wetlands are still vulnerable to significant short-term effects from oil, but the potential for recovery and its long-term effects, however, are less well known. This paper discusses the environmental assessments that are currently being published regarding the impact of oil on mangrove habitats. Furthermore, worldwide oil traffic is always increasing since the country's "mangrove biodiversity of the Niger delta region are regarded as the worst ruined in the globe." Since mangroves are often identified as places of importance for both maintenance and conservation, and since they are particularly sensitive to oil spills, the government should launch, The Mangrove Action Project (MAP), an international initiative to encourage mangrove preservation.

Keywords: Mangrove forests, Niger delta zone, Biodiversity, oil-spillage, Conservation initiative

Introduction

The heart of African mangrove eco-region, which is primarily situated in Nigeria along the coasts of West Africa, is home to the largest mangrove swamp in all of Africa. The Niger Delta is located 50 2′ east of the Greenwich meridian and spans latitudes 40 2′ to 60 2′ north of the equator on the Atlantic coast of Southern Nigeria. Mangroves are intertidal wetland vegetation found mostly in tropical and subtropical coastal regions. The ability of mangroves to feed marine animals, who are the major producers, makes them valuable for the environment even though many organic toxins, including pollution from oil, have damaged the mangrove systems. (NOAA, 2020). Mangrove forests are located in low-energy depositional zones, an area where oil tends to collect. Winds and tidal currents bring spilled oil into these woods. Crude oil spills usually infiltrate mangrove forests during high tide and land on the surface of the substrate. They also build up on propagules and root systems as the tide recedes. The resultant oil leak is typically dispersed unevenly due to the forest's varying tidal level.

The diversity of wildlife ensures that ecosystems continue to produce oxygen and absorb CO2, which reduces the rise of greenhouse gases and enables the environment to adapt to changing climate conditions more successfully. These natural resources account for forty percent of the world's resources. (Barry, 2017). Fertilizers and pesticides used in farming are the primary sources of contamination that are killing mangroves; these substances seep into streams and finally reach the mangroves. The destruction of mangroves is currently attributed primarily to agriculture as a whole, Numbere (2018) [30]. Oil is the most common pollution in the seas, and attempts to collect petrol and oil have resulted in a number of oil-related disasters that have negatively impacted both the environment of the Niger delta region and the livelihoods of coastal communities.

Although it is unclear how much of a problem they truly provide, sabotage, oil theft, and oil destruction of installations are unquestionably serious problems in the Niger Delta. (MBA, 2013). The extraction of revenue from oil and gas has resulted in destruction, urbanization, and environmental harm, all of which have drastically changed the landscape. However, as has occurred in the Niger delta of Nigeria, which is rich in mangroves, oil leaks could further choke out the trees. Some claim that Nigeria, which encompasses the estuaries of the Delta, Bayelsa, rivers, and Cross River, has the best mangrove ecosystem in all of Africa. This estuary is thought to have one of the most important mangrove diversities in the country. (Zabbey, 2019) Crude oil is still the world's main source of fuel despite the fact that it is known to be an unsustainable resource with significant detrimental effects on the ecosystem from processing through use and disposal, including harm to habitat, pollution, ozone layer destruction, decreased resource availability, and toxicity to humans and the environment. (Gundlach *et al*, 2021) [12]. When oil spills into bodies of water, it can disperse across a wide area with the aid of storms and tides, influencing both plant and animal populations. Because oil is a little thicker than water, it creates an obstruction at its outer layer that keeps oxygen from diffusing. Mangrove trees have lenticels that allow them to "breathe," but if oil gets on the bark, it impedes the tree's metabolism and causes it to become effectively suffocated. Similar to immature mangrove plants, seeds can also perish when exposed to petroleum products. (Nwobi *et al*, 2020) [31]. The amount of oil used as fuel has doubled globally over the last 35 years, leading to a seven-fold increase in GDP over that time. Over this period, petroleum products have been the primary fuel source worldwide, providing 34% of all energy supply in 2017. (World Bank 2019). Oil exploitation has been shown to impact habitats in a number of ways, including through its impact on climate change (Fischlin *et al*., 2007) [9], physical effects (Swer and Singh, 2004), chemical effects (Banks *et al*., 1997), and biological effects (Meyer *et al*., 1999) [25].

Things have gotten worse because of the oil companies' disregard for environmental issues and their lack of accountability when operating in the Niger Delta. Large-scale gas flaring and continuous oil contamination have thus been linked to oil operations. The fact that Shell's operations in Nigeria, which account for just 14% of the world's oil production, are to blame for an astonishing 40% of all petroleum spills worldwide serves as an indication of the recklessness of the oil activities in the Niger Delta (Gilbert, 2010) [10]. Oil experiences chemical and physical changes as it enters the aquatic habitat, expands, and floats with the wind and currents. The features of oil as well as the location and extent of its immediate surroundings influence are rapidly and gradually altered by these unforeseen events, which are often referred to as weathering. There are numerous, varied, and long-term effects of oil contamination on the ecosystem (Uriagu, 2011) [45]. The newsroom has featured pictures of oil-smothered birds to illustrate the serious short-term effects they may cause on biodiversity and environments. The amount and kind of oil, the manner of weathering, and interactions with the marine realm are some of the variables that determine the long-term effects. (Robert, 2019) [35].

Suppressing the biological and ecological consequences of drilling for oil in the Niger Delta region is one of the responsibilities of the Niger Delta Development Commission (NDDC), which was founded by the Nigerian government in 2000. Mangrove forest clearance and land grab have resulted from improper land use upstream from human influence, petrochemical operations, and related oil contamination (Chindah *et al*., 2007) [7]. Substantial ecological harm and instability. A few of the negative effects of oil on aquatic ecosystems on the environment are as follows:

Effects of oil on marine birds

One significant reason why birds are typically the most obvious subjects of oil contamination is that their feathers absorb oil instead of water. Actually, as soon as they come into contact with oil, feathers easily take in significant amounts of it. Consequently, the birds lose their ability to fly, stay warm, and be buoyant due to this. Birds that come into contact with oil may quickly lose warmth, sink, or become submerged. (NOAA, 2020). When preening, birds additionally swallow any oil that sticks to their bodies, which might have harmful consequences. If excessively greased, preening can become so intense as to interfere with regular feeding. This could lead to famine, along with a fast reduction in warmth from insulation loss. Oiled eggs might not develop and greased birds might hardly lay eggs as frequently. (Imobighe, 2011) [16]. Oil spills usually have an even greater effect on diving seabirds than on surface birds, while a few species are more vulnerable than others. While some birds might steer clear of greasy water, others might find it appealing. Accurately counting for the variety of birds harmed in a spill is typically challenging. A bird's capability to fly might be hindered by oil, making it difficult for it to forage or flee from predators. Birds may swallow the oil that coats their feathers while preening, which can irritate their intestines, change liver function, and harm the kidneys. They are less able to forage, which can quickly lead to dehydration and hormonal problems.

The majority of them drown or become food to scavengers and are never found again. (Adam *et al*, 2021). Regardless of the species mix, season, and relationship to movement and reproductive cycles, impact will differ significantly. Certain species of seabirds are sluggish to reproduce and have extended lifespans. It could take a long time for specific groups to recuperate from an event in such a scenario. Oil seeps into the form of animal fur and bird feathers, decreasing their capacity to withstand temperature changes and significantly decreasing their buoyancy in the water. There is still much debate regarding how to deal with oiled birds. (NOAA, 2020). Wild birds undergo severe stress from human interaction and treatment processes, which can frequently be just as deadly as the oil itself, even with skilled handlers. The slightly oiled birds that are later freed may not last more than

a few weeks or several months after receiving treatment. A few birds who have been subjected to crude oil also have hormonal imbalances, which include modifications to their luteinizing protein. Most birds impacted by oil spills perish via abnormalities if no action is taken by humans.

Fig 1: The environmental impacts of oil pollution on the marine environment of the Niger delta zone

Implication of oil on marine Fish

Due to the oil-repellent mucus covering their outermost areas, notably their gills, fish might have more resilient to oil than other marine species; however, larval fish that often congregate near the surface may be more susceptible. It's possible that these larvae will perish if a spill happens while they're in that stage of the life cycle. The impact of a petroleum disaster on fish supplies in a particular location is very hard to assess. Hjermann *et al*. (2007) [14]; Rooker *et al*. (2014) [36]. Because of existing overfishing tactics as well as natural fluctuation, there is already significant annual variance, and estimates of stock availability are typically inaccurate. Fish may be harmed by crude oil through their gills, internally, or by consuming oiled prey. The implications of different oil dosages on particular species are currently the subject of several laboratory research. Diverse species exhibit differences in their life cycle stages, fertilisation tactics, and behaviour.

Some researcher, (Carls *et al*., 1999; Hicken *et al*., 2011; Meier *et al*., 2010; Scott and Sloman, 2004; Sørhus *et al*., 2015) [4, 13, 24, 37, 38] observed that, it's possible that developmental damage won't be noticeable until the eggs emerge into larvae; when compared to benthic (bottom-dwelling) species, pelagic species appear to be more adaptable. Fish responsiveness may be significantly impacted by the temperature of the water. Lower temperatures tend to slow down fish metabolism, which could help them remove pollution, and to let oil stay in the water columns for longer. Even in tiny quantities, fish can get deemed unfit for sale due to off flavours or the impression of "tainting," despite the fact that they might be capable to withstand interaction and metabolise the minute quantities of oil molecules that penetrate the water column. (Hjermann *et al*., 2007) [14]. The effects on aquatic ecosystems are not limited to overfishing. Oil contamination, destruction of habitat, and climate change are some of the additional stresses on these significant communities. The effects on ecology and the surroundings may be mitigated if oil contamination and accidents are possibly decreased. The productiveness and richness of aquatic ecosystems would rise if the destruction brought about by activities that affect the aquatic environment—such as contamination, excessive fishing, and ecological loss—were reduced. (Langangen, 2015).

Fig 2: Devastating effects of oil pollution on fish in the Niger delta zone

Effects of oil on marine shellfish

The detrimental consequences of oil on shellfish—both bottom-dwelling (lobsters, crabs, etc.) and coastal (clams, oysters, etc.—have been extensively studied. It exists a lot of variance across species and between several species' phases of its life cycle. While extremely susceptible to oiling, intertidal shellfish might be marginally more resilient than marine species. Furthermore, juvenile and moulting stages are typically more fragile than matured adult stages, as would be expected. (NOAA, 2020). Given the potential for oil washing to shore to accumulate in a small strip down the coastline and the greater amount of oil across the water column caused by the shallow water, species that live in bays, estuaries, and other shallow settings are particularly vulnerable. Most invertebrate species can be actually smothered and rendered immobile by petroleum-based oils, further adding to their poisonous consequences. There are also observed sub-lethal consequences, such as modifications in development, metabolism, behaviour, and breeding. (Larry, 2020). Similar to fish, smallest concentrations of hydrocarbons may contaminate or produce "off" flavours, which can have negative effects on commerce.

Fig 3: The effects of crude oil pollution on shellfish (Perewinkle) in delta state

Impact of Crude oil theft on the environment

Although the Niger Delta has a variety of resources, the Nigerian government and extractive industries are primarily drawn to the oil and gas deposits, just as they were for British colonists a century ago. Nigeria reportedly has 206 trillion cubic feet of natural gas reserves, and the world's 10th-largest reserve of crude oil, amounting to around 25 billion

barrels. Oil contributed 7.24% of Nigeria's GDP in 2021, and oil exports continues to dominate the country's foreign exchange earnings. Nonetheless, mounting data points to the oil industry as the primary cause of the irreparable ecological harm that mangroves and humans alike are suffering from. Based on information collected by Nigeria's National Oil Spill Detection and Response Agency (NOSDRA), there have been over 8,636 oil spill occurrences in the last ten years, releasing a total of 385,909 barrels of oil into their surroundings.

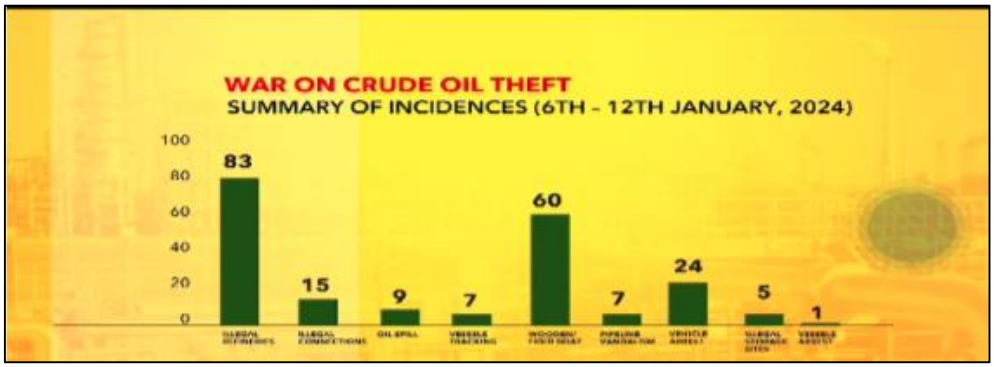

Fig 4: Chart showing incidences of oil theft from 6-12th of January, 2024: Reports from NNPC maritime intelligent system

Fig 5: Drown shorts showing pockets of illegal refineries in owazia: Reports from NNPC maritime intelligent system

According to the Nigeria Civil Defence Corps (NSCDC), Tanita Services confiscated a 3,500-ton capacity Cali-vessel that was loading straight onto a petroleum platform from Bayelsa state on January 11, 2024, after it was spotted stealing petroleum oil via an oil jacket offshore in the state. Upon its capture, the vessel was carrying more than two million litters of petroleum. Mr. Promise Eze, the chief engineer on board, stated over the phone with the captain at Tanita Services that the theft was although carried out in collaboration with some community members. The said ship, turned off its automatic detection technology on July 8, 2021, rendering it unnoticeable to nautical intelligence systems, NNPC's preliminary inquiry revealed that the ship had been engaging in shaded operations, such as crude oil theft, around the boundaries of the Niger Delta maritime realm ever since, committing five un-identification changes, multiple unlawful ship-ship activities, and multiple port calls in the Nigerian maritime ecosystem throughout the course of one year. The vessel, which arrived from Lagos a few days earlier to its capture, was primarily employed in crude oil installations, platforms, and oil wells, especially in the Niger Delta area. The ship, which is presently being held by the national security department while additional inquiry is being conducted, is manned by twelve people; 83 illicit associations are reported to have been detected in River state, Abia, Imo, and Bayelsa state, according to information gathered from the NNPC maritime intelligence system. Five illicit storage points were discovered in central boma and koko camp in Bayelsa state; Abia state, drown shorts depict pouches of illicit distilleries in the state; illicit linkages were also discovered in olodiama in Bayelsa and obuzo in Abia state. Although petroleum sacks were discovered in Iba, River State, and their contents were seized, 60 wooden and fibre boats were also discovered in Warri, Akwa-ibom, Delta, and River State; eight of these occurrences occurred in the deep blue waters. The last several weeks saw incidences of oil theft, 54 in the western region, 68 in the eastern region, and 81 in the centre region and twenty-two individuals were taken into custody. Regarding the occurrences of petroleum theft, the NNPC states that there won't be any retreating unless the threat is completely eliminated.

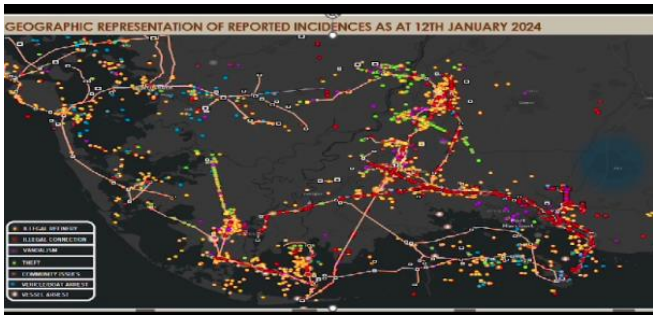

Fig 6: This slide gives a geographic representation of reported incidences as at 12th January 2024; Reports from NNPC maritime intelligent system

Fig 7: Crude oil (theft) bagged in sacks, found in delta state, Reports from NNPC maritime intelligent system

Implication of oil pollution on the roots of mangrove trees

The most abundant naturally occurring ecosystems on Earth are coral reefs, sea grass beds, and mangrove swamps.

Mangroves are coastal wetland ecosystems that provide a number of ecological benefits, including the ability to recycle nutrients, effectively release carbon and energy, absorb pollutants, and stop coastal erosion. Researchers (Othman, 1994; McKee & Faulkner, 2000; Chmura, 2003; Moberg & Rönnbäck, 2003; Valiela *et al*., 2004) [32, 23, 8, 26, 40] claim that... There are many advantages and benefits that mangrove forests offer to people. (Lee *et al*, 2014) [14] Mangrove forest regions can be economically advantageous, provide timber for commercial and agricultural purposes, and provide as a refuge or a land access for aquatic features that are home to fish, prawns, or crabs, according to Mukherjee *et al*, (2014) [27]. Mangrove forest loss, in addition to land alteration, plays a role in modifying the size of mangrove forests (Thomas *et al*., 2017) [42]. Smothering asphyxia can be especially deadly for red mangroves, which cover much of the Niger Delta region. According to Mazda *et al*. (2006) [21], aerial roots lessen the quantity of water that enters the swamp during high tide, which promotes the accumulation of debris and sediment in the mangrove margin, making smothering by sediment and debris a real problem (Horstman *et al*., 2017) [15]. Researchers, Chen *et al*., 2018 [6]; Horstman *et al*., 2017 [15]; Martin *et al*., 2019 [20f] claim that because mangrove roots are extremely effective at capturing particles and objects, they wind up in mangrove forests where they may suffocate knee roots and pneumatophores. As stated by, (Richards & Friess, 2016) [34], the use of remote sensing technology can provide time efficiency and effectiveness of funds in monitoring mangrove forest damage.

Fig 8: Effects of oil pollution on Mangrove ecosystem in delta state, there by suffocating the tress

Effect of crude oil sheen

As oil weathers, its chemical makeup varies, by means of evaporation, microbiological deterioration, chemical oxidation, and photochemical processes, as weathering takes place. While certain oils deteriorate quickly and have significant physiochemical feature shifts many hold steady over extended periods of time. Generally, by trying to break up the sheen, a non-petroleum slick can be identified as opposed to a crude oil one. (UNDP, 2010). Most often, a bacterial sheen will split into tiny flakes once a stick is inserted into it or once a stone is thrown into it. A crude oil sheen, on the other hand, will attempt to reestablish itself as soon as one is disturbed. For hydrocarbons having smaller atomic weights, evaporation causes weathering to occur more quickly—usually within 1 to 2 days. The longer process of bacterial breakdown and chemical oxidation is the main cause of breakdown of the more valuable components. Both the oil's characteristics and the ecosystem around us affect how spilled oil weathers and ends up (UNDP, 2010). Oil Characteristics show differences in the physical and chemical properties of crude and refined oils. Their flammability, hazardous substances, weathering level, and permanence are influenced by these qualities. This oil builds up into a thick coating on the water's surface, blocking radiation from penetrating the saltwater and, consequently, oxygen from reaching both the submerged fauna and plants. These attributes, impact its volatility on Pneumatophores and prop roots which can become coated with heavy processed compounds like Bunker C, which can hinder the tree's capacity of exchanging gases. The surface might be coated with heavy refined goods like Bunker C or crude oils. This might have an impact on seedling recruitment into the oiled area. Oil spills have the greatest impact on red mangroves, which are typically found towards the sea, both of the two species (white and red) are typically linked to low-energy shoreline. (World Bank, 2014). The most apparent sign of contamination is sheen, which is made up of very little oil. Huge modifications are often found both windward and in the middle of an area coated with sheen. Large volumes of oil are represented by thick areas. When contamination first appears, it is typically black or dark brown. A majority of bulky petroleum products and oils from crude petroleum have the capacity to create emulsions consisting of water in an oil, which are commonly referred to as chocolate mousse. Such substances are commonly utilised to restore sheens that are lost through natural disposal.

Fig 9: This is found across the whole of the Niger delta zones on most water bodies, causing severe oil pollution on the ecosystems of this region

Table 1: Appearance/Thickness/Volume of oil on the sea surface

Appearance / Colour	Approx. Thickness (µm)	Approx. Volume (m3/km2]
silvery sheen	0.02 - 0.05	0
grey sheen	0.1	0.1
Iridescent (rainbow) sheen	0.3	0.3
Blue	1.0	1
blue/brown	5.0	5
brown/black	15 – 25	15 – 25
dark brown/black	> 100	> 100
brown/red/orange/yellow mousse	> 1 mm	

Manual on Oil Pollution at Sea: Securing Evidence on Discharges from Ships", Bonn Agreement, 1993

Conclusion

Mangroves comprise barely 0.1 percent of the Earth's surface, and they cannot be easily replaced after they perish. That being said, they are distinct habitats that are essential to both the marine and terrestrial ecosystems as well as the world at large. They are rich in diverse life forms and have financial significance. They also shield coastal populations from natural disasters and erosion. Finally, mangroves store and capture carbon more efficiently than any other biome. Destruction to mangrove forests can result from a variety of factors, including trash disposal, land conversion, oil spills, sabotage, destruction of oil equipment, and theft of oil. The need for more land, increasing numbers of people, and growing manufacturing operations will inevitably cause these harms. For the advantage of the various animal residents and the natural environment as a whole, they should be maintained and protected as effective instruments against change in the environment and unique habitats. Because of inadequate institutional governance and erratic duties made at both the municipal and national levels, the nation's regulations and programmes to prevent ecological damage are not well enforced, The regulatory bodies in charge of managing mangroves and enforcing the law ought to be involved in strategic planning. Additionally, policies and programmes at the federal level ought to properly integrate mangrove projects in order to tackle growth of projects and prioritise regions for conservation, restoration, and sustainable governance initiatives. Programmes for monitoring, such as the Mangrove Action Project (MAP), a well-known international advocacy for mangrove conservation, might be pushed in Nigeria due to their important significance globally. The government needs to take action to reduce the significant danger of environmental contamination for all living forms and the ecology.

References

1. Augustyn A, Zeidan A, Zelazko A, *et al*. Oil spill. Britannica. May 3, 2021.
2. Stevens B. Greenhouse Gas levels are higher than the past 800,000 Years [Internet]. June 1, 2017. Available from: https://oilprice.com/Latest-Energy-News/World-News/Greenhouse-Gas-Levels-Are-Higher-Than-The-Past-800000-Years.html
3. Banks D, Younger PL, Arnesen RT, Iversen ER, Banks SB. Mine-water chemistry: The good, the bad and the ugly. Environmental Geology. 1997; 32:157–174.
4. Carls MG, Rice SD, Hose JE. Sensitivity of fish embryos to weathered crude oil: part I. Low-level exposure during incubation causes malformations, genetic damage, and mortality in larval pacific herring (Clupea pallasi). Environ Toxicol Chem. 1999; 18:481–493.
5. Canziani JP, Palutikof PJ, van der Linden C, Hanson CE, editors. Cambridge, United Kingdom: Cambridge University Press; pp. 211–272.
6. Chen Y, Li Y, Thompson C, Wang X, Cai T, Chang Y. Differential sediment trapping abilities of mangrove and saltmarsh vegetation in a subtropical estuary. Geomorphology. 2018; 318:270–282.
7. Chindah AC, Braide SA, Amakiri J, Onokurhefe JO. Effect of crude oil on the development of mangrove (Rhizophora mangle L.) Seedlings from Niger Delta, Nigeria. Estud Biol. 2007; 7:181-194.
8. Chmura GL. Global carbon sequestration in tidal, saline wetland soils. Global Biogeochem Cycles. 2003; 17:1111.
9. Fischlin A, Midgley GF, Price JT, Leemans R, Gopal B, Turley C, *et al*. Ecosystems, their properties, goods, and services. In: Parry ML, editor. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 2007.
10. Green Peace International. Shell Shocked: the Environmental and Social Cost of Living with Shell in Nigeria. 1994.
11. Gilbert LD. Youth Militancy, Amnesty and Security in the Niger Delta Region of Nigeria. In: Ojakorotu V, Gilbert LD, editors. Checkmating the Resurgence of Oil Violence in the Niger Delta of Nigeria. 2010; pp. 51-70.
12. Gundlach ER, McArthur A, Iroakasi O, Bonte M, Giadom FD, Shekwolo P, *et al*. Cleanup and restoration of 1000-ha of oiled mangroves, Bodo, eastern Niger Delta, Nigeria. International Oil Spill Conference Proceedings. 2021; 1.
13. Hicken CE, Linbo TL, Baldwin DH, Willis ML, Myers MS, Holland L, *et al*. Sublethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish. PNAS. 2011; 108:7086–7090.
14. Hjermann DØ, Melsom A, Dingsør GE, Durant JM, Eikeset AM, Roed LP, *et al*. Fish and oil in the Lofoten-Barents Sea system: synoptic review of the effect of oil spills on fish populations. Mar Ecol Prog Ser. 2007; 339:283–299.
15. Horstman EM, Mullarney JC, Bryan KR, Sandwell DR. Deposition gradients across mangrove fringes. Coastal Dynamics. 2017; 228:1874–1885.
16. Imobighe MD. Paradox of oil Wealth in the Niger-Delta Region of Nigeria: How Sustainable is it for National Development. Journal of Sustainable Development. 2011; 4(6):160-168.
17. West L. 5 Environmental Consequences of Oil Spills. November 11, 2020.
18. Langangen Ø, Ottersen G, Ciannelli L, FB V, Stige LC. Reproductive strategy of a migratory fish stock: implications of spatial variations in natural mortality. Can J Fish Aquat Sci. 2016; 73:1742–1749.
19. Lee SY, Primavera JH, Dahdouh-Guebas F, Mckee K, Bosire JO, Cannicci S, *et al*. Ecological role and services of tropical mangrove ecosystems: A reassessment. Global Ecology and Biogeography. 2014.
20. Martin C, Almahasheer H, Duarte CM. Mangrove forests as traps for marine litter. Environ Pollut. 2019; 247:499–508.
21. Mazda Y, Magi M, Ikeda Y, Kurokawa T, Asano T. Wave reduction in a mangrove forest dominated by Sonneratia sp. Wetl Ecol Manag. 2006; 14(4):365–378.
22. Mba CI. Impact of Oil Spillage on Community Development in Rivers and Bayelsa States with Reference to Poverty and Hunger Eradication by the Year 2015. A Ph.D Dissertation, Department of Adult and Non-Formal Education, University of Port Harcourt. 2013.
23. McKee KL, Faulkner PL. Restoration of biogeochemical function in mangrove forests. Restor Ecol. 2000; 8:247-259.
24. Meier S, Craig Morton H, Nyhammer G, Grøsvik BE, Makhotin V, Geffen A, *et al*. Development of Atlantic cod (Gadus morhua) exposed to produced water during

early life stages: effects on embryos, larvae, and juvenile fish. Mar Environ Res. 2010; 70:383–394.
25. Meyer JL, Sale MJ, Mulholland PJ, Poff NL. Impacts of climate change on aquatic ecosystem functioning and health. Journal of the American Water Resources Association. 1999; 35:1373–1386.
26. Moberg F, Rönnbäck P. Ecosystem services of the tropical seascape: interactions, substitutions and restoration. Ocean Coast Manage. 2003; 46:27–46.
27. Mukherjee N, Sutherland WJ, Huge D, Koedam N, Dahdouh-Guebas F. Ecosystem Service Valuations of Mangrove Ecosystems to Inform Decision Making and Future Valuation Exercises. PLoS ONE. 2014; 9(9):1–9.
28. Niger Delta Environmental Survey, Phase 1, 1 Technical report submitted by Environmental Resource Managers Limited. 2004.
29. National Oceanic and Atmospheric Administration. Oil spills. August 2020.
30. Numbere AO. Mangrove species distribution and composition, adaptive strategies and ecosystem services in the Niger River Delta, Nigeria. Mangrove Ecosystem Ecology and Function. 2018.
31. Nwobi C, Williams M, Mitchard ET. Rapid mangrove forest loss and nipa palm (Nypa fruticans) expansion in the Niger Delta, 2007–2017. Remote Sensing. 2020; 12(14):2344.
32. Othman MA. Value of mangroves in coastal protection. Hydrobiologia. 1994; 285:277.
33. Oil Spill Intelligent Report: How Does It Spill? The Guardian Nigeria News. January 11, 2024.
34. Richards DR, Friess DA. Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012. Proceedings of the National Academy of Sciences of the United States of America. 2016; 113(2):344–349.
35. Robert Byrne. National Assembly for Wales. April 2019.
36. Rooker JR, Kitchens LL, Dance MA, Wells RJD, Falterman B, Cornic M, *et al*. Spatial, temporal, and habitat-related variation in abundance of pelagic fishes in the Gulf of Mexico: potential implications of the Deepwater Horizon oil spill. PLoS One. 2013; 8:e76080.
37. Scott GR, Sloman KA. The effects of environmental pollutants on complex fish behaviour: integrating behavioural and physiological indicators of toxicity. Aquat Toxicol. 2004; 68:369–392.
38. Sørhus E, Edvardsen RB, Karlsen Ø, Nordtug T, van der Meeren T, Thorsen A, *et al*. Unexpected interaction with dispersed crude oil droplets drives severe toxicity in atlantic haddock embryos. PLoS One. 2015; 10:e0124376.
39. Swer S, Singh OP. Status of water quality in coal mining areas of Meghalaya, India. Proceedings of the National Seminar on Environmental Engineering with Special Emphasis on Mining. 2004.
40. Valiela I, Rutecki D, Fox S. Salt marshes: biological controls of food webs in a diminishing environment. J Exp Mar Bio Ecol. 2004; 300:131–159.
41. Introduction to Coastal Habitats and Biological Resources for Oil Spill Response NOAA / Hazmat Environment. United States Coast Guard's Marine Safety and Environmental Protection web site.
42. Thomas N, Lucas R, Bunting P, Hardy A, Rosenqvist A, Simard M. Distribution and drivers of global mangrove forest change, 1996-2010. PLoS One. 2017; 12(6):1–14.
43. United Nations. Population Division World Urbanization Prospects 2018. 2018.
44. United Nations Development Programme (UNDP). Niger Delta Human Development Report. Abuja, Nigeria. 2010.
45. Uriagu JN. Oil Industry and the Health of Communities in the Niger Delta of Nigeria. Encyclopedia of Environmental Health. 2011; 240-250.
46. World Bank. Defining an Environmental Strategy for the Niger Delta. Nigeria: World Bank Industry and Energy Operations Division, West Central Africa Department; 2019.
47. World Bank Initiative on reduction of Global Gas Flaring. 2014.