

# Abundance and Diversity of Meiofauna as Bioindicator of Water Quality and Health Status of Tombia Segment, New Calabar River, Niger Delta, Nigeria

Otene B. B.<sup>1\*</sup>, Anyiamuka-Chinedu O.<sup>2</sup>, Egerton S. B.<sup>3</sup>

## Abstract

*The abundance and diversity of meiofauna as bioindicator of water quality and health status of Tombia segment of the New Calabar River, Niger Delta, Nigeria was studied. Sediment samples from the respective stations were collected monthly in replicates between July and September, 2023 using a handheld perplex corer at a depth of 10cm and analysed in the Laboratory following standard method of APHA. The data obtained were subjected to descriptive and inferential statistics using Statistical Packages for Social Sciences (SPSS) version 25 and PAST 4.04. The results showed that a total of 199 individuals and 20 species of meiofauna were encountered from the six taxonomic classes, annelida (26%), oligochaeta (18.593%), arthropoda (13.065%), and coleoptera (12.060%), while the least was diptera (7.035%). The area was dominated by the class annelida in the order of occurrence, annelida > oligochaeta > polychaeta > arthropoda > coleoptera > diptera. Neresis Niren, Plesiopora species, Nototropis swamidomi Donacia species and Hirundo medicinalis, Capitella capitata, Lumbriculus variegatus (Mudworm). Spatio-temporally, station 3 had the highest number of fauna (90) in the month of July while the least (28) were observed in station 2 in the month of August. Some of the diversity indices included, dominance (0.076 and 0.099), Shannon wiener (2.636 and 2.390), evenness (0.956 and 0.909) and Margalef (4.405 and 3.150). It could be therefore recommended that anthropogenic activities be checkmated in the area to avoid further threats.*

**Keywords:** Abundance, diversity, meiofauna, bioindicator, water quality, health status, tombia segment, new calabar river

## INTRODUCTION

Aquatic ecosystems in regions such as the Niger Delta, Nigeria, are increasingly threatened by human activities including oil exploration, industrial waste discharge, and agricultural runoff. These anthropogenic pressures severely compromise water quality, posing risks to both biodiversity and ecosystem health [1]. To ensure the sustainable management of these vital environments, robust monitoring and assessment strategies are essential.

Meiofauna as defined by [2] and referenced in Vincx (1996) – are sediment-dwelling metazoans retained on a 38µm sieve. These small benthic invertebrates, which inhabit the sediments of aquatic systems, have gained recognition as effective bioindicators of water quality [3]. Ranging in size from approximately 0.042 to 1 mm, meiofaunal groups include nematodes, copepods, oligochaetes, and foraminiferans. Their short life cycles, high sensitivity to environmental fluctuations, and

### \*Author for Correspondence

Otene B. B.  
E-mail: benjaminotene56@yahoo.com

<sup>1</sup>Associate Professor, Department of Fisheries and Aquatic Environment, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria

<sup>2</sup>Lecturer, Department of Fisheries and Aquatic Environment, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria

<sup>3</sup>Student, Department of Animal and Environmental Biology, Ignatus Ajuru University, Rumuolumeni, Port Harcourt, Nigeria

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intimate contact with sediment layers make them particularly responsive to pollution and habitat degradation.

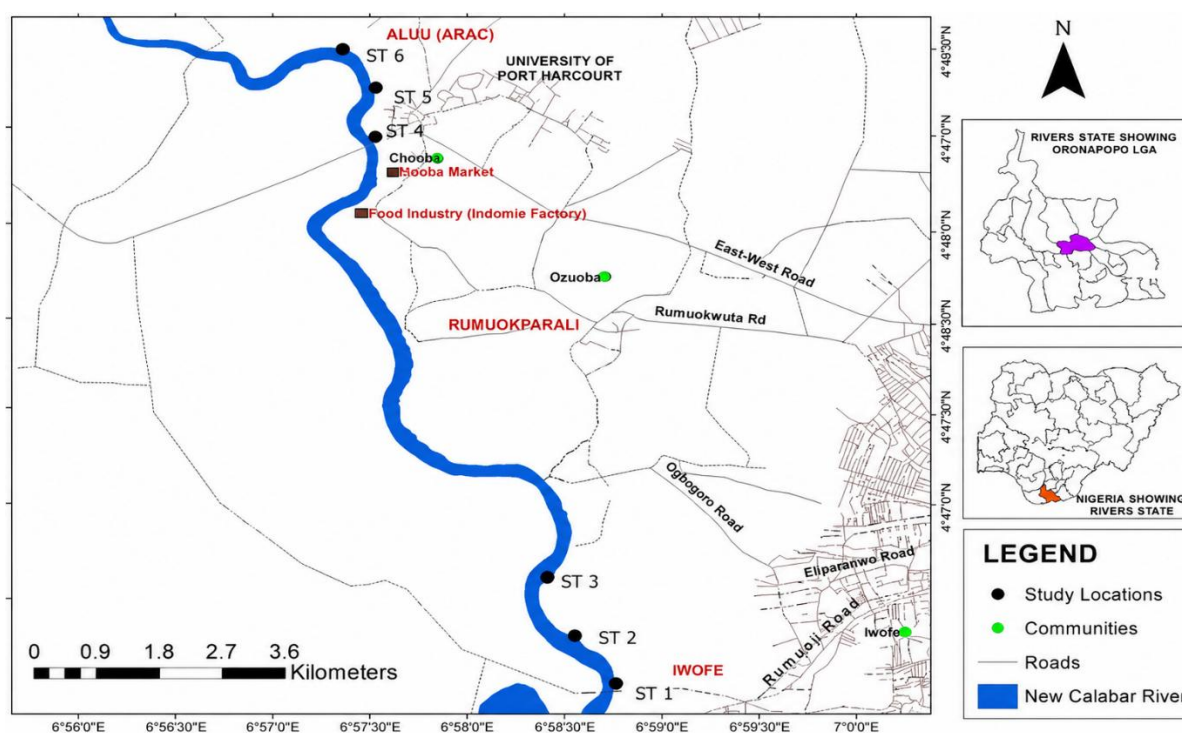
Meiofaunal communities exhibit rapid responses to shifts in environmental conditions, making them effective indicators for evaluating the ecological status and water quality of aquatic habitats [4]. Recent research has underscored the importance of meiofaunal diversity in environmental monitoring. Notably, changes in meiofaunal population structures often reflect anthropogenic impacts such as pollution and habitat degradation [5]. The presence or absence of specific meiofaunal taxa can provide critical insights into the ecological health of a water body, revealing the extent of human influence on aquatic ecosystems [6]. Recent studies have emphasized the significance of meiofauna diversity in water quality monitoring [7, 8]. Changes in meiofaunal community structure, abundance, and diversity can reflect the impact of pollutants and anthropogenic stressors on aquatic ecosystems [9]. For example, the presence or absence of specific meiofaunal taxa can provide insights into the ecological condition of a water body and the effects of human activities [10].

Given the ecological importance of the New Calabar River in the Niger Delta and the increasing environmental pressures it faces [11, 12], assessing the abundance and diversity of meiofauna is critical. This study aims to investigate the meiofaunal communities in the Tombia segment of the New Calabar River to evaluate their potential as bioindicators of water quality and overall ecosystem health. By examining meiofaunal assemblages in relation to environmental conditions, this research will contribute valuable data for the sustainable management and conservation of this vital aquatic resource.

## MATERIALS AND METHODS

### Study Area

The study was carried out in the Tombia section of the New Calabar River, situated in Port Harcourt, Nigeria. As a significant tributary of the Niger Delta system, the New Calabar River serves as a vital fishing ground for surrounding communities. The Tombia segment, positioned between Longitude  $6^{\circ}59'00''\text{E}$  to  $7^{\circ}01'00''\text{E}$  and Latitude  $4^{\circ}46'00''\text{N}$  to  $4^{\circ}48'00''\text{N}$  (Figure 1), was chosen for its close proximity to the urban center of Port Harcourt and its intense fishing activity.



**Figure 1.** Map of the study area showing the sampling station.

This area is characterized by dense mangrove vegetation, predominantly the red mangrove species *Rhizophora racemosa*. These well-established mangrove forests provide essential habitats for a variety of aquatic organisms. Alongside the mangroves, the Tombia segment supports a diverse array of aquatic macrophytes, including *Eichhornia crassipes* (water hyacinth) and *Nymphaea lotus* (water lily), which contribute to the ecological dynamics of the river.

The riverbanks are fringed with a mix of terrestrial vegetations such as grasses, shrubs, and scattered trees that help stabilize the shoreline and form a transitional zone between aquatic and terrestrial ecosystems.

### Sample Collection

Sediment samples were obtained using a coring method, where sediment cores were extracted to a depth of approximately 10 cm using a corer with a diameter of 2-4 cm. The samples were then processed in the laboratory by washing through a series of sieves (500  $\mu\text{m}$  and 63  $\mu\text{m}$ ) to separate meiofauna from sediment particles, followed by preservation in 4% formaldehyde for identification under a microscope.

### Laboratory Processing and Analysis

The fixed sediment samples were processed using standard meiofauna extraction techniques, including density gradient centrifugation and sieving. Meiofaunal organisms were identified to the lowest possible taxonomic level through microscopic examination. Both the abundance and community composition of meiofauna within the sediment were analyzed.

To assess meiofaunal abundance, individual taxa were isolated and examined macroscopically using the needle method. A wet mount slide was prepared by transferring a small portion of the culture with a dissecting needle onto a drop of lactophenol cotton blue stain placed on a grease-free slide. The slide was then examined under a low-power objective lens. Identification of the isolates followed protocols outlined in Malloch (1981) and Devi (2012) [13].

### Measurement of Species Diversity

Diversity indices refer to the quantitative measures used to assess the diversity of a community, particularly in ecology, to evaluate the variety and abundance of species within a given area. It helps in understanding the ecological balance and health of ecosystems (Table 1 & 2). The indices include

- Margalef ( $R_1$ ) and Menhinick ( $R_2$ ). Both measure the species richness in relative to the number of individual calculated as in equation 1,  $R_1 = S - 1 / \ln N$  (Margalef, 1967),  $R_2 = S / \sqrt{\sum ni}$  (Menhinick, 1964)

Where  $S$  = species number,  $N$  = Total number of individual

- Shannon-Wiener Index ( $H'$ ) measures the uncertainty in predicting the species of a randomly chosen individual and calculated as in equation 2,  $H' = -\sum (pi \cdot \ln(pi))$

where  $pi$  is the proportion of individual belonging to species

Referring to this index, the diversity-based criteria for water quality is as follows:

> 2.0: high diversity, 1.0-1.59: low diversity, 1.6-2.0: medium diversity < 1.0: very low diversity.

- Simpson's Diversity Index ( $D$ ) assesses the probability that two randomly selected individuals belong to the same species calculated as in equation 3:  $D = \sum (pi^2)$  (Krebs, 1989) where a lower value indicates higher diversity
- Simpson's Reciprocal Index ( $1/D$ ) is the reciprocal of Simpson's Index; higher values indicate greater diversity calculated as in equation 4,  $1/D = \sum (pi^2)^{-1}$
- Pielou's/ Evenness Index ( $J$ ) measures the evenness of species abundances calculated as in equation 5:  $J = H' / \ln(s)$  (Krebs, 1989)

Where H' is the Shannon-Wiener Index and S is the number of species.

The evenness index of a population varies between 0-1 with the following criteria:

-  $E > 0.6$ : high evenness, -  $0.4 < E < 0.6$ : medium evenness, and -  $E < 0.4$ : low evenness

- Fisher's Alpha ( $\alpha$ ) a measure of species richness that considers the number of species and the number of individuals calculated as in equation 6:  $\alpha = S - 1 / \ln(N)$  (Chao & Shen (2003) Where S=number of species, N=Total number of individual

**Table 1.** Range of fisher's alpha value and the levels of diversity and pollution.

Fisher's alpha value range	Diversity level	Pollution level
< 5	Low diversity	High pollution; limited species presence and significant ecological impact.
5 - 10	Moderate diversity	Moderate pollution; some species may thrive, but overall diversity is compromised.
10 - 15	High diversity	Low pollution; healthier ecosystems with a robust mix of species.
> 15	Very high diversity	Minimal pollution; ecosystems are thriving with a diverse array of species.

Source: Chao & Shen (2003), Gibson & Robb (2012).

- Dominance index(DI) is used to characterize most conspicuous and abundant species with its relative importance related to degree of influence it has on ecosystem components as represented in equation 7:  $DI = 1 - (\sum ni(ni-1) / N(N-1))$

Where  $ni$  = the number of individuals in the  $i$ th species  $N$  = the total number of individuals,  $1 =$  unity(1).

If C is close to 0 (zero), then there is no dominant species,

- If C is close to 1 (one), then there are at least one dominant species.

- Chao-1 index estimates species richness, particularly in situations where some species may not be observed in a sample. It helps to provide a more accurate picture of biodiversity, especially in cases where some species have not been detected or are present in low numbers. It is estimated as using equation 8,  $S_{obs} = n^2_1 / 2n_2$  (Chao & Shen, 2003) Where:  $S_{obs}$  = the number of species observed in the sample.

$n_1$  = the number of species observed only once (singletons).

$n_2$  = the number of species observed exactly twice (duplicates).

**Table 2.** Range of chao-1 and the levels of diversity and pollution.

Chao-1 value range	Diversity level	Pollution level
< 10	Low diversity	High pollution; significant habitat degradation and loss of species.
10 - 20	Moderate diversity	Moderate pollution; some species are affected, but a range of species may still persist.
20 - 30	High diversity	Low to moderate pollution, ecosystems are relatively healthy, supporting a variety of species.
> 30	Very high diversity	Minimal pollution: ecosystems are well-preserved, with a rich variety of species.

Source: Chao & Shen (2003), Gibson & Robb (2012)

### Statistical Analysis

The collected data were analyzed using SPSS (Statistical Package for Social Sciences) version 20, applying both descriptive and inferential statistical methods, including mean, standard deviation, and percentage calculations. To evaluate the effects of experimental factors, Analysis of Variance (ANOVA) was conducted based on a Randomized Complete Block Design (RCBD) with four replicates. Mean separation was performed using Duncan's Multiple Range Test (DMRT).

To explore the spatial relationships between meiofaunal communities and water quality parameters, Principal Component Analysis (PCA) was employed. This analysis was carried out using PAST version 4.04, where significant principal components (PCs) were identified based on their eigenvalues. For optimal interpretation, the Varimax rotation criterion was applied, enhancing the correlation of each variable with a single principal component.

### RESULTS

A total of 199 individual and 20 species of meiofauna were encountered from the six taxonomic classes, annelida (4), arthropoda (3), polychaeta (4), oligochaeta (4), coeloptera (2) and diptera (2) in the study area (Tables 3–5). The percentage composition of each class encountered are annelida consisting of 26% which is the highest followed by oligochaeta (18.593%), arthropoda (13.065%), coleoptera (12.060%), while the least was diptera (7.035%) (Table 3–5). Annelida, polychaeta and oligochaeta had equal number of species (3) each while diptera had the least number of species (2) in the study areas (Table 3–5). The order of occurrence of the phyla in this study was annelida> oligochaeta>polychaeta>arthropoda>coleoptra>diphthera. *Neresis niren*) from the phylum annelida had the highest (17) species abundance followed by *Plesiopora species* (14) from the phylum oligochaeta while *Nototropis swamidomi* from the phylum arthropoda and *Donacia species* (6) from the phylum coeloptera were the least species (6) (Table 3–5).

Spatially, station 3 had the highest number of fauna (90) while the least (28) were observed in station 2 (Table 3 and 4). Similarly, the highest number of fauna was observed in July while the least was observed in August (Table 5).

Table 6 represents the diversity indices of meiofauna in the study area. The dominance index ranged between 0.076(ST4) and 0.099(ST2). Shannon wiener index ranged between 2.636 (ST4) and 2.390 (ST2). Evenness index ranged from 0.956(ST3) to 0.909(ST2). Margalef and Menhinick indices ranged from 4.405(ST4) to 3.150(ST3) and 3.062(ST4) to 1.778(ST3) respectively. Equitability index also ranged between station 3(0.983) and station 2(0.962).

**Table 3.** Spatial values of meiofauna in the study area.

Class	S/N	Species	ST 1	ST 2	ST 3	ST 4	Total	Percentage
Annelida	1	<i>Neresis niren</i>	5	1	7	4	17	8.54
	2	<i>Urechis caupo</i>	2	1	8	1	12	6.03
	3	<i>Glycera species</i>	1	2	7	1	11	5.53
	4	<i>Hirudo medicinalis</i>	4	2	6	1	13	6.53
		Total	12	6	28	7	53	26.63
Arthropoda								
	1	<i>Gammarus locusta</i>	3	1	6	1	11	5.52
	2	<i>Nototropis swamidomi</i>	2	0	3	1	6	3.01
	3	<i>Orchomenalla nana</i>	2	2	4	1	9	4.52
	Total	7	3	13	3	26	13.05	
Polychaeta								
	1	<i>Capitella capitata</i>	0	3	3	1	7	3.51
	2	<i>Notomastus latericieus</i>	1	3	3	2	9	4.52
	3	<i>Marphysa sanguine</i>	2	3	4	2	11	5.53
	4	<i>Sythil species</i>	3	0	5	2	10	5.03
	Total	6	9	15	7	37	18.59	

Oligochaet	1	Plesiopora species	3	2	7	2	14	7.04
	2	Dero obtuse	4	0	4	2	10	5.03
	3	Lumbricus species	5	1	6	0	12	6.03
	4	Dugesia polychroa	1	2	5	1	9	4.52
		Total	13	5	22	5	45	22.62
Coleoptera	1	Donacia species	2	1	6	1	10	5.03
	2	Dytiscus species	2	1	3	2	8	4.02
	3	Donacia species	3	0	0	3	6	3.01
		Total	7	2	9	6	24	12.06
Diptera	1	Chironomus transvalensis	2	1	3	1	7	3.51
	2	Tabanus species	3	2	0	2	7	3.51
		Total	5	3	3	3	14	7.02
		Grand total	50	28	90	31	199	100.00

**Table 4.** Meiofauna distribution and abundance per station.

S/N	Class	ST 1	ST 2	ST 3	ST 4	Total	Percentage
1	Annelida	12	6	28	7	53	26.633
2	Arthropoda	7	3	13	3	26	13.065
3	Polychaeta	6	9	15	7	37	18.593
4	Oligochaeta	13	5	22	5	45	22.613
5	Coleoptera	7	2	9	6	24	12.060
6	Diptera	5	3	3	3	14	7.035
	Total	50	28	90	31	199	100.00

**Table 5.** Temporal abundance, distribution and compositions of meiofauna.

Class	S/N	Species	July	August	Sept	Total	Percentage
Annelida	1	Neresis niren	5	1	7	4	17
	2	Urechis caupo	2	1	8	1	12
	3	Glycera species	1	2	7	1	11
	4	Hirudo medicinalis	4	2	6	1	13
		Total	18	18	17	53	26.63
Arthropoda	1	Gammarus locusta	6	3	2	11	5.53
	2	Nototropis swamidomi	3	2	1	6	3.01
	3	Orchomenalla nana	5	1	3	9	4.52
		Total	14	6	6	26	13.06
Polychaeta	1	Capitella capitata	3	2	2	7	3.51
	2	Notomastus latericieus	2	4	3	9	4.52
	3	Marphysa scanguine	3	5	3	11	5.53
	4	Syphil species	3	2	5	10	5.03
		Total	11	13	13	37	18.59
Oligochaet	1	Plesiopora species	6	4	4	14	7.04
	2	Dero obtuse	3	3	4	10	5.03
	3	Lumbricus species	6	2	4	12	6.03
	4	Dugesia polychroa	3	3	3	9	4.52
		Total	18	12	15	45	22.62

Coleoptera	1	Donacia species	3	3	4	10	5.03
	2	Dytiscus species	3	2	3	8	4.02
	3	Donacia species	2	2	2	6	3.01
		Total	8	7	9	24	12.06
Diptera	1	Chironomus transvalensis	2	4	1	7	3.51
	2	Tabanus species	3	2	2	7	3.51
		Total	5	6	3	14	7.02
		Grand total	72	62	63	63	100.00

**Table 6.** Diversity indices of meiofauna in the study area.

Parameter	ST1	ST2	ST3	ST4
Taxa_S	15	12	14	15
Individuals	38	22	62	24
Dominance_D	0.078	0.099	0.078	0.076
Simpson_1-D	0.922	0.901	0.922	0.924
Shannon_H	2.627	2.390	2.594	2.636
Evenness_e^H/S	0.923	0.909	0.956	0.931
Brillouin	2.155	1.833	2.267	2.006
Menhinick	2.433	2.558	1.778	3.062
Margalef	3.849	3.559	3.150	4.405
Equitability_J	0.970	0.962	0.983	0.974
Fisher_alpha	9.147	10.810	5.633	17.120
Berger-Parker	0.132	0.136	0.113	0.125
Chao-1	15.140	14.000	14.000	17.630

Key: ST1-4=Stations 1-4

Figure 2 showed the scattered plot of the principal components analysis (PCA) of the meiofauna and the environmental factors in the various stations in the study area. The first component (PC1) has the highest eigenvalue (around 60%), indicating it explains a significant portion of the variance in the data. This suggests that the characteristics or attributes captured by this component are the strongest among all components.

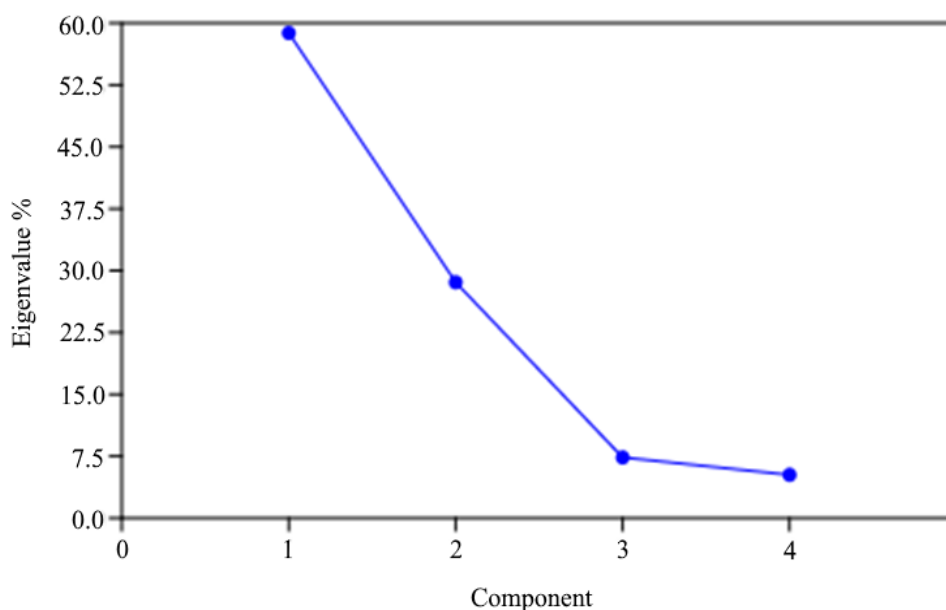
Table 7 & 8 showed the correlation coefficient in the area. Stations 3 and 4 are notably influenced by their respective components (0.967 and 0.9687), suggesting they have distinct profiles based on the underlying data. Further exploration of what each principal component represents can provide deeper insights into the nature of these correlations.

**Table 7.** PCA.

PC	Eigenvalue	% Variance
1	4.20458	58.805
2	2.04388	28.586
3	0.52602	7.3569
4	0.375527	5.2521

**Table 8.** Pearson correlation.

Station	PC 1	PC 2	PC 3	PC 4
1	0.1636	0.7385	0.64295	-0.1205
2	-0.0203	-0.6575	0.7519	-0.0451
3	0.9673	-0.1211	-0.0671	0.2125
4	-0.1929	0.0878	0.1297	0.9687



**Figure 2.** Screen plot.

## DISCUSSION

Meiofaunal communities are known to respond quickly to changes in environmental conditions, making them valuable tools for assessing the ecological status and water quality of aquatic habitats [14, 15].

In this study, twenty meiofaunal species were identified, exceeding the thirteen species reported [16] in the Buguma mangrove forest, but aligning [17, 18], who recorded sixteen species in similar Niger Delta environments. The observed spatio-temporal variations in meiofaunal abundance and composition are likely influenced by fluctuations in food supply, particularly organic matter represented by total protein concentrations [19, 20]. Additional factors such as detrital food sources, habitat complexity, predation pressure, and oxygen availability also contribute to these variations [21, 22].

These findings reinforce the role of meiofaunal communities as sensitive indicators of environmental change and water quality [23]. The presence of pollution-tolerant species such as *Hirudo medicinalis*, *Capitella capitata*, and *Lumbriculus variegatus* suggests anthropogenic stress in the study area [24, 25]. Similarly, species like *Nereis pelagica* and *Polydora cornuta*, previously identified in stressed habitats [26, 27], further support this assessment.

The low presence of meiofauna at Stations 2 and 4, in contrast to the higher counts at Stations 1 and 3 in this research, may be linked to variations in human activities and the rainwater that transported both organic and inorganic pollutants downstream to the respective Stations. Consequently, the spatial and temporal differences, showing greater meiofauna populations at Station 3 compared to the other stations, can be explained by the more favorable environmental conditions in that area. Ajao and Fagade (1990) also noted reductions in the abundance and distribution of benthic fauna, highlighting the negative impacts on fish through food webs as a result of pollution from human influences.

The diversity index serves as a quantitative indicator that reflects the number of different species present in a dataset while also considering the evenness of the basic entities, such as individuals, distributed across an inadequate environment to evaluate ecosystem health [28–30]. The minor differences in diversity observed in this study between the months, as well as across various locations, can be linked to the types of human activities occurring in those specific areas.

The low values of the dominance index and Simpson's dominance index ( $<1$ ) observed in this study aligned with findings by Yusai *et al.* (2024) at Losari Beach, Makassar, suggesting that no single species dominated the aquatic community. According to Zhigila *et al.* (2022), such low dominance values typically indicate ecosystems with limited species diversity but enhanced organism interactions, contributing to greater ecological stability and health.

In contrast to previous studies by Otene *et al.* (2025a & b), which reported fluctuations in Shannon-Wiener index values across stations attributed to varying species numbers, this study showed consistent values across sampling sites. Ravera (2001) and Otene *et al.* (2019) also linked such fluctuations to species variability. Meanwhile, Zahraddeen (2006) documented Shannon-Wiener index values ranging from 1 to 2 for macroinvertebrates in the Nassarawa reservoir, Katsina State, providing a comparative benchmark for ecological assessments.

According to Mandaville (2002), Shannon-Wiener diversity index values above 3.0 indicate a stable habitat, while values below 1.0 suggest pollution and habitat degradation. In this study, Shannon index values fell within the 1–3 range, indicating moderate pollution, consistent with the classification by Otene *et al.* (2020).

The study also recorded high evenness and equitability in meiofauna distribution across stations, with evenness index values approaching 1 – contrasting with the lower range (0.49–0.62) reported by Zahraddeen (2006) in the Nasarawa reservoir. This suggests a balanced distribution of species with no single taxon dominating.

Fluctuations in Margalef and Menhinick indices across stations reflect variations in species richness, likely due to changes in species number, as noted by Ravera (2001) and Otene *et al.* (2019, 2025). Additionally, the consistently low Berger-Parker index (0.1–0.3) observed indicates high biodiversity and even species distribution, suggesting a relatively healthy aquatic ecosystem with minimal pollution stress.

Chao-1 and Fishers alpha help in tracking changes in species richness over time, providing insights into the effects of habitat loss, climate change, or pollution on biodiversity. Chao-1 and Fishers indices values in this study highlighted the varying levels of species richness and dominance across the four stations, with Station 4 showing the greatest potential for biodiversity.

The observed strong correlations between stations 3 and 4 with their respective components in this study indicates that the environmental variables measured at those stations are well-represented by those particular PCs, suggesting that these stations significantly contribute to the overall patterns of variation captured by the PCA [31]. This can be interpreted as stations with high loadings on a particular PC having similar environmental attributes that drive the major trends in the dataset [32].

## CONCLUSION AND RECOMMENDATION

This study assessed the abundance and diversity of meiofauna as bioindicators of water quality and ecosystem health in the Tombia segment of the New Calabar River, Niger Delta, Nigeria. Results revealed significant spatio-temporal variations in meiofaunal composition, with stations 3 and 4 exhibiting distinct ecological profiles. The presence of pollution-tolerant species such as *Hirudo medicinalis*, *Capitella capitata*, and *Lumbriculus variegatus* indicates environmental stress and potential pollution in the area. These findings highlight the need to regulate anthropogenic activities to prevent further ecological degradation and proliferation of pollution-indicator species.

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