Original Research Article

Impact of Mangrove Deforestation on Fiddler Crab Distribution and Soil Physicochemistry at Eagle Island, Rivers State

Abstract

Mangrove forest in the Niger Delta and its associated biotic and abiotic has been greatly impacted by several factors, some natural and others anthropogenic in nature. Anthropogenic activities have negatively affected the organisms that inhabit the forest resulting in the decrease in size of population of fiddler crabs (*Uca tangeri*). To investigate the influence of anthropogenic activities on the mangrove habitat, burrow distribution and population of fiddler crabs and soil physico-chemistry were determined in forested and deforested sites. Burrows and number of crabs outside burrows were counted while samples of soil were retrieved and moved to the laboratory for the determination of cadmium (Cd), lead (Pb), total hydrocarbon content (THC) and Zinc (Zn) using atomic absorption spectrophotometer. The conclusions show a lack of significant difference in burrow distribution between forested and deforested areas ($P>0.05$). Contrastingly there is significance in the difference in crab population in forested and deforested sites. ($P<0.05$), which showed that there were more crabs in deforested areas than forested areas. There was also a significant difference in chemical and microbial population ($P<0.05$). There was higher THC in deforested areas, which was probably impacted by the heavy-duty vehicles used to cut down the trees. The result implies that human activities of deforestation and pollution influence crab population and soil physicochemistry in mangrove forest.

Keywords: mangrove forest, deforestation, soil physicochemistry, heavy metal, fiddler crabs, bioturbation, burrow construction, bioengineers.

Introduction

With the earth's population ever increasing and an obvious need for urbanization and industrialization coupled with economic inequalities has brought human dependence on the environment and its resources to a point of degradation, depletion and in some cases, a threat of partial or total extinction. The environment (aquatic and terrestrial) provides vital support and sustenance to humans. One of such environmental ecosystems that has over time been researched and found to be very crucial to the support and sustenance of coastal communities is the mangrove forest ecosystem also known as tidal forest or coastal woodland. The mangrove forest ecosystem made up chiefly of mangrove trees, boast of a luxuriant assemblage of flora and fauna biodiversity working to create an ecological balance. Mangrove forests tend to flourish on comparatively low energy, sedimentary littoral coastlines of the torrid zone and sub-torrid zone between 30° N and 30° S latitude (Giri et al., 2011). Tides overflow these aquatic forest communities daily and bi-daily, with seasonal and continual freshwater supplies (Mazda et al., 2005). As defined by Spalding *et al.,* (2010), the mangrove forest is often a torrid zonal community of plants of high saline-tolerance that inhabits the intertidal areas of protected shores near tidal inlets and lagoons. The trees of the mangrove are physiologically and morphologically adapted to the littoral environment's conditions, which include high and unpredictable salt levels, anoxic conditions, limited availability of nutrition, and movement of substrate (Ellison et al., 2012). An approximate of 73 species and hybrids of mangrove exist in 123 nations and regions worldwide (Spalding et al., 2010), spanning about 137,760 km2-152,360 km2 of the earth's surface (Kainuma et al., 2013), however they represent a severely threatened coastal forest habitat. Mangroves cover the western coast of Africa from Mauritania to Angola in the Gulf of Guinea, with roughly one third being in the Nigerian region of the Niger Delta. By estimation, mangroves cover about 32,000 km^2 in Africa, making up a little less than 20% of the earth's coverage (FAO & UNEP1981).The spread of the tidal forest in the Niger Deltaconstitutes around 35% of all mangroves inWest Africa. With a total size of around 105,000 hectares, Nigeria is home to the most expansive mangrove forest in the African continent and third in order of size on the earth's coverage (Ndukwu & Edwin-Nwosu, 2007).

The Niger Delta region is home to the majority of the mangrove forest in Nigeria, which is believed to be one of the more impacted in terms of mangrove exploitation in the world. Nwosu (2005) opined that mangrove ecosystem in Nigeria is counted among the most expansive and abundant reserves of biodiversity on earth, comprising mangrove trees and shrubs, ferns and palms, in addition to a rich diversity of fauna including micro-organisms, crustaceans, molluscs, amphibians, fishes, reptiles, birds and mammals. Agreeing with Oyieke, (1996) that with about 2,145 species of plants and animals, the Nigerian mangrove environment is estimated to have the richest biodiversity in the sea, providing roughly 25% of all biological output.

The Nigerian mangrove ecosystem has always provided ecological support to coastal communities and its population such that in most communities where their deforestation and depletion is extreme, it has brought on adverse effects. In addition to providing vital ecological benefits to humanity, mangroves supply a variety of items. They produce a range of plant-based products, enhance the quality of water, supply fish and shellfish to nearby settlements, promote coastline stability, sustain the near-shore fisheries food chain, and engage in carbon sequestring. Also, they function as habitat for various fish species. Additionally, (Onyena & Sam, 2020) noted that mangroves serves as a source of firewood, medicinal decorations, and honey for the native community. Mangrove ecosystems in addition to absorbing the energy from waves and wind, also control the quality of water of the coastlines through sedimentation and uptake of nutrition. The Nigerian mangrove forest belt, according to Chima and Larinde, (2016), has the potential to protect rural coastal communities from extreme weather events brought on by climate change. This is because rising sea levels are expected to raise flooding risk in low-lying coastline regions, which will in turn make coastal cities more vulnerable on a physical and socioeconomic level. Mangroves among many other uses and benefits, also serve as crucial filters to clean water and cultivable land, aid in reducing coastline degradation and siltation of sea grass beds, and function as barriers of protection against hazardous storms and wave activity, avoiding considerable loss of land and reducing erosion and flooding. They also act as carbon sinks, helping to mitigate the consequences of global warming.

Maybe consequent to its vitality, uses and benefits, the mangrove forest ecosystem have been massively exposed to overuse, abuse, degradation and deforestation. In many cases, mangroves have been a victim of human development and expansion leading to a significant loss of the world's mangrove. Mangroves as recognized by Numbere (2019) are very tolerant and resilient but due to the fact that they live close to their tolerance limits, (Kathiresan & Bingham, 2001) further disturbances pose major threats to their existence and sustenance. Mangrove forest habitats are among the most vulnerable natural habitats on the planet, with almost half of the global area already destroyed (Spalding et al., 2010). Human activities are still a basic driver of mangrove ecosystem deterioration and loss in all regions of the world (Zabbey & Tanee, 2016). Oil leakages, excessive exploitation for fuel wood, converting to various types of development, dredging and industrial release of waste, and unfettered growth of Nypa fruticans (nypa palm) are some of the biggest factors threatening the mangroves in the Niger Delta, according to Zabbey et al., (2010). Among the rich biodiversity of the mangrove forest ecosystem, exist a fauna whose activities many scholars have agreed to be quite vital to the sustenance of the mangrove forest. Clearly marked out by its distinctively asymmetric claws, fiddler crabs are located in mangroves, in salt marshes, and on sandy or muddy beaches of West Africa, the Western Atlantic, the Eastern Pacific, Indo-Pacific and Algarve region of Portugal (Mokhtari *et al*., 2015). They are common benthic macrofauna in coastal areas.

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Though debatable, fiddlers are counted amongst the most ecologically vital fauna within the mangrove ecosystems, playing an important part as a result of their bioturbation and burrowing activities, resulting in the engineering of the ecosystem (Kristensen, 2008). Their activities in outlining and constructing interconnections of burrows within the soil is an exhibition of their architectural prowess. Fiddler crabs (*Uca tangeri*) have been known to function as bio-monitoring agents in measuring the extent of human disturbance in mangrove environment (Numbere, 2020) because their burrow constructing behaviours are highly impacted by human influences and disturbance. Burrow building activities of fiddlers and other crab population are quite vital to the survival of the mangrove ecosystem. At low tides, fiddler crabs gather up debris and relocate seedlings from one region of the mangrove environment to another, causing the establishment of zonation patterns in tidal woodlands. Fiddlers affect formation of sediment by their bioturbation actions, amongst which includes re-designing burrows, cutting outlets for ventilation, creating flow pathways, and constructing defensive barriers against external invaders (Kristensen, 2008). In addition, their burrowing affects the chemistry of soil by altering the soil pH, heavy metal content, nutritional, and dinitrogen oxide levels (Sarker, 2020).

The research objectives are therefore drawn as follows:

i. Determine the fiddler population in the forested and deforested sites.
ii. Evaluate the burrow distribution between forested and deforested sites.
iii. Compare microbial population in forested and deforested sites
iv. Determine heavy metal concentration between forested and deforested sites

Materials and Methods

Description of study area

Several parts of a deforested region and sand-filled mangrove forest on Eagle Island, Port Harcourt local government, Rivers State, Niger delta, Nigeria, were studied. The complete layout of Eagle Island encompassed a total area of 62.26 hectares, with 621 sections of varying parcel area (square metres), including portions dedicated for leisure and commercial uses. It is flanked to the north by Rivers State University, to the west by Diobu townships, to the east by the Nigerian Agip Company Limited, and to the south by rivers and marshes that serve as grounds for several industries. The Rivers State Government established the Eagle Island layout master plan in 1979, however it was later revised in 1982 by the Rivers State Surveyor General's office to satisfy significant interests. The area was bought and planned purely for residential uses; prior to its acquisition by the State government, the area was covered with vegetation, agriculture, mangroves, and marsh (Daminabo, 2013). The layout is no longer complete and free of incursion; it has been characterised by encroachment and unlawful purchase and development by individuals, government workers, and natives, with all restricted areas impacted. Eze and Goodwill (2022) in a research reviewing the original map of Eagle Island concluded that the rate of encroachments especially on land parcels reserved for for other purposes were very high. There are a combination of mangrove and non-mangrove species growing in the area. The major species of mangrove found in the area are: red (*Rhizophora racemosa*), black (*avicennia germians*) and white (*laguncularia racemosa*) while the non-mangrove species are mostly grasses like *m.longibracteatus* (Numbere, 2020). Some Nypa palm species (*Nypa fruticans*) can also be found in the area. The sand-filled area also has a large population of *Uca tangeri*, a species of fiddler crab. With a pH of 7.5, the soil is slightly alkaline. The soil temperature is 26.10ppm, the salinity is 1.16ppt, and the total dissolved solids are 360x10ppm. The area is primarily divided into two seasons: wet and dry, which last from March to October for wet seasons and November to March for dry season (Numbere & Camilo, 2018).

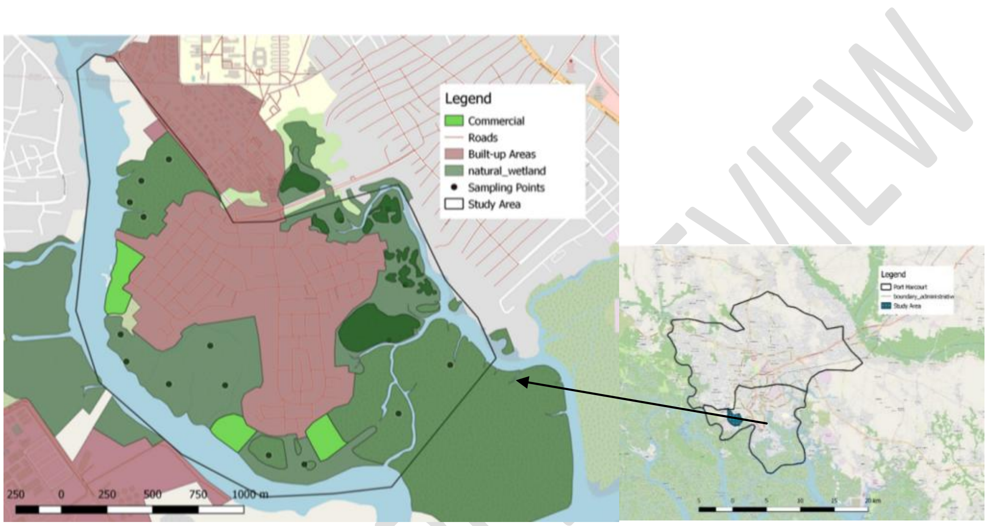

Figure 1: Map of the study area (Eagle Island) with sample points

Experimental Design:

This research was carried out in the year 2021. Sample collection spanned between the months of July through December. Within this period, a monthly visit to the sample site was carried out for observation and sample collection totally about six visits to the sample site. During each visit to the sample site, soil samples were collected using soil auger 5cm below soil surface from both afforested and deforested site of the mangrove for further laboratory analysis and comparison. The sandy soil is composed of 90% sand, the semi-muddy soil is composed of 30% clay and 50% sand, and the muddy soil is composed of 90% silt. The soils were recognised and classified *in situ* using the soil textural triangle and western Nigerian soil qualities (Smyth and Montgomery, 1962). The sample locations were geolocated using a Gamin GPS, and photographs and video of the site were taken to ensure precise counting of the fiddler crab population and burrow distribution. Thirty images were examined over the research area, and the number of burrows and crabs recognised and tallied in both wooded and deforested regions. These figures were saved in an excel spreadsheet.

Soil sample collection

During each visit to the sample site, a hand-held soil augur was used to retrieve soil sample 5cm below the soil surface from the afforested and deforested regions of the site. The soil was transferred to a properly labelled polyethylene bag and moved to the laboratory for further analysis.

Crab population estimation

Fiddler crabs escape into their burrows at the site of any predatory element and this presented a unique problem in the population estimation. As a solution, photographs were taken of several sites where crabs were in groups from a safe distance that would not trigger flight after which the number of crabs that were found on site was counted physically. An overview photograph of the sample site was also taken to show the crabs at their burrowing grounds. The pictures were then downloaded into a computer and carefully counted to get a more accurate population estimate. This process was repeated both for the afforested and deforested regions within the site of study.

Burrow Distribution

A transect for the burrows within the afforested and deforested regions was created in plots and counted. The whole site was carved into four experimental plots where the burrows within each plot were counted and summed up. Each plot measurement was 20m x 20m in size. Pictures were taken showing the burrow distribution.

Laboratory Analysis

Total Heterotrophic Bacteria Count Analysis (THC)

Measuring THC involves the use of spectrophotometric method using calorimeter (e.g., HACH DR 890). Samples were crushed and two grams of it was retrieved and weighed into glass beaker; 20ml of hexane was added. The mixture was stirred and then filtered into a glass funnel filled with cotton wool, silica gel and anhydrous sodium sulphate. Following that, 10ml of organic extract was put to a 10ml sample curvet and placed in the calorimeter. The detection limit for THC is 0.01mg/l (Eaton et al., 1995).

Heavy Metal Analysis

Extraction of heavy metals followed the methods of Aigberua &Tarawou (2018). It involves the air drying of 0.25g of soil sample, which is weighed into a Teflon inset of a microwave digestion vessel and 2ml concentrated (90 %) nitric acid (Sigma-Aldrich, Dorset, UK) added. A microwave accelerated reaction system (MARS Xpress, CEM Corporation, Mathews, North Carolina, U.S.A) was used to extract the metals. The detection limit for the metals analysed in mg/l ranged from 0.001-0.002 (Aigberua & Numbere, 2019)

Sample and Sampling Techniques

The samples are soil and the fiddler crabs that were counted in four different isolated plots in Eagle Island. The sampling technique used was a randomized complete block where soil samples were collected randomly within each plot. Similarly, the crabs found in each delineated plots were counted before they escaped into their burrows. Photograph and videos were taken of the crabs in their feeding ground before they were counted. This is done to capture the crabs photographically since they are mobile.

Statistical Analysis:

An analysis of variance (ANOVA) was carried out since there was multiple samples i.e.,>2 per block (n=30) to test for any significance in difference in soil metal concentration between the forested and deforested areas (Quinn & Keough, 2002). Logarithmic transformation of the data was undertaken to meet assumptions of normality and homoscedasticity (Logan, 2011). Furthermore, Pearson's product-moment correlation was done to compare whether there was any significant difference between number of burrows and crab populations in both forested and deforested areas in the study site. All analysis was done in R statistical environment 4.2.2(R Development Core Team).

RESULT

Burrow Distribution in Forested Versus Deforested Areas

From the ANOVA Table above given that the P>0.05, I fail to reject the null hypothesis, and draw the conclusion that there isn't any significant difference in the number of burrows in forested and deforested areas. Although there isn't any significant difference in the number of burrows in deforested and forested areas, Table 1 and Figure 2 reveal that there were more burrows in deforested than forested areas in all sites. There was, however, a significant difference in the number of burrows in sites 1, 2 and 3 ($F_{1, 28} = 3.92$, $P<0.05$).

Table 1. Number of burrows in forested and deforested areas at Eagle Island, Rivers State, Nigeria

Treatment	Site 1	Site 2	Site 3
Forested	50.00±10.58	60.00±9.00	110.00±27.79
Deforested	70.71±10.14	110.63±20.90	170.00±42.16

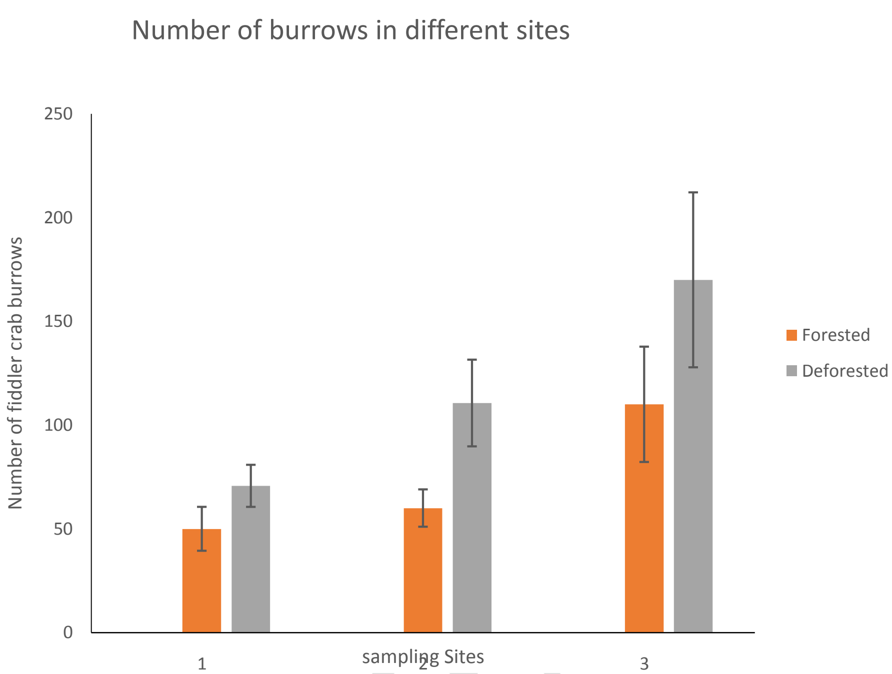

Figure 2: Number of burrows counted in forested and deforested sites at Eagle Island, River State, Nigeria.

Crab Population in Forested Versus Deforested Areas

From the ANOVA Table above given that the $P<0.05$, I reject the null hypothesis, and accept the alternate hypothesis that states that there is significant difference in the number of crabs in forested and deforested areas. There were more crabs in deforested areas in all sites (Table 2, Figure 3).

Table 2: Number of crabs in forested and deforested areas at Eagle Island, Rivers State, Nigeria

Treatment	Site 1	Site 2	Site 3
Forested	30±10.5	25±6.5	35±5.5
Deforested	55±5.1	70±20.3	85±10.6

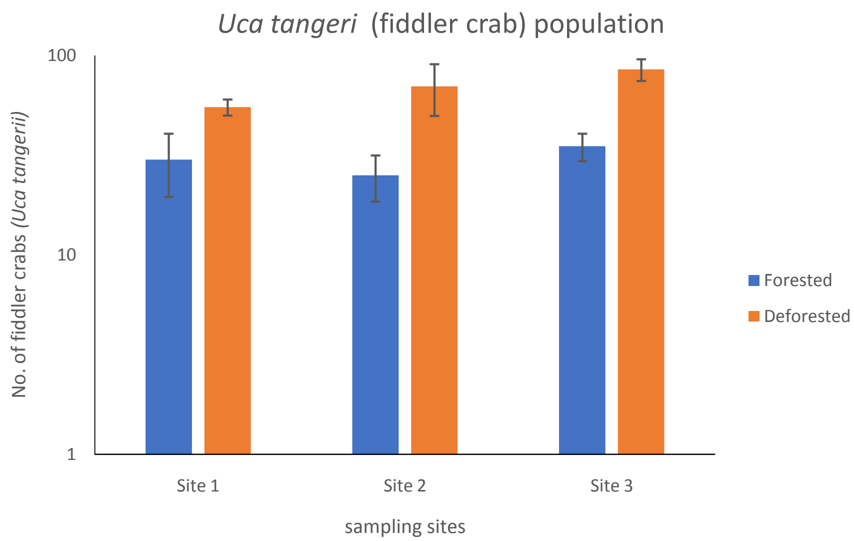

Figure 3: Number of crabs counted in forested and deforested sites at Eagle Island, River State, Nigeria.

Correlation between crab population and burrows

There was little or no correlation between crab population and burrow distribution {t = -0.14919, df = 28, p-value = 0.8825; cor = -0.02818282, (Figures 4 and 5)}. However, the negative correlation sign means that there is a tendency for the crab population to reduce with increasing burrows.

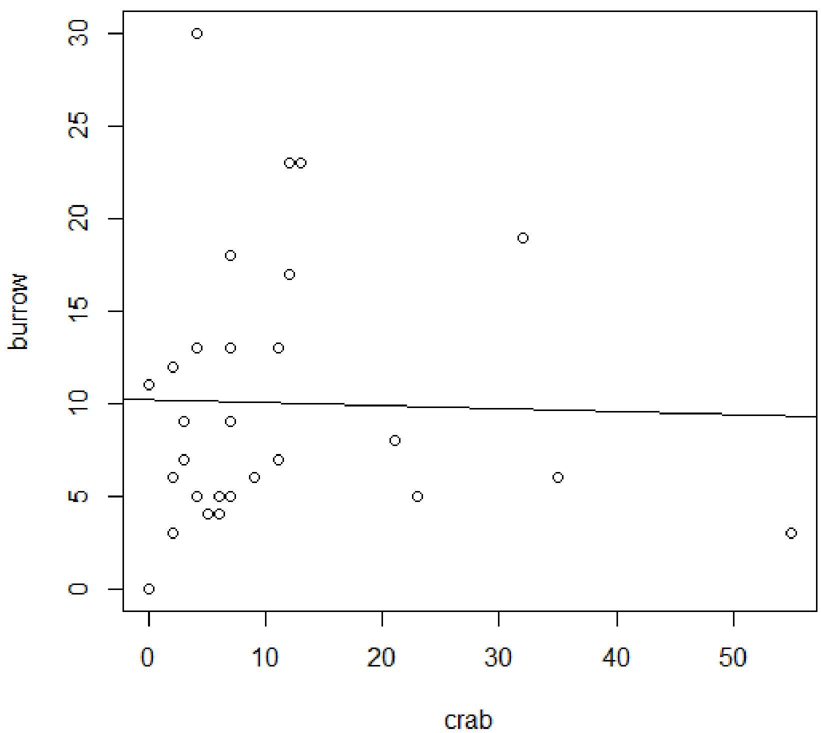

Figure 4: Correlation of number of burrows and crab population in Eagle Island, Rivers State, Nigeria.

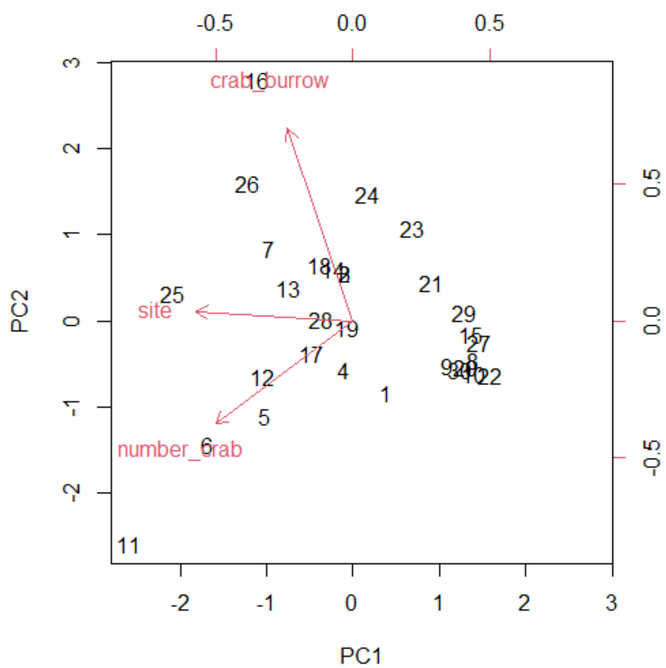

Figure 5. Number of burrows are more than the number of crabs indicating many empty burrows without crabs as observed during field work at Eagle Island.

Soil Physico-Chemistry of Study Sites

The ANOVA result reveal that there is a significant difference in heavy metal concentration in deforested and forested sites ($F_{3, 20}$ = 5.60, $P < 0.01$, Table 3, Figure 6). The result shows that THC has a higher concentration in deforested (0.56±0.55 MG/KG) than forested (0.09±0.05MG/KG) area (Table 3). In contrast, Zinc concentration in forested (12.49±6.59 mg/kg) in higher than in the deforested (6.69±3.25 mg/kg) site. In all, Zinc has the highest concentration followed by THC and Lead. Cadmium has the least concentration. Whereas the concentration of Cadmium and Lead were the same and did no vary significantly

Table 3. Mean concentration of metals in deforested and forested soils at Eagle Island, Rivers State, Nigeria.

Metal	Cadmium	Lead	THC	Zinc
Deforested	0.001±0.00	0.001±0.00	0.56±0.55	6.69±3.25
Forested	0.001±0.00	0.001±0.00	0.09±0.05	12.49±6.59

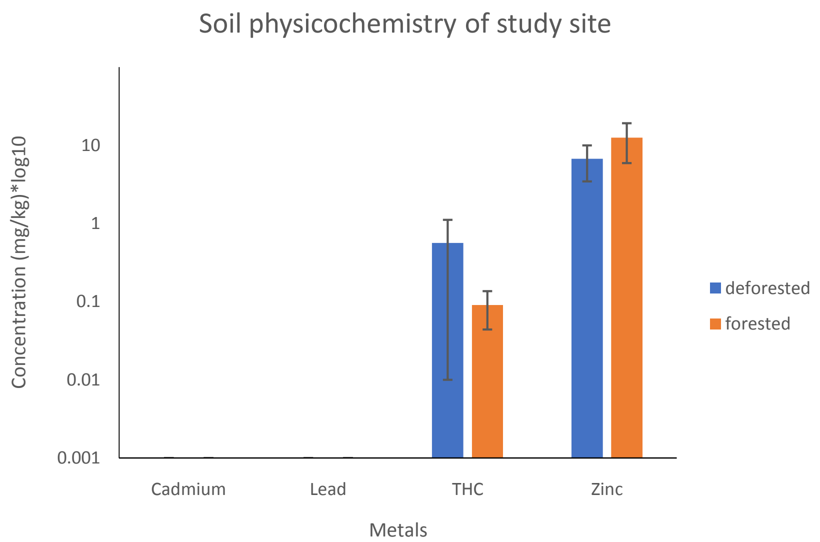

Figure 6. Metal concentration in deforested and forested soil at Eagle Island, Rivers State, Nigeria (±SE).

Microbial population in forested and deforested areas

The t-test shows that there is a significant difference between microbial population in forested and deforested areas (P=0.03, Figure 7). There were higher bacterial and fungal populations in deforested areas compared to the forested areas (Figure 7).

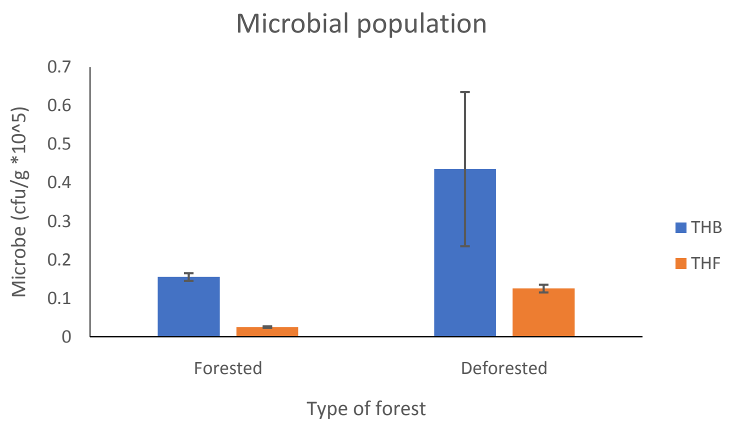

Figure 7. Microbial population in forested and deforested areas in Eagle Island. Rivers State, Nigeria.

Discussion

Burrow Distribution in Forested Versus Deforested Areas

The construction of crab burrows is influenced by several conditions, amongst which are the presence of vegetative structures in the mangrove forest, texture of soil, safety from predatory elements and accessibility to resources. This is because softer soils make it easier for crabs to build burrows and to enable them to create deep tunnels and better architectural designs where they stay to breed and seek protection from external predators. The canopy cover of the mangrove trees provides protection from flying predators and a shelter from excessive weather elements. Thus, the result of this study reveals that there were more burrows in deforested areas than in forested areas (Table 1). The presence of large numbers of burrows in deforested areas contradicts the earlier stated crabs' preference for forested areas for burrow construction and shows a preference of an open area devoid of canopy cover. This according to observation could be adduced to several reasons such as less resistance to burrowing activities by root and vegetative structures, visibility of social cues and mating signals to conspecifics and the preference of certain crabs for open spaces as also observed by (Osborne & Smith 1990 and Nobbs, 2003) where sunlight and rainfall could help to provide a refreshing environment to aid proper circulation of air to support the limited air within the burrows. The construction of more burrows in the deforested areas could also be a deceptive behavior by the crabs to evade capture by ground predators such as rodents and snake that may enter the holes to devour the crabs as this is a known tactics by fiddler crabs to evade predators. But chief amongst these reasons is the increase in anthropogenic activities. The obvious presence of plastic waste and other waste materials and debris littered around the forested areas as observed during the period of this study could be a definite pointer to this fact. A lot of waste is disposed into the river and during high tides this waste is pushed into the mangroves and get trapped in their roots, when the tide subsides the waste create a cover on the ground that prevents the crabs from either accessing their burrows or building new ones. This makes the forested areas less habitable and the deforested areas a better alternative for burrow construction by the fiddler crabs. This reduction in burrow distribution in the forested area has negative impacts both to the fiddler crabs and the mangrove forest. This is because as stated by (Zilius et al., 2020) the bioturbation activities of fiddler crabs during burrow construction influences biogeochemical processes that aids the growth of mangroves while the trees provide shelter and protection for the fiddler crabs. This then means that the forested areas of the study site lose a very vital component of fiddler crabs burrow construction activities while the fiddler lose the cover and protection that would have usually been provided by the mangroves.

Crab Population in Forested Versus Deforested Areas

The result shows that there is a significant difference in the population of crabs in both the forested and deforested areas of the study site. The higher number of crabs in the deforested areas is in line with the higher numbers of burrows in the deforested areas. The large crab population in deforested area shows a unique preference by the crabs for an open area to construct their burrows and live. This could be mainly because of four observed reasons namely (i) exposure to sunlight and aerobic conditions, (ii) land formation and nature of soil (iii) presence of predators and (iv) increased anthropogenic activities around the forest areas. Since the crabs live in burrows, they have limited air circulation, which makes them to build their burrows in an environment where they have access to oxygen circulation. Crabs also require a good amount of exposure to sunlight which helps to build up their shells through the provision of vitamin D. This is why during low tides a large number of crabs are found to bask under the sun to feed and mate. The nature of the soil also attracts crabs to build burrows especially if the ground is soft enough to enable easy burrowing to construct tunnels. The crabs also take in a little soil particle during its feeding, which helps to provide calcium for the development of their shell. The non-presence of trees makes the ground suitable for burrowing because of limited underground root parts that may prevent their ability to burrow easily. The deforested area provides a good platform for the crabs to feed and breed. Because of the presence of food materials brought in by tidal currents and deposited during ebb tides. Furthermore, the study site is often covered by water during high tide and becomes bare during low tide. The presence of wide areas without trees provides a better ability to see and sense the presence of predators unlike the forested areas that has trees where predators hide to capture the crabs. Also, since fiddler crabs communicate primarily through waving cues and signals, there usually is a preference to open spaces around the mangrove forest where visibility and sight is optimal. Fiddler crabs are very sensitive to predatory elements and as such will build burrows in areas where they sense less threats. Increased anthropogenic activities threaten the mangrove ecosystem and so fiddler crabs will seek to migrate to areas of less disturbance and as observed the forested area is more littered with waste and refuse which could be a sign of higher anthropogenic activities.

Correlation between crab population and burrows

The study found a negative correlation between the number of burrows and crab population, which means the total number of burrows exceeds the total fiddler population (i.e., the more the burrow the lesser the crab population). This finding can be because many burrows are abandoned as a result of increased anthropogenic activities (sand mining, dredging, marine transport, fishing and hunting activities and pedestrian intrusion, etc.) in the study areas. In addition, many of the burrows are relics of thriving crab population before the advent of human-mediated activities. Other reasons could also be that more burrows are built not necessarily as habitats but as dummies to create a diversion for predators. More burrows construction also helps to aerate the ground for the crabs in terms of oxygen circulation. There is also an underground connection of the burrows to enable escape from predators.

Soil Physico-Chemistry of Study Area

The deforested site has higher concentration of THC because of natural and anthropogenic reasons. The deforested site has no trees therefore, it has low quantity of ground surface litter, which is often decomposed by soil bacteria including the hydrocarbon utilizing bacteria. Hydrocarbon utilizing bacteria breaks down hydrocarbons and reduces the soil concentration. Anthropogenic factors include the deposition of used fuel by the bulldozers used to mow down the trees. Zinc, concentration on the other hand, is caused by natural weathering process that releases heavy metals from the parent sedimentary rocks beneath the earth crust. Therefore, high concentration of Zinc in the forested site may be caused by variability of heavy metals across the land surface in the study area as reported by previous research (Escarré et al., 2000). Increased zinc concentration at a given site is caused by a combination of human-mediated additions and natural weathering process whether the site is deforested or forested.

Microbial population in forested and deforested areas

The deforested area has more organic products from plants and animal matter deposited by tidal currents as observed during the field work. In the same vein, waste products brought into crab burrows also contain remnants of food items taken into the ground by the crabs.

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Conclusion

A world without mangroves will be significantly disadvantageous. Efforts must therefore be made to effectively discourage the negative trend of mangrove deforestation and attempts made at restoration of mangrove forest. These efforts must also include the protection of the fiddler crabs as their importance to the existence of a healthy mangrove ecosystem cannot be over emphasized. From the result of the experiment, the fiddler crab population and burrow distribution in the mangrove of Eagle Island has been greatly impacted by the anthropogenic activities over time. It is also clear that the surviving mangrove forest around the eagle island is under a viable threat of extinction if concerned authority do not rise to the occasion and take better informed decision that will lead to a cessation of further encroachment, sand filling and other anthropogenic activities that are currently threatening the existence of a mangrove forest and a vibrant fiddler crab population.

The data analyzed from this study when compared with previous studies from this site vividly portrayed fiddler crabs as bio indicators of a disturbed and diminishing mangrove forest and this concept could be further studied and even taught to the local population around coastal regions as a natural way of measuring the level of impact of human activities on nearby mangrove forest.

Conclusively, it is a fact even as proved by this study that the mangrove forest in Nigeria and its accompanying abiotic and biotic components like the fiddler crabs are under a real and potent threat that if not quickly and sufficiently addressed could deprive Nigeria of the immense benefits of a rich and vibrant mangrove ecosystem.

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