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Assessment of the Impact of Land-Use Change on the Abundance, Composition and Diversity of Mangrove Insects in Bundu-Ama, Niger Delta

Mbam Itumo[1]* Ikechukwu O. Agbagwa[2] Okorite Itumo[3] Onyinye Choko[4] Paschal N. Okeke[5]

1. Fenner School of Environment and Society, Bushfire Research Centre of Excellence, The Australian National University, Canberra, ACT 2601, Australia.
2. Department of Plant Science & Biotechnology, Faculty of Science, University of Port Harcourt, East West Road, 500102 Choba, Nigeria
3. Fenner School of Environment and Society, The Australian National University, Canberra, ACT 2601, Australia.
4. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, Georgia 30602, USA
1. Institute of Geoscience and Environmental Management, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria

* E-mail of the corresponding author: itumombam@gmail.com

Abstract

Mangrove insect abundance, richness and diversity are currently experiencing a huge decline due to human activities especially in developing nations. In this study, we set out to assess the impact of land use change on the abundance, composition and diversity of mangrove insects in Bundu-Ama, Niger Delta, between the year 2017 and 2023. For this to be achieved, sampling exercise was conducted every other week for a period of three months. Insects were collected and documented with reference to the particular tree species where it was foraging at the point of collection. Insect identification was conducted in the field and later verified in the lab. A Geographic information systems software was used to determine the change in mangrove vegetation between both study periods. The result showed that about 3.39Ha of mangrove in the immediate surroundings of the sample site have been lost to infrastructure development during the period. This also resulted in a huge decline in the insect biodiversity of the mangrove ecosystem. In *Avicennia*, the insect population reduced from twenty-two to nine insect species, twenty-one to nine insect families, with a shift in dominance from Formicidae to Tabanidae. More so, diversity reduced to 1.766, evenness reduced to 80% and a dissimilarity value of 58% was recorded during the period. Meanwhile in Rhizophora, the insect community reduced from seven to three insect species; the family also reduced from seven to three, with Formicidae retaining its dominance. The ecological indices showed that diversity was very low (0.874), evenness increased slightly to 80% and the dissimilarity index was 41%. The study asserts that consequence of the loss of insect communities in the area would result in the decline in ecosystem services such as food provision, diseases control, loss of gene pool, plus an alteration in the natural, biological and environmental cycles. Hence, there is an urgent need for action from stakeholder groups to halt this menace and rehabilitate the mangrove ecosystem halting the detrimental impact on insect biodiversity. Moreover, there is an imminent need to educate the citizens on the consequences of their activities on the environment.

Keywords: Mangrove, Insect, Land use, Niger Delta, Biodiversity

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1. Introduction

Insect abundance, richness and diversity are currently experiencing a huge decline due to anthropogenic activities and this has been gathering attention of experts all over the world and is generating debates (Dirzo *et al.,* 2014; Lister & Garcia, 2018; Yeo *et al.,* 2021). The sustained debates on the subject is largely tied to the fact that there is a huge deficiency of available and reliable data on insects, plus a trivial knowledge of the rate or magnitude of change in species composition along predefined spatial or environmental gradients (Yeo *et al.*, 2021). This paucity in knowledge has greatly impacted the value-based system for insects in the ecosystem. Unknowing to so many, insects are key components in the ecosystem, providing services such as pollination, food for birds and reptiles, and diseases control. Although they are not structurally huge, they are a key stone species, as they guaranty the continuity of plant species, which are the primary producers in the ecosystem (Gómez *et al.,* 2007; Yang & Gratton, 2014). But due to the knowledge gap, its habitat is greatly impacted by anthropogenic activities and the rate of conversion is massive (Ewers *et al.,* 2015; Yeo *et al.,* 2021).

The situation is especially horrible in developing nations of the tropics, in which other issues such as hunger, poverty, insecurity, political unrest, high rate of inequality, in addition to the threat posed by climate change tending to be more pressing, distracting the attention of stakeholders towards focusing on insect biodiversity (Bhakuni, 2023; Murshed & Regnault, 2023; Rahaman *et al.,* 2021; Raihan, 2023). Hence, there is no comprehensive database of the insect fauna of these regions, and as such there are no baseline which could serve as indicators for monitoring change. The bulk of information available largely focuses on insects of freshwater ecosystems, but those of the mangrove are highly neglected (Adeniyi & Adeyinka, 2013; Basset *et al.,* 2012; Yeo *et al.*, 2021). Some authors argue that the reason for this gross neglect is as a result of the low plant diversity and richness which also affects the insect dynamics in the ecosystem (Asuk, 2018). Others hinge it on the difficulty in accessing the ecosystem, hence carrying out detailed study in the area poses a humungous challenge (Munji *et al.,* 2014; Younes Cárdenas *et al.,* 2017).

The case of the Niger Delta Mangrove and its insect population is not different from those of other developing nations. The Niger Delta Mangrove is the largest in Africa and it is considered the third largest in the world, covering over 853km (Numbere, 2019; Oloyede *et al.,* 2022; Ogbeibu *et al.,* 2023). This ecosystem bounds the coastlines of the Niger Delta from the upsurge of the Atlantic waves, sequesters carbon in its soil and plants, serves as breeding ground for fishes and provides fuel wood for the locals (Numbere, 2019; Oloyede *et al.,* 2022; Ogbeibu *et al.*, 2023). Despite these services, the mangrove ecosystem has been declining in an alarming rate. Previous study on the Niger Delta shows that between year 2007 and 2017, there was a 12% loss of mangrove in the region (Nwobi *et al.,* 2020); and results by (Itumo *et al.*, 2023) captured a cumulative decline of about 47% of mangrove in the mangrove of Port Harcourt, a region in the Niger Delta. A study by (Omo-Irabor *et al.,* 2011) showed that the vulnerability index of population pressure and deforestation was about 75%, hence implying that mangroves are at the mercy of human development. These uncontrolled losses have greatly impacted these habitats of insects, hence reducing their activities.

Although only a handful of study on the insect biodiversity of the Niger Delta mangrove have been conducted thus far, but none have actually focused on the impact of land use change on the mangrove insects of the Niger Delta. (Membere *et al.,* 2021) conducted a study on the abundance and diversity of insects associated with the mangroves of a county in the Niger Delta; (Gbarakoro & Okene, 2020) also assessed the mangrove Insect Functional Groups in Asarama community, in the Niger Delta; and (Uwagbae *et al.,* 2019) investigated the impact of disturbances on the biodiversity of Ijala-Ikeren Wetland Ecosystem in Niger Delta, of which insect population was accounted for. However, in this present study, we present the impact of land use change on the abundance, composition and diversity of mangrove insects in Bundu-Ama community in the Niger Delta.

2. Materials and Methods

2.1 Study area

Located in Port Harcourt metropolis, Bundu-Ama is a community in the Niger Delta sedimentary Basin (Fig 1), and within latitude 3.055 N and longitude 5.047 E. The Bonny River floods the area every day with tidal water. *Rhizophora mangle*, *Avicennia germinans*, and a few stands of *Rhizophora racemosa* and *Laguncularia sp*. are the predominant mangrove species at the site. Here, fishing, hunting for crabs, and trading are the primary human activities. A diverse range of built-up landcover, serving both commercial and residential uses, envelops the study region. There is an Eagle Cement Production Company near the study area. There are deforested areas inside the mangroves that are being used to build affordable houses. Due to their abundance, the plant species sampled for the study belonged to the *Rhizophora* and *Avicennia* genera.

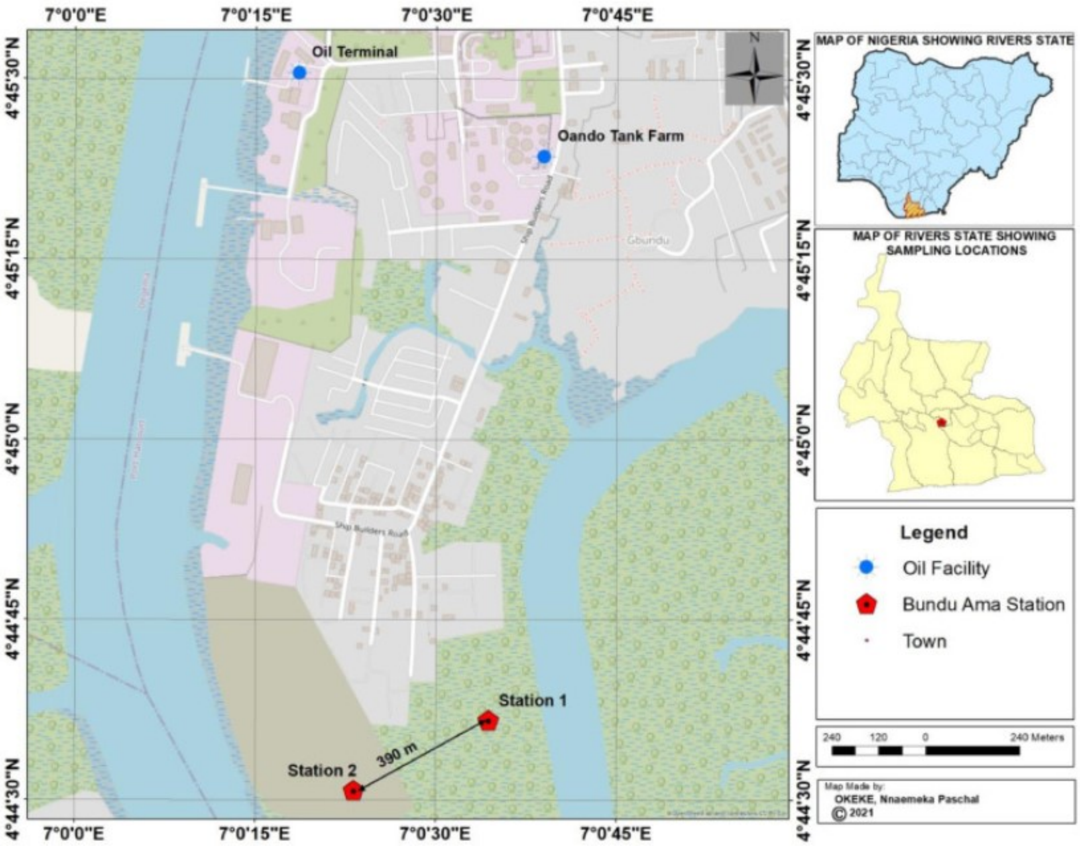

Figure 1. Map showing Bundu-Ama in the Niger Delta (Source: Membere *et al.,* 2021)

2.2 Change Detection – GIS Mapping

Sentinel 2 imagery of the site was acquired for the year 2017 and 2023. The imageries were georeferenced and orthorectified. Buffer distances of 200meters, 500meters and 1000meters were generated and overlaid on the imageries to signify the area of interest. Image classification was then performed on the imageries to establish the landuse/landcover (LULC) classes that are present. At the end of the classification process, eight LULC classes were identified and delineated. They are Water, Freshwater swamp forest, Mangrove, Agriculture, Built Up, bareground, Grassland and secondary forest. The LULC were vectorized and the intersect tool detect was used for the change in the two LULC datasets by taking the attribute from both LULC dataset and creating a new output data.

2.3 Sample Collection

For three months during the dry season, samples were taken every two weeks (April, May and June) in 2017 and 2023. Based on the abundance of the plant species sampled, two sampling sites were set up. Two 90-meter transect lines separated by 20 meters were placed at each station. Three 10 × 10 m plots measuring 20 m apart were set up in each station inside each transect line for the purpose of sampling mangrove trees. Each plot had three plants sampled, one each of *Rhizophora* and *Avicennia,* for a total of eighteen trees for each sample site and thirty-six trees for the two sampling stations. During the course of the study, samples from 216 trees were taken. Ten minutes were spent sampling each tree. At low tide, between 7 and 11 am, when the majority of insects were most active, the insects were collected. At each plot, insects were collected from the randomly selected trees using sweep net, hand net, hand picking methods and also by taking photographs of insects and noting on which plant the insect was observed. All insects were preserved in 70% ethanol in well labelled vials. Insects were gathered from the randomly chosen trees in each plot using a sweep net, a hand net, hand picking techniques, as well as by taking pictures of the insects and marking the plant on which they were seen. Every specimen was kept inside vials of 70% ethanol and was clearly labelled.

2.4 Identification

In accordance with Ameen *et al.* (1982) and Ameen & Nessa (1985), every sample taken from the study area was identified. The Department of Crop Protection at Ahmadu Bello University in Zaria's and Curator Insect Museum also validated the identification of the insects.

2.5 Statistical Analysis

The diversity of insect species in the mangrove research region was ascertained and explained using biodiversity indices such as Shannon Wiener Diversity, Pielou evenness and Bray Curtis dissimilarity indices. The JMP software version 17 was used for these analysis, and Microsoft Excel was used to create the graphical displays.

3. Result

3.1 Change Detection

The result of the change in mangrove vegetation in the station is contained in figure 2 to 5. Figures 2 and 3 shows the satellite imagery layout of the observed change in mangrove vegetation in the area for the year 2017 (Fig 2) and 2023 (Fig 3); while figures 4 and 5 shows the color coded analysis of the imagery denoting the change in mangrove vegetation for the site and period under investigation. The buffer distances of 200meters, 500meter and 1000meters already created were used to clip the change dataset for the site. The change detection analysis was then performed for site at the three distances. The result shows that at Bundu-Ama 200, 500 and 1000 meters from the sample point, mangroves had lost 3.397831Ha. This is a significant decline as mangrove depletion around squatter-settlements begins from the boundaries of human settlements with the mangroves and encroaches deeper into the forest. This is also denoted in the figure 6 below showing a change in mangrove vegetation equivalent to 3% loss, during the period under investigation.

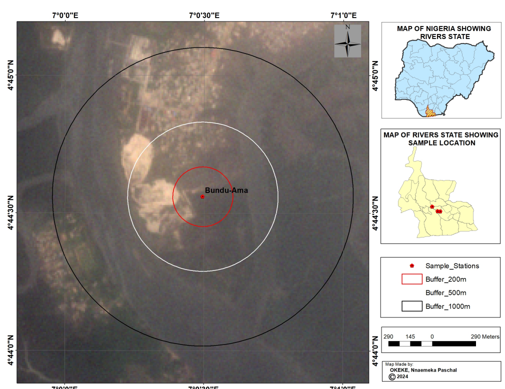

Figure 2: Year 2017 Imagery of Bundu Ama

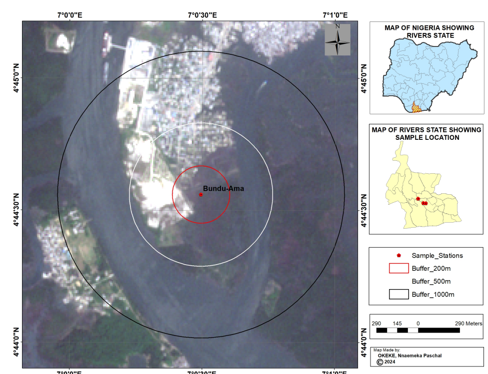

Figure 3: Year 2023 Imagery of Bundu Ama

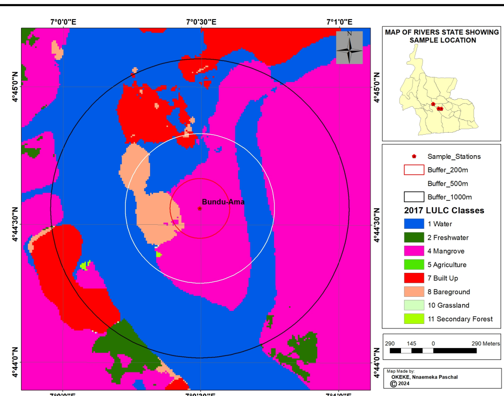

Figure 4: Year 2017 LULC of Bundu Ama

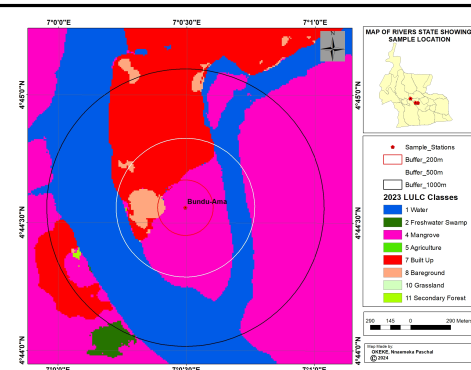

Figure 5: Year 2023 LULC of Bundu Ama

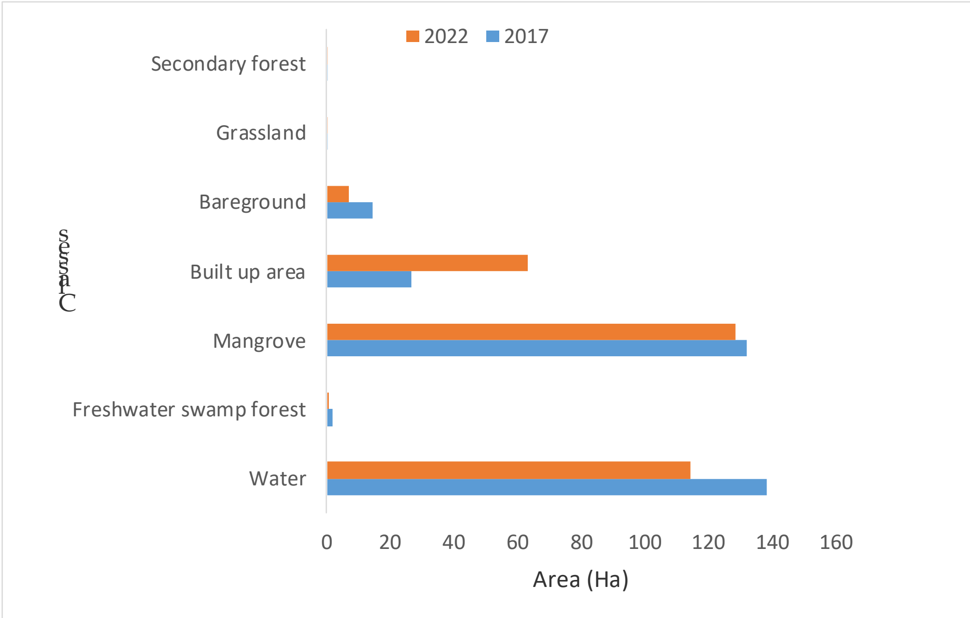

Figure 6. Area of change between land use types

Table 1. shows the relative abundance of *Avicennia* bound insect species and their corresponding families within the period under investigation. In the year 2017, twenty-two insect species were identified, with a maximum relative abundance of 21% and a minimum of 1%; while in the year 2023 only nine insect species were identified, having a maximum relative abundance of 38% and a minimum of 2%. The test of significant difference of the insect abundance between the two period was not significant (p = 0.09694). Additionally, the relative abundance of insect families (Fig 7) shows that twenty-one families were identified in the year 2017, and nine families in the year 2023. Family Formicidae had the most frequency (22%), and Coccinellidae, Pyrrhocoridae, Libellulidae and Lycaenidae all had the least frequency of 1% in the year 2017. Meanwhile Tabnidae recorded the highest frequency (38%) and Coccinellidae, Tephritidae and Alydidae had the least frequency (2%) in the year 2023.

Table 1. Relative abundance of Avicennia bound insect species and families

Species_ID	Family	*Avicennia*_2017	*Avicennia*_2023	p-value
Faina elongata	Miridae	3%		0.09694
Brumoides foudrasi	Coccinellidae	1%		
Atheriogo binubila V. Emden	Muscidae	2%		
Atherioogo pallidipleura	Muscidae	5%		
Apis millifera	Apidae	3%		
Tiphia sp.	Tiphiidae	2%		
Chrysops lengicormis	Tabanidae	2%	38%	
Hyperaspis senegalensis	Coccinellidae	2%	2%	
Didacus sp.	Tephritidae		2%	
Chrysomyia albiceps	Calliphoridae	7%	10%	
Lasius niger	Formicidae	21%	24%	
Acantholepsis sp.	Formicidae	1%		
Riptortus acantharis	Cantharidae	6%	7%	
Chrysis sp.	Alydidae	2%	2%	

Species_ID	Family	*Avicennia*_2017	*Avicennia*_2023	p-value
Dysdercus volkeri	Pyrrhocoridae	1%		
Auplopus commendabilis	Pompilidae	6%	7%	
Bembex liturata	Crabronidae	6%		
Cheilomenes sulphurea	Coccinellidae	3%		
Orthetrum icteromelas	Libellulidae	1%		
Sarcophaga cruentata	Sarcophagidae	9%	7%	
Euchrysops pallidipteura	Lycaenidae	1%		
Oestrus ovis	Oestridae	3%		
Sceliphron spirifex	Sphecidae	9%		

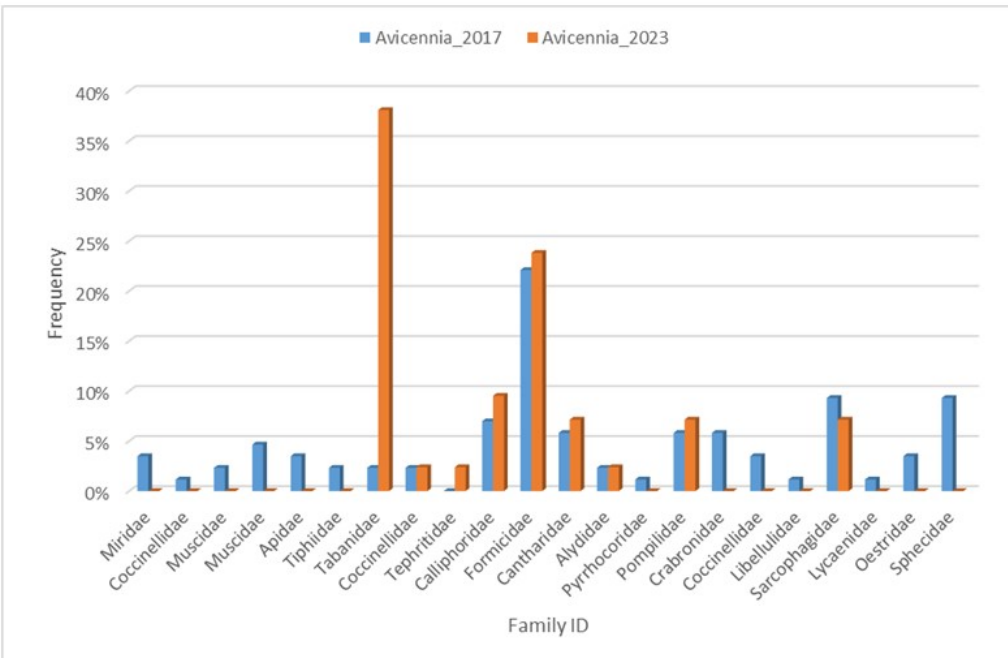

Figure 7. Relative abundance of *Avicennia* bound insect families for the year 2017 and 2023

Table 2. shows the relative abundance of *Rhizophora* bound insect species and their corresponding families within the period under investigation. In the year 2017, seven insect species were identified, with a maximum relative abundance of 56% and a minimum of 4%; while in the year 2023 only three insect species were identified, having a maximum relative abundance of 65% and a minimum of 12%. The test of significant difference of the insect abundance between the two period was not significant (p = 0.57871). Additionally, the relative abundance of insect families (Fig 8) shows that seven families were identified in the year 2017, and three families in the year 2023. Family Formicidae had the most frequency in the year 2017 (56%) and 2023 (65%), while Coccinellidae, Sarcophagidae and Dictyopharidae all had the least frequency of 4% in the year 2017, and Calliphoridae had the least frequency (12%) in 2023.

Table 2. Relative abundance of *Rhizophora* bound insect species and families

Species ID	Family	*Rhizophora*_2017	*Rhizophora*_2023	p-value
Chrysops lengicormis	Tabanidae		24%	0.57871
Chrysomyia albiceps	Calliphoridae	15%	12%	
Lasius niger	Formicidae	56%	65%	
Riptortus acantharis	Cantharidae	11%		
Auplopus commendabilis	Pompilidae	7%		
Cheilomenes sulphurea	Coccinellidae	4%		
Sarcophaga cruentata	Sarcophagidae	4%		
Paradictya sp.	Dictyopharidae	4%		

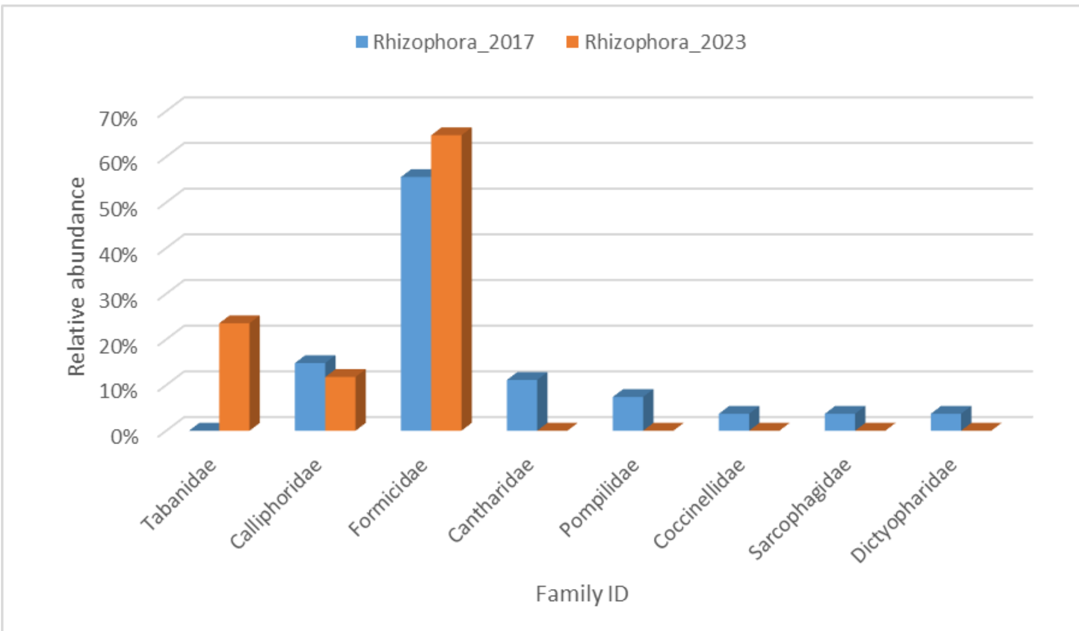

Figure 8. Relative abundance of *Rhizophora* bound insect families for the year 2017 and 2023

The Shannon-Weiner diversity, evenness and Bray and Curtis dissimilarity indices are contained in table 3. For *Avicennia*, there was a decline in species diversity between the period of investigation. Year 2017 had a greater diversity and evenness than year 2023, and the site recorded a 58% dissimilarity index during the period. Similarly, *Rhizophora* recorded a higher insect diversity in the previous year than the later, but a lower evenness in the previous than the later. More so, a dissimilarity index of 41% was observed in Rhizophora insect population between the periods under investigation:

Table 3. Diversity, Evenness and dissimilarity index of the study area

Index ID	*Avicennia*_2017	*Avicennia*_2023	*Rhizophora*_2017	*Rhizophora*_2023
Shannon-Wiener (H)	2.76	1.766	1.413	0.874
Evenness (%)	89	80	73	80
Bray & Curtis (%)	58		41	

4. Discussion

The finding of this study has shown a huge change in the mangrove ecosystem and its associated impact on the insect population in the study area within the period of interest. It revealed a decline in the mangrove vegetation and a commensurate increase in built up areas as a result of anthropogenic activities. This decline in mangrove vegetation poses a huge threat to biological lives in the ecosystem and on the long run would also affect human lives.

During the period under investigation, a decrease in mangrove of about 3.397831Ha which is equivalent to 3% was observed, mainly due to an upsurge in the population of the metropolis and as such, there is a huge requirement for developmental projects to meet the need of the teaming population. Amongst the apparent projects are roads, houses, bridges, which are critical utilities that supports human existence, but to the detriment of other biological components of the environment. There have been several studies in the Niger Delta region highlighting the conversion of mangrove to other land use type. Itumo *et al.* (2023) conducted a study on the diminishing mangrove vegetation in a selected part of Rivers State, and observed about a 47% decrease between a twenty-year period (1993 to 2013). Nwobi *et al.* (2020) also studied the rapid loss of mangrove vegetation and the occupation of harvested mangrove area by an invasive Nipa Palm (*Nypa fruticans*) between years 2007–2017 in the region. During the period under investigation, about 4.5% of mangrove vegetation was lost and the whole are lost was overtaken by the opportunistic *Nypa fruiticans* (Nwobi *et al.,* 2020). Hence, conversion of mangrove vegetation to other land use type has been an ongoing practice of the locals, which if neglected by the relevant stakeholders could be detrimental to the environment and the society at large. The impact of this change according to Zabbey (2008), ranges from subtle to sub-lethal impairment and then outright mortality of both plants and animals.

As observed in this present study, the change greatly impacted the abundance and diversity of insect population in the study area within the period under investigation. During this period, a total of 14 individual species and 13 families were lost in the *Avicennia* bound insect population, while a total of 5 individual species and 5 families were lost in the Rhizophora bound insect population. Additionally, the ecological indices were also impacted greatly as seen in the decline observed in the diversity of insect species observed in both *Avicennia* and *Rhizopora* group; and evenness also reduced in the *Avicennia* population but increased in the Rhizophora group. The extent of dissimilarity in the insect population between the period of interest was 58% for the *Avicennia* group and 41% for the Rhizophora group. However, *Lasius niger* and Formicidae family maintained their status as the most dominant species and family respectively in the Rhizophora community during the period, but lost it to species *Chrysops lengicormis* and family Tabanidae in the *Avicennia* community; meanwhile *Chrysops lengicormis* and *Didacus sp.* were newly observed in the *Rhizophora* and *Avicennia* insect community groups respectively.

Nevertheless, it is apparent that there has been a great loss of insect biodiversity as a result of mangrove vegetation depletion due to human activities. This decline in insect population definitely has an impact on certain ecosystem services. Ecosystem services such as pollination, food provision, diseases control, seed dispersal, dead wood decomposition, energy flow and culture preservation could be highly impacted by the loss of insect species. Continuity of predatory mangrove insect groups such as the Tabanidae, whose larvae develop in the sediments would have been impacted a great deal due to the land use change. This assertion supports the findings of Yeo *et al.* (2021) who also reported that altering mangrove ecosystem could have dire consequences on the reproduction of certain insect groups. Decline in families like Cantharidae and Coccinellidae belonging to the coleopteran insect order, which are detritivores, feeding on decaying leaves or dead wood, might have created a niche in the decomposition of organic matter in the ecosystem. Additionally, the decline in populations of Apidae family might also impact the pollination and plant productivity in the study area. Meanwhile adjacent agricultural land and gardens would have been impacted significantly as a result of the decline of herbivorous groups of insects belonging to families such as Dictyopharidae; and the population of some other insects would have exploded as a result of a decline in predatory species in the family of Tabanidae and Formicidea. These assertions corroborate the findings of Grampurohit and Karkhanis (2013), Rahman (2015) and Yeo *et al.* (2021) on the role of insects in crucial ecosystem services previously stated. Other issues that could be affected as a result of the impact on insect population include turnover rate, energy flow, and loss of insect and plant genepool (Grampurohit & Karkhanis, 2013; Rahman, 2015; Yeo *et al.,* 2021).

Given the observations in this study, it is clear that the insect biodiversity of the study area has been impacted negatively. This calls for urgent strategies in halting further encroachment of human settlements into the mangroves, plus efforts to recover the lost habitat and reinstate the species in other to mitigate current impacts and prevent future eventualities that could arise because of their continued absence.

5. Conclusion

This study has shown the impact of land use change on the mangrove insect population in Bundu-Ama, Niger Delta. This change was evident in the decline in population and loss of insect species and families during the period under investigation. More so, the insect population, diversity and evenness in the distribution was greatly impacted. If this decline persists, the insects of the mangrove would either be destroyed or they will migrate to more suitable environments or skew towards certain specie dominance. This would be a significant loss to the study area because the services provided by these insects in the environment would be lacking and the ecosystem services will be threatened. Hence, there is an urgent need for action from stakeholder groups to halt this menace and rehabilitate the mangrove ecosystem and the insect biodiversity. In addition, there is a need to educate the citizens on the consequences of their activities on the environment. In other to have a holistic understanding of the impact, it is highly recommended that the direct or indirect value of the services provided by the insect population should be quantified and published, which would be used as a yardstick for policy adjudication on conservation.

References

Adeniyi, S., & Adeyinka, O. J. (2013). Diversity and Abundance of Arthropods and Tree Species as Influenced by Different Forest Vegetation types in Ondo State, Nigeria. *International Journal of Ecosystem*.

Ameen, M., Akhter, R. U. S., & Rabbi, M. F. (1982). Final instar larvae of common damselflies (Odonata: Zygoptera) of Dhaka city and their identification key. *Bangladesh Journal of Zoology*, **10**(2), 81–91.

Ameen, M., & Nessa, S. K. (1985). A preliminary identification key to the aquatic hemiptera of Dhaka city [Bangladesh]. *Bangladesh Journal of Zoology*, **13**(1), 49–60.

Asuk, S. (2018). *Species composition and diversity of mangrove swamp forest in southern Nigeria*.

Basset, Y., Cizek, L., Cuénoud, P., Didham, R. K., Guilhaumon, F., Missa, O., Novotny, V., Ødegaard, F., Roslin, T., Schmidl, J., Tishechkin, A. K., Winchester, N. N., Roubik, D. W., Aberlenc, H.-P., Bail, J., Barrios, H., Bridle, J. R., Castaño-Meneses, G., Corbara, B., … Leponce, M. (2012). Arthropod Diversity in a Tropical Forest. *Science*, **338**(6113), 1481–1484.

Bhakuni, S. (2023). *Poverty and sustainable development: perspective from developed and developing nations*. **12,** 68–81.

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J. B., & Collen, B. (2014). Defaunation in the Anthropocene. *Science*, **345**(6195), 401–406.

Ewers, R. M., Boyle, M. J. W., Gleave, R. A., Plowman, N. S., Benedick, S., Bernard, H., Bishop, T. R., Bakhtiar, E. Y., Chey, V. K., Chung, A. Y. C., Davies, R. G., Edwards, D. P., Eggleton, P., Fayle, T. M., Hardwick, S. R., Homathevi, R., Kitching, R. L., Khoo, M. S., Luke, S. H., … Turner, E. C. (2015). Logging cuts the functional importance of invertebrates in tropical rainforest. *Nature Communications*, **6**(1), 6836.

Gbarakoro, T., & Okene, P. (2020). *Assessment of insect functional groups of mangroves parts at Asarama, Andoni, rivers state, Nigeria*. 18–27.

Gómez, J. M., Bosch, J., Perfectti, F., Fernández, J., & Abdelaziz, M. (2007). Pollinator diversity affects plant reproduction and recruitment: The tradeoffs of generalization. *Oecologia*, **153**(3), 597–605.

Grampurohit, B., & Karkhanis, H. (2013). Insect Biodiversity at Mangrove Ecosystem. *National Conference on* Biodiversity*: Status and Challenges in Conservation*.

Itumo, M., Itumo, O., & Choko, O. (2023). Diminishing Coastal Vegetation in Parts of Rivers State: An Emphasis on Mangrove Depletion. *Journal of Environment and Earth Science*, **13**(10), 16.

Lister, B. C., & Garcia, A. (2018). Climate-driven declines in arthropod abundance restructure a rainforest food web. *Proceedings of the National Academy of Sciences*, **115**(44), E10397–E10406.

Membere, O., Bawo, D. D. S., Onwuteaka, J., Ugbomeh, A. P., & Nwosu, O. R. (2021). Abundance and diversity of insects associated with *Rhizophora mangle* and *Avicennia germinans* in Bundu-Ama mangrove ecosystem of the Niger Delta, Nigeria. *Scientific African*, *14*, e01058.

Munji, C. A., Bele, M. Y., Idinoba, M. E., & Sonwa, D. J. (2014). Floods and mangrove forests, friends or foes? Perceptions of relationships and risks in Cameroon coastal mangroves. *Estuarine, Coastal and Shelf Science*, **140,** 67–75.

Murshed, S. M., & Regnault, B. (2023). Inequality: The scourge of the twenty-first century. *Contemporary Social Science*, **18**(5), 580–598.

Numbere, A. O. (2019). Mangrove Habitat Loss and the Need for the Establishment of Conservation and Protected Areas in the Niger Delta, Nigeria. In *Habitats of the World—Biodiversity and Threats*. IntechOpen.

Nwobi, C., Williams, M., & Mitchard, E. T. A. (2020). Rapid Mangrove Forest Loss and Nipa Palm (Nypa fruticans) Expansion in the Niger Delta, 2007–2017. *Remote Sensing*, **12(**14), Article 14.

Ogbeibu, A. E., Oribhabor, B. J., Ogbeibu, A. E., & Oribhabor, B. J. (2023). The Niger Delta Mangrove Ecosystem and Its Conservation Challenges. In *Mangrove Biology, Ecosystem, and Conservation*. IntechOpen.

Oloyede, M. O., Williams, A. B., Ode, G. O., & Benson, N. U. (2022). Coastal Vulnerability Assessment: A Case Study of the Nigerian Coastline. *Sustainability*, **14**(4), Article 4.

Omo-Irabor, O. O., Olobaniyi, S. B., Akunna, J., Venus, V., Maina, J. M., & Paradzayi, C. (2011). Mangrove vulnerability modelling in parts of Western Niger Delta, Nigeria using satellite images, GIS techniques and Spatial Multi-Criteria Analysis (SMCA). *Environmental Monitoring and Assessment*, **178**(1), 39–51.

Rahaman, A., Kumari, A., Zeng, X.-A., Khalifa, I., Farooq, M. A., Singh, N., Ali, S., Alee, M., & Aadil, R. M. (2021). The increasing hunger concern and current need in the development of sustainable food security in the developing countries. *Trends in Food Science & Technology*, **113**, 423–429.

Rahman, A. (2015). *Mangrove insects*. National Seminar on Conservation of Eastern Ghats, Tirupati, Andhra Prade.

Raihan, A. (2023). A review of the global climate change impacts, adaptation strategies, and mitigation options in the socio-economic and environmental sectors. *Journal of Environmental Science and Economics*, **2**(3), 36–58.

Uwagbae, M., Dirisu, A.-R., Gbarakoro, N., El-Surtasi, E., Agwu, E., Aisien, M., & Rotimi, J. (2019). *Impact of Disturbances on the Biodiversity of Ijala-Ikeren Wetland Ecosystem in Niger Delta* (pp. 1–19).

Yang, L. H., & Gratton, C. (2014). Insects as drivers of ecosystem processes. *Current Opinion in Insect Science*, **2**, 26–32.

Yeo, D., Srivathsan, A., Puniamoorthy, J., Maosheng, F., Grootaert, P., Chan, L., Guénard, B., Damken, C., Wahab, R. A., Yuchen, A., & Meier, R. (2021). Mangroves are an overlooked hotspot of insect diversity despite low plant diversity. *BMC Biology*, **19**(1), 202.

Younes Cárdenas, N., Joyce, K. E., & Maier, S. W. (2017). Monitoring mangrove forests: Are we taking full advantage of technology? *International Journal of Applied Earth Observation and Geoinformation*, **63**, 1–14.

Zabbey, N. (2008). Shrimp farming in Nigeria: Implications for mangroves and rural livelihood in the Niger Delta. *Global Hunger: Is Food for Man or Machine*, 19–21.