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Ecosystem analysis of meiofauna taxa and physicochemical characteristics in Nembe Mangrove Swamp, Bayelsa State, Nigeria

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Abstract

This study investigated meiofauna taxa and physicochemical characteristics of Nembe mangrove swamp. Sediment and water samples were collected in triplicate within a 1.5m^2 quadrat across three communities. The aim was to create an inventory of meiofaunal datasets and relate them to the physicochemical properties of the water column and sediment, influenced by anthropogenic activities. Standard collection and analysis methods were employed. Physicochemical parameters such as Total Dissolved Solids (TDS), Electrical Conductivity (EC), pH, water temperature, and salinity were measured in-situ, while others were analyzed at the Biology Lab, Federal University Otuoke, Nigeria. Statistical analyses, including Mean±SD, Least Significant Difference, species relative abundance, diversity indices, and environmental correlation, were used to quantify significance. Results revealed significant spatial variations across the three sampling communities. Basambiri exhibited the highest TSS (71.27 ± 3.14 mg/l), TDS (779.33 ± 1.15 mg/l), and DO (4.93 ± 0.25 mg/l). Sabatoro recorded the highest temperature (32.20 ± 5.68) and salinity (7.63 ± 0.21). Basambiri's pH levels indicated alkaline conditions (7.4 ± 0.1), whereas Obiama (6.8 ± 0.1) and Sabatoro (6.73 ± 0.17) were slightly acidic. A total of 815 individual species were recorded, identifying eight taxa in the water column and ten in the sediment stratum. Nematodes were most abundant in Obiama and Basambiri, while Polychaete Worms and Copepods were prevalent in Sabatoro. Obiama exhibited the highest meiofauna diversity (2.06), with significant similarities between communities. The findings suggest distinct environmental conditions and the need for conservation efforts to preserve biodiversity and ecological integrity of Nembe mangrove zones.

Keywords: Meiofauna; Mangrove-Swamp; Water; Sediment; Physicochemical; Nembe

1. Introduction

Nembe mangrove zone of Bayelsa state, Nigeria, is an ecotone within the tropics, and boasts the largest mangrove forest expanse in Africa [1,2]. Mangroves are among the most productive ecosystems and biologically diverse ecosystems on earth, with important roles in coastal protection, biodiversity maintenance, serving as nurseries for juvenile fish, climate regulation, filtering pollutants, retaining sediments, preventing coastal erosion, and providing valuable ecosystem services to surrounding communities [3,4,5,6,7]. Despite this importance, global mangrove cover has significantly decreased in recent decades. According to [8] approximately 35% of mangrove forests worldwide have been degraded over the past twenty years, primarily due to human activities such as deforestation, coastal development, oil spills, pollution, and unsustainable fishing practices [9,10]. These pressures have been particularly impactful in mangrove of tropical developing countries with high demographic pressure, often resulting in a decline in the populations of organisms that depend on the mangrove ecosystems [11,12,13]. Consequently, major ecological functions such as feeding grounds and nurseries, climate regulation, erosion prevention, and the retention of sediment and contaminants have been severely weakened.

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Meiofauna occupy a fundamental niche in mangrove ecosystems. Widespread degradation of mangroves forests can heavily impact meiofauna communities, with recovery potential taking a decade [14]. As a group of small invertebrates that range in size from 20 to 1000μm, they inhabit both the water column and sediment strata, where they contribute to detritus processing, organic matter breakdown, sediment structuring, nutrient cycling, and as food sources for higher trophic levels [15,16]. According to [16], these organisms can offer valuable insights into aquatic community structure and function, and may also reveal benthic community responses to anthropogenic impacts. It has been revealed that the presence and identification of meiofauna, even at low taxonomic level (family, class or phylum) can provide sufficient information to characterize community structure and gauge ecosystems health, particularly in mangrove environments [17]. Despite their ecological significance, knowledge of meiofaunal diversity in Nigerian mangrove ecosystems, especially in Bayelsa State remains limited. The dearth of studies on meiofauna in the region occasions the need for comprehensive assessments of meiofauna diversity in Nembe mangrove swamp, which harbors the most extensive mangrove forest in the Niger Delta, and faces substantial environmental pressures.

2. Materials and methods

2.1. The Study Area and Sampling Communities

The study was conducted in three communities (Basambiri, Obiama, and Sabatoro) in Nembe Local Government Area (LGA) of Bayelsa State, Nigeria. Nembe LGA is one of the prominent administrative regions in Bayelsa State, Nigeria. It is known for its extensive natural resources, and serves as an essential hub for both ecological and socioeconomic activities. The region lies within latitudes 4°25'N and 4°50'N and longitudes 6°15'E and 6°35'E. It is bordered by the Atlantic Ocean to the south, Brass LGA to the west and Ogbia LGA to the north. Nembe is characterized by a tropical rainforest climate, with high temperature and humidity throughout the year. Annual rainfall typically exceeds 3500 mm, contributing to its lush vegetation and aquatic ecosystems. Geographically, it is defined by a network of estuaries, creeks, and mangrove swamps, contributing to its unique biodiversity.

2.2. Samples Collection and laboratory analysis

Sediment and water samples were collected in three independent replicate samples from different points within a 1.5m^2 quadrat manned in the mangrove swamp of three sampling communities (Basambiri, Obiama, and Sabatoro) between January 10th and February 15th 2023. The sediment samples were collected by inserting a Perspex cylindrical corer of a 1 cm inner diameter into the sediment to a depth of 2cm at each sampling points, these were transfer into labeled airtight sterilized sample bags, and treated with 6% buffered formaldehyde to maintain the integrity of the meiofauna specimens before being conveyed to the laboratory for later analysis. The procedures of [18] were followed to collect water samples from three different points within the 1m^2 quadrat into clean transparent plastic bottles (with 1 liter water sampler) from shallow interstices made with clean hand trowels to let pore water drain in. These were stored in a cooler box with ice packs to preserve the water samples and avoid biological degradation during transport. Meanwhile, physicochemical parameters such as Total Dissolve Solid (TDS), Electrical conductivity (EC), pH, water temperature and Salinity were determined in-situ using Sper scientific 860033 Bench-top water quality meters. Other parameters DO, BOD, Turbidity, Nitrate, Phosphorus, Ammonia, Chloride, and Hardness were analyzed at the Biology Lab. Federal University Otuoke, Nigeria following the standard procedures of [19].

2.3. Identification and Extraction of the Meiofauna

The method of [15] and [20] were utilized for the meiofauna extraction. The sediment was transferred into a large container, and a pre-prepared saline solution was added. The sediment was stirred vigorously to dislodge meiofauna from sediment particles. The slurry was washed through a stack of sieves (500 μm on top and 64 μm at the bottom). The retained materials on the smaller mesh sieve (64 μm) contained the meiofauna. The washing process was repeated three times to ensure maximum recovery. Subsequently, the extracted meiofauna were stained with Rose Bengal to help distinguish organisms from debris under the microscope. The samples were then examined under a stereomicroscope following Higgins and Thiel [20] protocol. The water samples were also passed through a fine-mesh sieve with a 45 μm mesh size to concentrate the meiofauna from the collected water. The retained materials were backwashed into a collection container using filtered brackish water. A Rose Bengal stain (0.5g per liter of sample) was added to the filtered material. Following [20], the flotation method was used. A Magnesium Sulfate solution with a specific gravity of 1.15 was prepared, ensuring its salinity matched the brackish water environment to minimize organism stress. Subsequently, the retained material from filtration was mixed with the flotation solution in a large beaker and allowed to settle for 10 minutes. The supernatant, which contained the meiofauna, was carefully decanted into a clean container through a fine sieve (64 μm). The flotation process was repeated three times to maximize meiofauna recovery. 75% ethanol was added to the extracted meiofauna. The extracted sample was transferred into a petri dish (with a piece of graph paper beneath it) and examined under a movable stereomicroscope, following the protocols of [20] and [15].

Identification was conducted up to species level using taxonomic guides such as [20, 22, 23, 24]. The data obtained were subjected to descriptive statistics, mean ± SD, and LSD was used to determine significance. Meiofauna relative abundance in percentage of the species were calculated, diversity indices and environmental correlation were carried out following the procedures of [25,26,15].

3. Results

The results of the physicochemical analysis of water columns in the three sampling communities (Basambiri, Obiama, and Sabatoro) in Nembe are presented in Table 1. The results reveal variations across parameters. The Total Suspended Solids (TSS) were significantly high (p<0.05) in Basambiri (71.27 ± 3.14 mg/l), compare with the TSS values in Sabatoro (61.27 ± 1.01 mg/l), and Obiama (56.60 ± 2.22 mg/l). Also, Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) levels were significantly different in the three sample communities when compared (p<0.05); with Basambiri exhibiting the highest concentrations of TDS (779.33 ± 1.15 mg/l) and DO (4.93 ± 0.25 mg/l).

Table 1 Physicochemical Characteristics of Water Columns in Three Nembe Mangrove Estuary Communities

Parameter	Basambiri	Obiama	Sabatoro
TSS (mg/l)	71.27 ± 3.14 (a)	56.60 ± 2.22 (b)	61.27 ± 1.01 (c)
Temperature (°C)	29.33 ± 1.25 (b)	28.63 ± 0.97 (b)	32.20 ± 5.68 (a)
pH	7.4 ± 0.1 (a)	6.8 ± 0.1 (b)	6.73 ± 0.17 (b)
Conductivity	11.63 ± 1.24 (a)	10.07 ± 0.11 (b)	10.47 ± 0.37 (b)
TDS (mg/l)	779.33 ± 1.15 (a)	506.67 ± 11.55 (c)	705.00 ± 5.77 (b)
BOD (mg/l)	4.07 ± 0.06	4.00 ± 0.00	4.00 ± 0.00
DO (mg/l)	4.93 ± 0.25 (a)	2.83 ± 0.06 (c)	4.20 ± 0.10 (b)
Salinity (PPT)	7.33 ± 0.05 (b)	7.23 ± 0.06 (c)	7.63 ± 0.21 (a)
Turbidity (NTU)	36.33 ± 0.58 (a)	25.33 ± 0.58 (c)	29.00 ± 1.00 (b)
Nitrate (mg/l)	0.73 ± 0.058 (a)	0.30 ± 0.000 (b)	0.33 ± 0.058 (b)
Phosphorus (mg/l)	0.47 ± 0.115	0.67 ± 0.058	0.57 ± 0.058
Ammonia (mg/l)	0.67 ± 0.058 (a)	0.43 ± 0.058 (b)	0.13 ± 0.058 (c)
Chloride (mg/l)	1006.67 ± 4.16 (a)	1001.00 ± 0.82 (b)	983.33 ± 3.51 (c)
Hardness (mg/l)	93.43 ± 0.61 (a)	84.17 ± 0.42 (b)	83.50 ± 0.50 (c)

Note: Triplicate mean values (mean ± SD), Mean with the same alphabet in each row are not significant differences.

Sabatoro records the highest temperature (32.20 ± 5.68 °C), compared to Basambiri (29.33 ± 1.25 °C) and Obiama (28.63 ± 0.97 °C) (P<0.05). The pH values revealed that Basambiri have a more alkaline condition (7.4 ± 0.1) compare to Obiama (6.8 ± 0.1) and Sabatoro (6.73 ± 0.17). The highest conductivity value occurred in Basambiri (11.63 ± 1.24) compared to Obiama (10.07 ± 0.11) and Sabatoro (10.47 ± 0.37) (P<0.05). The Salinity values varied significantly across the three communities, with Sabatoro showing the highest salinity (7.63 ± 0.21 PPT), compared to Basambiri (7.33 ± 0.05 PPT) and Obiama (7.23 ± 0.06 PPT) (P<0.05). However, the turbidity levels were highest in Basambiri (36.33 ± 0.58 NTU), and significant differences (P<0.05) when compared with Sabatoro (29.00 ± 1.00 NTU) and lowest in Obiama (25.33 ± 0.58 NTU). These variations reveal the distinct environmental conditions and potential anthropogenic influences in each of the community. Basambiri exhibited the highest nitrate concentration (0.73 ± 0.058 mg/l), hardness (93.43 ± 0.61), chloride (1006.67 ± 4.16 mg/l) and ammonia (0.67 ± 0.058 mg/l) compared to the values in Obiana and Sabatoro (p<0.05).

A total of 815 individual (meiofauna) species were recorded in this study. Eight meiofauna taxa were identified in the water column (Fig.1). Nematodes were the most abundant and diverse in Obiama (23%), followed closely by Sabatoro and Bamsambiri (both 21%). Tintinnids and Nauplii showed relatively similar abundances across all communities, with Tintinnids being slightly higher in Sabatoro (13%), and Nauplii in Sabatoro (16%). Polychaete-worms were more prevalent in Sabatoro (10%) than in Obiama and Bamsambiri. Copepods were notably abundant in Sabatoro (18%), while tolerant Rotifers had a significant presence in Sabatoro (20%). Mollusk larvae were most abundant in Obiama (15%), while Crustacean Larvae were more prevalent in Bamsambiri (11%).

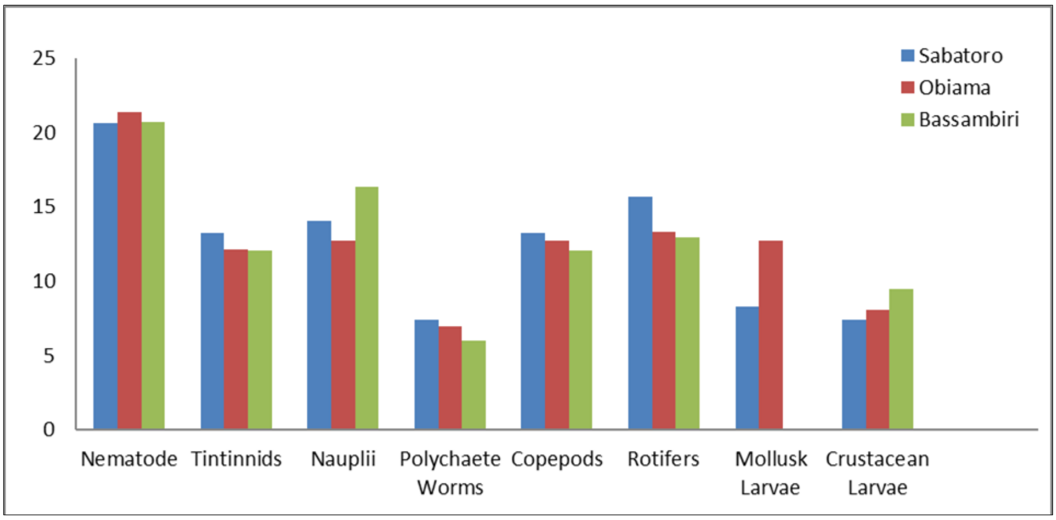

Figure 1 Relative Abundance (%) of Meiofauna Taxa in Water Columns of Three Mangrove Community Zones in Nembe

The relative abundance (%) of meiofauna taxa at the sediment stratum of the sampling communities are shown in Figure 2. The results show that ten meiofauna taxa were identified. Nematodes were the most abundant taxa in Obiama (24%) and Bamsambiri (22%), while Copepods dominated in Sabotoro (23%) compare to those in Obiama and Basambiri. Ostracods were more prevalent in Bamsambiri (18%) compared to Sabotoro and Obiama. Polychaete-worms showed higher abundance in Sabotoro (20%) than in the other two communities. Gastrotrichs were most abundant in Bamsambiri (20%), and unidentified species were more prevalent in Obiama (15%).

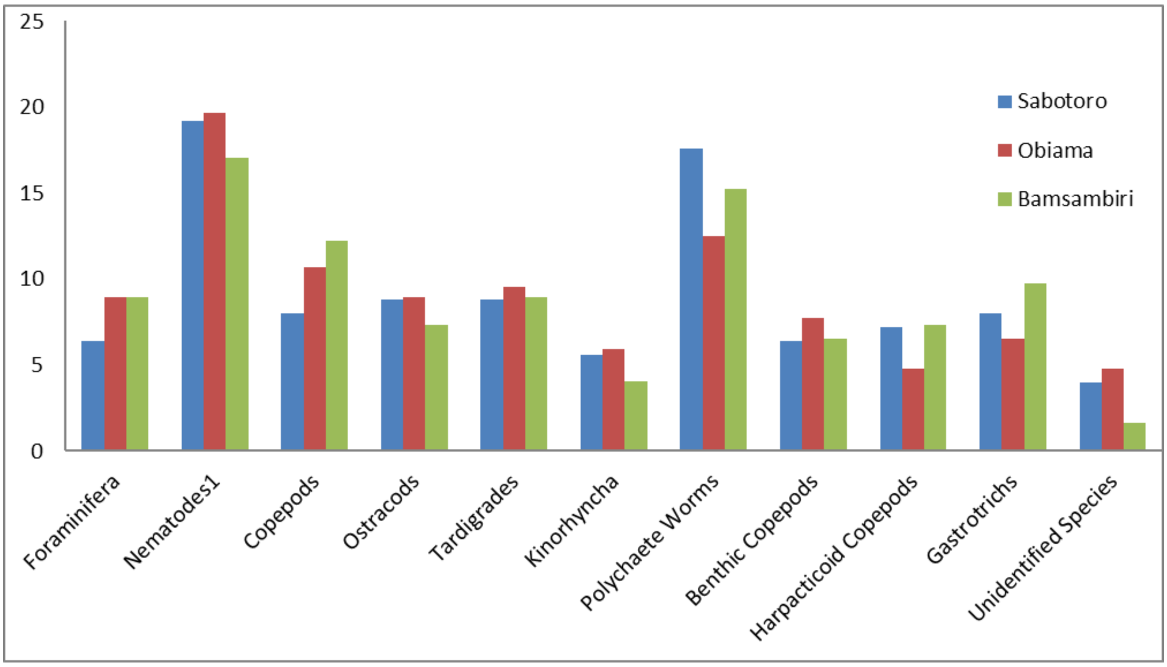

Figure 2 Relative Abundance (%) of Meiofauna Taxa in Sediment Strata of Three Mangrove Communities in Nembe

The diversity indices of the sediment meiofauna species across Sabatoro, Obiama, and Bamsambiri Mangrove Estuaries are presented in Table 2. The results of the indices show significant differences. The Shannon-Wiener index (H) indicated that the highest diversity occurred in Obiama (2.06), followed by Sabatoro (2.03) and Bamsambiri (1.99).

Table 2 Diversity Indices of Sediment Meiofauna Species Across the Three Sampling Communities

Diveristy index	**Sabatoro**	**Obiama**	**Basmbiri**
Shannon-Wiener (H) index	2.03	2.06	1.99
Bray-Curtis (BC) diversity matrix	BC_{Sa-Ob} (0.16)	BC_{Ob-Ba} (0.16)	BC_{Sa-Ba} (0.06)
Berger-Parker Dominance Index (d)	$d_{Sabatoro}$ = 0.21	d_{Obiama} = 0.21	$d_{Bassambiri}$ = 0.21

While, Bray-Curtis (BC) diversity matrix values were highest between Sabatoro and Obiama (0.16) and Obiama and Bamsambiri (0.16), suggesting higher similarity between these pairs of communities, the lowest value occurred between Sabatoro and Bamsambiri (0.06). The Table also indicates that Berger-Parker Dominance Index values are the same for all three communities (0.21), it also reveals that nematodes are the most abundant species, accounting for 21% of the total individuals in each sampled community, and their dominance is relatively consistent across all three stations.

4. Discussion

The studied communities, though situated within the same mangrove estuarine stretch, shows distinct and significant different in water variables as well as the meiofaunal diversity observed in both the water columns and the sediment strata. These differences may have been influenced by both natural and anthropogenic factors. The high TSS, TDS, ammonia and turbidity level recorded in Basambiri suggests a higher input of particulate matter (dissolved organic and inorganic materials), possibly from industrial discharge or oil pollution [27,28,29], which according to [30] impact water clarity and the aquatic habitat dynamics, while the ammonia levels imply greater organic matter decomposition [31], the phosphorus levels across the communities may have contributed to nutrient enrichment in the estuary [32]. BOD values suggest similar levels organic matter decomposition and uniform sources in the communities [33]. However, the low value of DO in Obiama might be due to higher load of organic matter, whereas the high level in Basambiri could be attributed to better aeration and mixing conditions [34]. High temperatures in Sabatoro could be linked to water level and or reduced level of leaves shading due to deforestation. Previous studies of [35,36] asserted that this could affect meiofauna zonation patterns, dissolved oxygen levels and the metabolic rate of aquatic species. The alkaline pH in Basambiri (7.4), in contrast with the slightly acidic conditions in Obiama (6.8) and Sabatoro (6.73) indicates a higher buffer capacity, which may be due to different geochemical processes or reduced acidic inputs compared to the other locations. This Corroborates [37], who opined that slightly alkaline conditions can enhance nutrient availability, favors certain aquatic organisms, and contribute to biodiversity, but may also support certain pollutants [38]. The higher chloride concentrations and conductivity in Basambiri (11.63 µS/cm), reflects the ionic content of the water column, probably from upstream sources or saline intrusion [39, 40]. This assertion is further support by the salinity variation, with Sabatoro showing the highest salinity (7.63 PPT), indicating a mix of freshwater and marine influences [41].

4.1. Meiofaunal Diversity

The total number of individual species recorded and the variations observed in the relative abundance of the meiofauna taxa in the sampling points show the level of ecological diversity within the mangrove estuarine habitats. Nematode dominance resulted from favorable conditions such sediment texture which may have supported their populations, as well as their ability to adapt to harsh environment. These findings lend credence to the previous reports [42,43,44,45,21], which attributed nematodes prevalence to rich primary production and organic matter availability. Mangrove meiofauna dominated by nematodes, could be a potentially good gauge of environmental changes in the mangrove swamps.

The high abundance of Copepods in Sabotoro probably suggests a distinct ecological niche, which [46] related to specific water quality and sediment characteristics. The abundance of Ostracods and Gastrotrichs in Bamsambiri could be attributed to a sedimentary conditions and food availability. Meanwhile, the relatively even distribution of Tardigrades and Kinorhyncha across all three communities implies that the taxa are sensitive to varying environmental conditions within the mangrove zone [47]. The significant presence of Polychaete Worms and copepods in Sabotoro points to a higher level of organic enrichment within the area. This finding agrees with [48], who asserted that the dominance of Copepods reflect varied sediment characteristics. Water quality and potential eutrophication might have occasioned the significant presence of tolerant rotifers in Sabatoro, corroborating [49]. It was observed that Mollusk larvae were most abundant in Obiama, while Crustacean larvae were prevalent in Basambiri. The differences in their distribution among the communities may be due to varying reproductive conditions and habitat suitability across the communities [50].

The Shannon-Wiener index (H) shows that Obiama (2.06) yielded the highest diversity, suggesting a more heterogeneous meiofaunal community, probably due to lower pollution levels and diverse microhabitats. This finding agrees with [51], who attributed higher Shannon-Wiener index (H) value among compare sites to variations in sediment composition, organic matter, and habitat complexity that favor a diverse meiofauna community. Higher similarity of Bray-Curtis (BC) diversity matrix between Sabatoro and Obiama (0.16) and Obiama and Basambiri (0.16), indicate shared species and environmental conditions. The low similarity level between Sabatoro and Basambiri (0.06) reflect environmental pressures and distinct ecological niches (Chindah et al., 2001). The consistent Berger-Parker Dominance Index values across all the three communities (0.21) suggest that certain dominant species, such as the nematodes, exert a similar ecological influence across Nembe estuarine ecosystem, which might be vital to the communities restructuring (Chindah and Braide, 2001). In conclusion, the distinct physicochemical and biological characteristics of Nembe estuary ecosystem suggest a need for effective management and conservation efforts with focus on maintaining habitat heterogeneity and mitigating anthropogenic impacts to preserve meiofauna diversity and the ecosystem health.

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