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Floristic and Microbial Status of Fragmented Urban Mangrove Forest in Eagle Island Port Harcourt

Simbi-Wellington W. S.[1*], Le-ol Anthony E. N.[2], Ikechukwu L. O.[1]

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ABSTRACT

This study assessed the floristic and microbial status of fragmented urban mangrove forests at Eagle Island, Port Harcourt, Nigeria. Vegetative and sediment samples were collected from three fragmented zones using a random sampling technique. Species richness, composition, abundance, and diversity were determined using Margalef's and Simpson's indices, while standard laboratory procedures were employed to analyze microbial populations in the sediments. A total of 14 plant species from 9 families, including Rhizophoraceae, Palmae, Avicenniaceae, Poaceae, and Combretaceae, were recorded. Fragment A contained 1,742 individuals (12 species, 7 families), Fragment B had 2,261 individuals (8 species, 7 families), and Fragment C had 7,787 individuals (10 species, 7 families). *Nypa fruticans* exhibited the highest abundance in all fragments (20.21%, 89.52%, and 88.15%, respectively). Species richness and diversity were highest in Fragment A (Margalef index = 1.60071; Simpson index = 5.31011). Microbial analysis revealed bacterial species including *Klebsiella sp., Bacillus sp., Pseudomonas sp.,* and *Staphylococcus aureus,* and fungal species including *Candida albicans*, *Aspergillus sp., Penicillium bilaiae,* and *Fusarium sp.* Hydrocarbon-utilizing microbes such as *Bacillus spp.* and *Pseudomonas bilaiae* suggest the influence of anthropogenic pollution on the mangrove sediments. Rapid urbanization has altered the forest structure, favoring mangrove associates and non-mangrove species over true mangrove species. It is recommended that the remaining fragmented mangrove areas be formally protected to conserve their ecological, social, and economic functions.

INTRODUCTION

Mangroves are coastal forests stretched between the land and sea, occurring in sheltered estuaries, along riverbanks, and within lagoons across tropical and subtropical regions of the world (Akram *et al.,* 2023; Kathiran & Bingham, 2001). The term mangrove refers both to the unique ecosystem and plant families that have evolved specialized adaptations for survival in dynamic, tidally influenced environments (Kathiran & Bingham, 2001). Urban mangroves are mangroves located in cities and residential areas; they occur along coastal zones and waterways within urban settings (Reyes *et al.,* 2022). These ecosystems are highly productive, providing critical ecological services such as shoreline protection, nutrient cycling, nursery habitats for aquatic species, and support for endangered fauna including *Panthera tigris tigris*, dolphins, otters, manatees, and various avian species like egrets, pelicans, and eagles (Alongi, 2014; Nagelkerken, *et al.,* (2008)). Choudhary (2024) highlights that mangrove ecosystems are important carbon stores (blue carbon) and help capture and sequester CO_2 from the atmosphere often at rates higher than many terrestrial forests.

However, mangrove ecosystems are increasingly threatened by human activities, particularly in urbanized coastal zones. Rapid and poorly planned urban expansion, industrial development, and infrastructure growth have led to habitat loss, fragmentation, and degradation, which compromise the ability of mangroves to maintain their ecological functions. Fragmentation reduces connectivity, increases susceptibility to invasive species, accelerates sediment erosion, and lowers species diversity (Haddad *et al.,* 2015; Dahdouh-Guebas *et al.,* 2005; Thampanya *et al.,* 2006). Human access associated with unplanned urban development often results in overharvesting and exploitation of mangrove resources (Barber *et al.,* 2014; Li *et al.,* 2013).

In the highly industrialized city of Port Harcourt, the pressure of urbanization and industrial activities on mangrove forests is particularly evident at Eagle Island. Anthropogenic activities have drastically reduced the size of the mangrove forest existing in that axis, fragmenting it into an irreversible state with a negative impact on both the flora and other organisms in the ecosystem. This study therefore aims at providing a baseline data of flora species diversity and microbial population status of the fragmented portions of the forest as a reference material for further studies, emphasizing the urgent need for sustainable urban planning alongside conservation efforts due to the continuous infrastructural development in the area.

MATERIALS AND METHODS

This study was conducted in Eagle Island, Port Harcourt, Rivers State, Nigeria. Port Harcourt is located between latitudes 4°43' and 4°54' N and longitudes 6°56' and 7°03' E, at an elevation of approximately 59 feet (18 meters) above sea level. The area is characterized by a humid

[1] Department of Forestry and Environment, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria
[2] Department of Urban and Regional Planning, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria
[*] Corresponding author's e-mail: werisuo.simbi-wellington@ust.edu.ng

tropical climate, with a mean annual rainfall exceeding 2,000 mm and an average annual temperature of about 29 °C. Port Harcourt is a highly industrialized city and serves as a major industrial hub in Nigeria, hosting numerous multinational companies and industrial establishments, particularly those associated with the petroleum sector. It is the country's principal oil-refining city, with crude oil representing one of Nigeria's most important commodities and the primary source of foreign exchange earnings (NMS, 1998). Vegetative and sediment samples were randomly collected in three replicates from three distinct fragmented zones of the mangrove forest labelled A, B and C. Collected samples were carefully placed in well-labelled polyethylene bags and vial bottles for vegetation and sediments respectively, before being transported to the Department of Forestry and Environment, Rivers State University, for proper identification and labouratory analysis.

Table 1: Coordinates of Study Locations

Location	N(Latitude)	E(Longitude)
Fragment A	4^0 47'11"	6^0 58'34"
Fragment B	4^0 47'19"	6^0 58'42"
Fragment C	4^0 47'16"	6^0 59'40"

Floristic species diversity was assessed using Simpson's Species Diversity Index (Simpson, 1949). The index was calculated using the expression:

$$D = 1 - \left(\frac{\Sigma\, n(n-1)}{N(N-1)} \right)$$

where D represents the index of diversity, N is the total number of individuals observed, and n is the number of individuals of a given species. Simpson's Inverse Index of Diversity was subsequently computed to enhance interpretability and was expressed as:

$D^1 = (1/D)$

Species richness was estimated using Margalef's Index (Margalef, 1958), a simple and widely applied measure of species richness. Margalef's index was calculated as:

d = (S – 1) / In N

where S denotes the total number of species recorded, N is the total number of individuals in the sample, and ln represents the natural logarithm.

Sediment samples were subjected to ten-fold serial dilution using sterile physiological saline as the diluent. Aliquots from appropriate dilutions were inoculated onto nutrient agar (NA) plates for the determination of total bacterial counts. Fungal species were isolated using mineral salt agar (MSA) and the vapour-phase transfer technique as described by Okpokwasili and Amanchukwu (1987).

Distinct microbial colonies observed were subcultured repeatedly to obtain pure isolates. The purified isolates were subsequently characterized and identified based on macroscopic and microscopic examination, as well as biochemical tests, following standard identification procedures outlined by Cowan and Steel (1965).

RESULTS AND DISCUSSIONS

The floristic composition of the fragmented mangrove forest at the study locations is presented in Table 2. The results show that a total of 14 plant species belonging to 9 families were recorded across the study area. The families encountered include Rhizophoraceae, Palmae, Avicenniaceae, Pteridaceae, Poaceae, Arecaceae, Combretaceae, Asteraceae, and Commelinaceae. The plant species identified include *Rhizophora racemosa, Rhizophora harrisonii, Rhizophora mangle, Elaeis guineensis, Avicennia germinans, Acrostichum aureum,* and *Terminalia catappa*, among others. Across the three fragmented zones, a total of 1,742 individuals belonging to 12 species and 7 families were recorded in Fragment A, while Fragment B contained 2,261 individuals representing 8 species and 7 families. Fragment C had the highest abundance, with 7,787 individuals belonging to 10 species and 7 families. Results presented in Table 2 further indicate that *Nypa fruticans*, a non-mangrove species, recorded the highest number of individuals in Fragment C (6,864). Figure 1 illustrates the distribution of true mangrove species across the fragments. Members of the family Rhizophoraceae were most abundant in Fragment A, with *Rhizophora racemosa* (58 individuals), *Rhizophora harrisonii* (34 individuals), and *Rhizophora mangle* (45 individuals) recording the highest occurrences in that fragment. In contrast, *Avicennia germinans* and *Laguncularia racemosa* showed their highest abundances in Fragment C, with 47 and 14 individuals, respectively.

Table 2: Floristic Species Composition

Species	Family	Fragment A	Fragment B	Fragment C
Rhizophora racemose	Rhizophoraceae	58	7	13
Rhizophora harrisonii	Rhizophoraceae	34	0	0
Rhizophora mangle	Rhizophoraceae	45	19	33
Elaeis guineensis	Palmea	0	2	0
Avicenia germinans	Avicenniaceae	13	10	47
Acrostichum aureum	Pteridaceae	0	171	38
Paspalum viginatum	Poaceae	430	0	168
Axonopus compressus	Poaceae	250	0	45
Cynodom Procumbens	Poaceae	478	25	215

Nypa fruticans	Arecaceae	352	2024	6864
Laguncularia racemosa	Combretaceae	9	3	14
Terminalia catappa	Combretaceae	1	0	0
Tridax procumbens	Asteraceae	45	0	350
Commelina benghalensis	Commelineceae	27	0	0

Source: Field survey, 2024

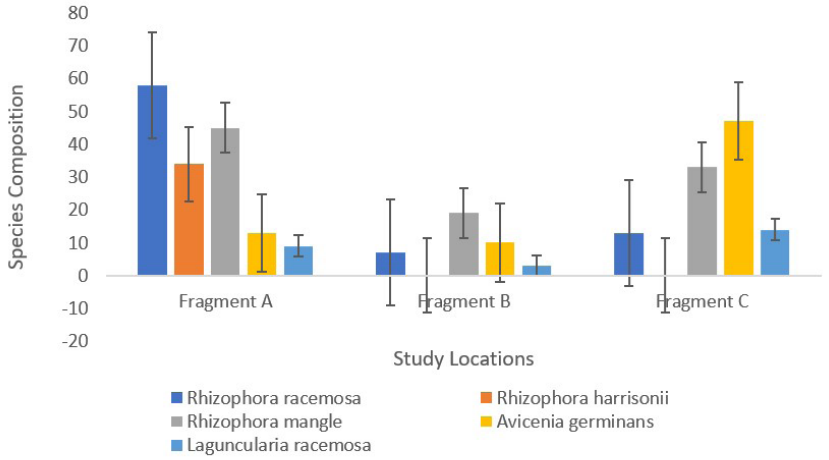

Figure 1: True Mangrove Species Composition

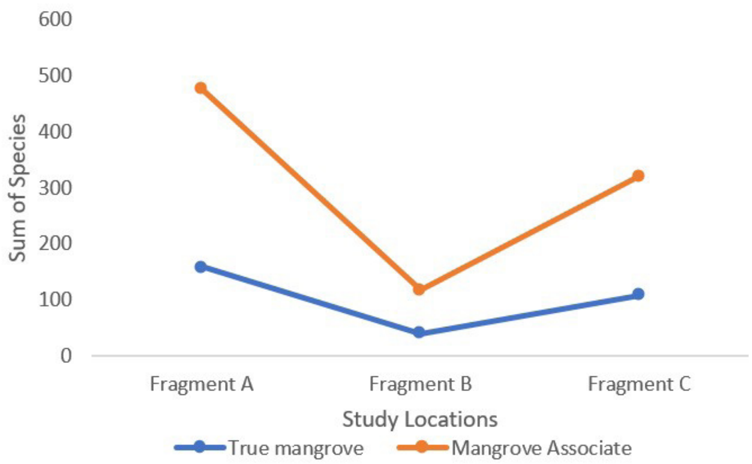

Figure 2: Abundance of True Mangrove and Mangrove Associates

Mangrove associate species were observed to be more abundant than true mangrove species across all fragmented zones, as illustrated in Figure 2. Results presented in Table 3 show the species abundance and relative abundance across the three fragmented zones of the mangrove forest. *Nypa fruticans* recorded the highest species abundance in all fragments, accounting for 20.21%, 89.52%, and 88.15% of the total individuals in Fragments A, B, and C, respectively. In contrast, *Terminalia catappa* recorded the lowest species abundance in Fragment A (0.06%), while *Elaeis guineensis* showed the lowest abundance in Fragment B (0.09%). In Fragment C, *Rhizophora racemosa* recorded the lowest species abundance (0.17%).

Table 3: Floristic Species Abundance and Relative abundance

Species	Abundance /Fragment			Relative Abundance/Fragment		
	A	B	C	A	B	C
Rhizophora racemose	58	7	13	3.33	0.31	0.17
Rhizophora harrisonii	34	0	0	1.95	0	0
Rhizophora mangle	45	19	33	2.58	0.84	0.42
Elaeis guineensis	0	2	0	0	0.09	0
Avicenia germinans	13	10	47	0.75	0.44	0.60

Acrostichum aureum	0	171	38	0	7.56	0.49
Paspalum viginatum	430	0	168	24.68	0	2.16
Axonopus compressus	250	0	45	14.35	0	0.58
Cynodom Procumbens	478	25	215	27.44	1.11	2.76
Nypa fruticans	352	2024	6864	20.21	89.52	88.15
Laguncularia racemose	9	3	14	0.52	0.13	0.18
Terminalia catappa	1	0	0	0.06	0	0
Tridax procumbens	45	0	350	2.58	0	4.59
Commelina benghalensis	27	0	0	1.55	0	0
SUM (N)	1,742	2,261	7,787	100	100	100
Number of Species	12	8	10			

Source: Field survey, 2024

Species richness and diversity, as assessed using Margalef's and Simpson's indices, are presented in Table 4. Both species richness and diversity were highest in Fragment A, with Margalef's richness index of 1.60071 and Simpson's diversity index of 5.31011, respectively.

Table 4: Richness and Diversity of Floristic Species

Indices	**Fragment A**	**Fragment B**	**Fragment C**
Margalef's Species Richness	1.60071	1.03549	1.11574
Simpson's Species Diversity (D)	0.18832	0.80365	0.77653
Simpson's Inverse (D^1)	5.31011	1.24432	1.28778

Source: Field survey, 2024

The bacteria and fungi species isolated and identified from the mangrove sediments are presented in Table 5. The bacterial identified include *Klebsiella sp., Bacillus sp., Pseudomonas sp., Citrobacter sp., Staphylococcus aureus, Aeromonas aquariorum, Streptococcus sp.,* and *Micrococcus sp.* Fungal species identified from the sediments comprised *Candida albicans, Aspergillus sp., Penicillium bilaiae, Fusarium sp., Rhizopus sp.,* and yeast species.

Table 5: Bacteria and Fungi Species in the Mangrove Sediments

Mangrove Fragments	**Microbes**	
	Bacterial	**Fungi**
A	*Klebsiella sp* *Bacillus sp.* *Pseudomonas aeruginosa* *Citrobacter sp.* *Staphylococcus aureus* *Micrococcus sp* *Aeromonas aquariorum*	*Candida albicans* *Penicillium bilaiae* *Yeast sp.* *Aspergillus niger* *Fusarium solani* *Rhizopus stolonifera*
B	*Bacillus subtilis.* *Staphylococcus aureus* *Streptococcus sp.* *Aeromonas aquariorum*	*Fusarium solani* *Penicillium bilaiae* *Rhizopus stolonifer* *Candida albicans* *Aspergillus niger*
C	*Bacillus subtilis* *Staphylococcus aureus* *Klebsiella sp* *Aeromonas aquariorum* *Pseudomonas aeruginosa* *Aeromonas aquariorum* *Streptococcus sp.*	*Mucor amphiborum* *Rhizopus stolonifera* *Fusarium solani* *Yeast* *Aspergillus niger*

Source: Field survey, 2024

Discussion

The true mangrove species observed in the fragmented zones included *Rhizophora racemosa, Rhizophora harrisonii, Rhizophora mangle, Avicennia germinans,* and *Laguncularia racemosa*, consistent with reports from Omogoriola *et al.,* (2012) and Numbere (2014), who identified these species as dominant in Niger Delta mangroves.

The dominance of mangrove associate and non-mangrove species, such as *Nypa fruticans, Acrostichum aureum,* and *Paspalum vaginatum,* across all fragments indicates significant ecosystem disturbance. This finding aligns with Okpiliya *et al.,* (2013) and Simbi-Wellington and David-Sarogoro (2022), who reported similar trends in disturbed mangrove ecosystems. In the context of Eagle Island, this shift from true mangroves to associates is strongly linked to the effects of rapid and poorly planned urban expansion, including industrial development, settlement growth, and inadequate coastal land-use planning.

Species diversity, as measured by Simpson's index, and species richness, as measured by Margalef's index, were highest in Fragment A, suggesting that even small, less-disturbed patches retain relatively high biodiversity. However, the overall floristic composition reflects a landscape under pressure from urbanization, where habitat fragmentation and human activity have favored resilient or opportunistic species.

Microbial analysis revealed the presence of bacterial species including *Klebsiella sp., Bacillus sp., Pseudomonas sp.,* and *Staphylococcus aureus,* and fungal species such as *Candida albicans*, *Aspergillus sp., Penicillium bilaiae,* and *Fusarium sp.*, consistent with previous reports (Simbi-Wellington & Chukunda, 2019; Nwaugo *et al.,* 2005; Ukoima *et al.,* 2016). The detection of hydrocarbon-degrading microbes, including *Bacillus spp.* and *Pseudomonas bilaiae*, suggests anthropogenic pollution, likely exacerbated by industrial activities in the area (Ezeigbo *et al.,* 2013; Prescott *et al.,* 1999). The presence of such microbes highlights the combined impact of habitat disturbance and pollution resulting from poor urban planning. These findings underscore that unplanned urban expansion has significant ecological consequences on urban mangrove, including reduced abundance of true mangrove species, proliferation of non-mangrove associates, habitat fragmentation, and sediment contamination, all of which threaten the sustainability of mangrove ecosystems in Eagle Island, Port Harcourt.

CONCLUSION

This study assessed the floristic and microbial status of fragmented mangrove forests at Eagle Island, Port Harcourt. A total of 14 plant species from 9 families were recorded, with *Nypa fruticans* dominating all fragments. Species richness and diversity were highest in Fragment A (Margalef = 1.60071; Simpson = 5.31011). Microbial analysis revealed both common sediment microbes and hydrocarbon-degrading bacteria, indicating anthropogenic pollution. Rapid and poorly planned urban expansion in the Eagle Island area has altered the mangrove forest structure, reducing the abundance of true mangrove species and promoting mangrove associates and non-mangrove species. To mitigate further degradation, it is recommended that: The remaining fragmented mangrove areas be formally designated as protected reserves to conserve ecological, social, and economic functions. Sustainable urban planning strategies be implemented to regulate industrial, residential, and infrastructural development along coastal zones, minimizing habitat destruction, and preserving natural resources. Public awareness programs be conducted to educate local communities on the ecological and economic importance of mangroves.

REFERENCES

Akram H., Hussain S., Mazumdai P., Chua K.O., Butt T.E & Harikrishna J. A (2023). Mangrove Health: A Review of Functions, Threats, And Challenges Associated with Mangrove Management Practices. *MDPI 14*(9), 1698;https://doi.org/10.3390/f14091698

Alongi, D. M. (2014). Carbon cycling and storage in mangrove forests. *Annual Review of Marine Science, 6,* 195–219. https://doi.org/10.1146/annurev-marine-010213-135020

Barber, C. P., Cochrane, M. A., Souza, C. M. & Laurance, W. F. (2014). Roads, deforestation, and the mitigating effect of protected areas in the Amazon. *Biol. Conserv. 177,* 203–209. Article Google Scholar

Choudhary, B. (2024). Blue carbon and the role of mangroves in carbon sequestration: Its mechanisms, estimation, human impacts and conservation strategies for economic incentives. *Journal of Sea Research, 199,* 102504. https://doi.org/10.1016/j.seares.2024.102504

Cowan, S. T., & Steel, K. J. (1965). *Manual for the identification of medical bacteria.* Cambridge University Press.

Dahdouh-Guebas, F. Jayatissa, L P., Nitto, D.D., Bosire, J. O. Seen, D.L., & Koedam, N. (2005). How effective were mangroves as a defence against the recent tsunami? *Curr. Biol. 15,* 1337–1338.

Ezeigbo O.R., Okike-Osisiogu, F.U., Ihemanma C.N. & Agomoh, N.G. (2013) Microbial Effects of Gas Flaring on Agricultural Soil at Izombe Flow Station, Imo State Nigeria. *Journal of Biology, Agriculture and Healthcare, 2*(15).

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., Lovejoy, T. E., Sexton, J. O., Austin, M. P., & Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances, 1*(2), e1500052. https://doi.org/10.1126/sciadv.1500052

Kathirensan, K., & Bingham, B. L. (2001). Biology of mangrove and mangrove ecosystems. *Advances in Marine Biology, 40,* 81–251.

Li, M. S., Mao, L. J., Shen, W. J., Liu, S. Q., & Wei, A. S. (2013). Change and fragmentation trends of Zhanjiang mangrove forests in southern China using multi-temporal Landsat imagery (1977–2010). *Estuarine, Coastal and Shelf Science, 130,* 111–120.

Margalef, R. (1958). Information theory in ecology. *General Systems, 3,* 36–71.

Nagelkerken, I., Blaber, S. J. M., Bouillon, S., Green, P., Haywood, M., Kirton, L. G., Meynecke, J. O., Pawlik, J., Penrose, H. M., Sasekumar, A., & Somerfield, P. J. (2008). The habitat function of mangroves for terrestrial and marine fauna: A review. *Aquatic Botany, 89*(2), 155–185. https://doi.org/10.1016/j.aquabot.2007.12.007

Nigerian Meteorological Services. (1998). *Nigeria meteorological services report, 2,* 1–10.

Numbere, A. O. (2014). *Impact of hydrocarbon pollution on the mangrove ecosystem of the Niger River Delta, Nigeria* (Doctoral dissertation, Saint Louis University).

Nwaugo, V. O., Onyeagba, R. A., & Nwachukwu, N. C. (2005). Effect of gas flaring on soil microbial spectrum in parts of Niger Delta area of southern Nigeria. *African Journal of Biotechnology, 5*(19).

Okpiliya, F. L., Effiong, E. B., & Imoke, E. (2013). Mangrove forest ecosystem utilization and depletion: Implication for occupational changes in Calabar South, Nigeria. *European Journal of Sustainable Development, 2*(1), 149–162.

Okpokwasili, G. C., & Amanchukwu, S. C. (1987). Petroleum hydrocarbon degradation by Candida species. Environment International, 13(2–4), 245–248.

Omogoriola H.O., Williams A.B. & Ukaomu S.C. (2012) survey Biodiversity and Impact of Economics Activities on Mangrove Ecosystem in Eastern Parts of Lagos Lagoon, Nigeria. *Journal of Nature and Science 10*(10) pp 30-34

Prescott, L. M., Harley, J. P., & Klein, D. A. (1999). *Microbiology* (4th ed.). McGraw-Hill.

Reyes, G., Smyth, A., & Reynolds, L. (2022). *What are urban mangroves?* University of Florida IFAS Extension.

Simbi-Wellington, W. S., & David-Sarogoro, N. (2022). Status of floristic species in a mangrove forest around a gas flaring station in Rivers State, Nigeria. In *Proceedings of the 43rd annual conference of the Forestry Association of Nigeria (FAN)* (pp. 44–55).

Simbi-Wellington, W.S. & Chukunda F.A. (2019). Impact Assessment of Gas Flaring on the Microbial Population of Mangrove Forest of Awoba Flow Station in Bille, Rivers State. *Merit Research Journal of Agricultural Science and Soil Science, 7*(12),177-185

Thampanya, U., Vermaat, J. E., Sinsakul, S., & Panapitukkul, N. (2006). Coastal erosion and mangrove progradation of southern Thailand. *Estuarine, Coastal and Shelf Science, 68,* 75–85.

Ukoima, H. N., Chukunda, F. A., Ngerebara, D. O., & Halliday, S. (2016). Bacteria, plant nutrients, and plant population following gas flare in Oloma community, Rivers State, Nigeria. *International Journal of Agriculture and Earth Science, 2*(2), 1–15.