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ARTICLE

Population Dynamics of Parasitic Nematodes as an Indicator of Soil Health of Eagle Island Mangrove Ecosystem, Port Harcourt

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ABSTRACT

Mangrove forests globally are biodiversity hotspots, supporting microbes, vertebrates, and invertebrates. We thus postulate that, because mangrove soil is a habitat for numerous organisms, it will be a hotbed of both soil- and plant-based nematodes. This study is significant because there is a dearth of information on nematode studies in the Niger Delta region. The present study was based on samples collected from five stations to assess dynamics in population and trophic diversities in a mangrove ecosystem. Data Analysis showed a significant difference ($p \leq 0.05$) of nematodes in *Rhizophora* spp. (61.2%) and *Avicennia* spp. (38.8%). Nematode community composition was evaluated as enumerated by the Shannon-Wiener diversity (H'), Simpson's (D) and Hill's Index of evenness based on the weighted means of Colonizer-Persister (c-p) guilds. A total of 13 genera of nematodes were recorded with bacterivores representing (10%), fungal feeders (13%) and obligates (77%). Based on taxonomic groups, (49%) belong to the family, Tylenchoidae, 28.3% Dorylaimoidae, 10.3% Rhabditidae, 7.4% Criconematoidae and 4.1% Aphelenchoididae. The Shannon and Simpson indices registered values of 1.0 and 0.5 respectively indicating low diversity. Evenness Index scored a value of 0.8, which is close to 1. Our findings indicate an average even distribution amongst families within the Eagle Island soil which indicates stability of the community. The contribution of bacterivorous and herbivorous nematodes with high c-p values was high in our study. This thus led to high Maturity Index (3.5), indicating stability.

Keywords: Diversity; Mangrove; Prevalence; Parasitic Nematodes; Public Health; Soil Fauna

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1. Introduction

Mangroves are said to be unique trees due to their ability to survive in saltwater and thrive in unique intertidal forests at the edge of land and sea. Mangroves are mainly distributed in the tropics close to the equator, where there is hot weather. They are hardly found in temperate regions, which are known for coldness. Mangroves are distributed in 118 countries and regions, with a total global area of approximately 137,760 km^2, accounting for 0.7% of the tropical forests in the world [1]. Mangrove-lined estuaries and coastal ecosystems are significant to global biogeochemical processes, and they regulate the structure and function of surrounding coastal ecosystems disproportionately relative to their limited land cover [2]. Mangrove forests cover only about 1% of the Earth's terrestrial surface, but they are among the highest carbon-storing and carbon-exporting ecosystems globally. Mangrove is described as the supermarket of the sea because it serves as a habitat for numerous marine, estuarine and terrestrial organisms. The mangrove forest environment is also rich in mineral resources such as crude oil, which comes from peat that is found in sedimentary rocks that are derived from millions of years of decomposition of plant and animal matter. The resource-rich mangrove forests are also centers of detrimental human exploitative activities, which result in the rapid decline in the mangrove population in coastal areas around the world. Mangroves are typically halophilic plants that occupy the intertidal zone of sheltered coasts around estuaries and lagoons. The mangrove forests serve various socioeconomic and ecological functions, especially in the coastal communities.

For instance, they provide breeding grounds for fish species and numerous non-wood products that contribute to rural livelihoods. Mangrove forests are among the world's most important repositories of salt-tolerant organisms. Mangrove acts as the planet's lungs, a natural reservoir of genetic diversity, offering a rich source of medicinal plants, high-yield aquatic foods, and many other valuable products. Mangroves vary in size from shrubs to tall trees and are known to be an essential carbon sink on the planet; they act as a coastal defence against floods and tsunamis, can help mitigate coral bleaching. Mangrove communities are classified into five physiographic and physiognomic types namely fringe, riverine, overwash, basin, and dwarf mangroves.

International oil transportation from ocean-going oil tankers introduces oil and other contaminants into the sea, which circulate around the world and contaminate the coastal environments. West Africa is connected to the Atlantic Ocean and serves as a major route for trans-Atlantic oil business. Thus, the entry of ships and the movement of flushing tides in and out of the Atlantic Ocean bring in columns of oil-laden water and plastic debris into the African coast. In Africa, introduced invasive species (e.g., *Nypa fruticans*) have also taken over many mangroves forest leading to the decline in mangrove population [3]. Nigeria is the largest producer of crude oil in Africa; therefore, oil and gas exploration activities have greatly impacted the coast. In addition, coastal development and livelihood activities (e.g., hunting, fishing) are other factor that lead to mangrove forest loss. Recently, sand mining activities have become rampant in many coastal communities in the Niger Delta. This is caused by the proliferation of the building industry, which has led to an increase in the demand for building materials such as sand and gravel.

The ecosystems of mangrove has been providing home for many animals and macro-organisms. They also offer essential functions and services to coastal population, like timber and other forest products [4] and the coastal zone protection [5]. Abundance is often utilized as a key feature of nematode populations to imply connections between the community and its surroundings. The size of single nematodes, which can differ between environments is due to nutrient supplies, governs a strong and beneficial relationship between nematode density and population biomass [6]. Since shallow-water nematodes have larger food sources than deep-dwelling nematodes, they are typically considerably bigger than their equivalents that deep-dwellers. Therefore, nematode occurrence is usually employed as a substitute for community biomass which differs from a small to thousands of individuals per 10 cm^2. Root knot disease infects most plant roots and mangrove roots are not free from this infection. The disease is prevalent in the roots of farm crops, where it destroys the root and eventually leads to their death. As for mangrove trees the root is adventitious and have 70% growing out of the soil. The outer red mangrove roots are hard and less penetrable by organisms because of their lack of contact with soil. The part of the root buried in the soil is more permeable and prone to contamination by parasitic nematodes. The roots are often the site for waste accumulation by tidal current and centre of waste disposal by humans. The mangrove forest also serve toilet for many homeless persons who defecate within the forest. Human waste contains intestinal parasites that contaminate the soil and the roots. Different species of geo-helminths are found in the mangrove soil as a result of human activities. For instance, *Meloidogyne* species are root knot disease found in the soil environment, and are also present in the mangrove forest soil. The aim of this study is to determine the parasitic nematode in the roots of different species of mangroves.

This diversity enables comparisons of variation across groups of samples of various sizes and between locations with varying sampling methods [7]. In attempt to explain nematode assemblages, numerous diversity indices (Simpson, Shannon-Wiener, Pielou's evenness) have been formulated and used always in addition to species or genus richness [8]. The major benefit of diversity indices other than richness is that they provide a more accurate description of species supremacy and evenness by taking the commensurate occurrence of each taxon into account. A detailed review of nematode uses may be found in many books [9,10]. Modifications in nematode aggregations portray disturbances and measured with variety of ecological indices based on diversity, life course information [11], as well as a comprehensive review of their taxonomic make-up [11–13]. Several indices have been employed to investigate nematode groups in both polluted and unpolluted ecological situations such as the Shannon-Wiener index, Simpson index, and diversity index with higher diversity expected in the unpolluted regions than the polluted regions [14,15].

This research has the following objectives: i. To determine the plant parasitic nematodes of the mangrove plants (*Rhizophora racemosa* and *Avicennia germinans*) in the study area; ii. To compare the prevalence of plant parasitic nematode in *Rhizophora racemosa* and *Avicennia germinans*; iii. To determine the population dynamics of nematode fauna in the mangrove ecosystem; iv. To determine the maturity index of the nematode fauna in the study area.

2. Materials and Methods

2.1. Description of Study Area

The study area is the Eagle Island (4°49′ N and 6°58′ E, **Figure 1**) located in the South-West of Port Harcourt and bounded on the North by the Rivers State University in Nkpolu-Oroworukwo area of Diobu, in Port Harcourt Local Government Area of Rivers State [16]. Eagle Island is a coastal community surrounded by thick mangrove forest vegetation. Anthropogenic activities emanating from increased urban development such as deforestation and construction activities has led to the decline in biodiversity and mangrove population [17]. The specific area of study is behind the Rivers State University back gate. This area is fragmented into small mangrove islands within the river system because of increased human activities such as dredging, construction of residential quarters and establishment of local wood industries. There are generally two seasons in the Niger Delta region of the country, the wet and the dry seasons. The wet season occurs from March to July, with a brief break in August called the "August break" while the dry season occurs from September to February. However, because of the climate change there is a blurring of the seasons with rainfall occurring even in December and January. The study area has rain occurring throughout the year except; November, December and January that has little or no rain. Peak rain is in May and the average annual rainfall is 1,466.0 mm. The mean temperature range is 27.1–30.5 °C [18]. Changes in the precipitation pattern will have an implication on nematode prevalence and dynamics. This is because most nematode cysts are buried in soil and during the dry season are carried by wind energy several locations. In the same vein, during rainfall tidal energy carries human waste along the coast leading to wider contamination of parasitic infection by sea goers and fisher folks.

The study area has a thriving mangrove forest that was cut down and fragmented to make way for sand mining. The sand mine was operated between 2017 and 2020, before it was shut down. The abandoned site later became a seedling trap because of a hydrological connection that permits the entry of seeds brought in by tidal currents. The location is directly opposite to a university campus and has a marine transportation activity going on next to the research site. The area has two seasons, the dry and the wet season. The soil is sandy, semi-muddy, and muddy in texture (**Table 1**). The site is surrounded by some grass species. The place is biodiversity-rich and made up of species such as fiddler crab, periwinkle, water snail, swimming crab, monitor lizard, etc. A total of 13 avian species from the population of 159 birds have been identified in Eagle Island. The species were identified with the aid of Birds of West Africa[19]. The 13 avian species identified were composed of 6 orders and 8 families. The orders were Accipitriformes, Charadriiformes, Falconiformes, Passeriformes, Pelecaniformes, Suliformes. The families recorded were Accipitridae, Ardeidae, Charadriidae, Corvidae, Falconidae, Phalacrocoracidae, Pycnonocidae, and Turdidae. The most abundant order and family in Eagle Island is Pelecaniformes while the most abundant family is the Ardeidae. The least abundant order in Eagle Island is Accipitridae and Turdidae. The prevalence of birds in the study area can also lead to the proliferation of nematodes, as bird droppings impact the soil and water. Birds are carriers of parasites, so their presence in large numbers could be a source of nematodes in the area. The bird droppings also act as manure to facilitate the growth of other plant species in the area, such as weeds and grasses. Bird droppings serve as a rich source of microbes in the study site. In Eagle Island, previous studies have indicated that the bacterial population is greater than the fungal population. There is a rich population of bacteria and fungi in soil, water, and plant roots. Thus, the prevalence of root nematodes is an indication of the rich microbial diversity in the areas.

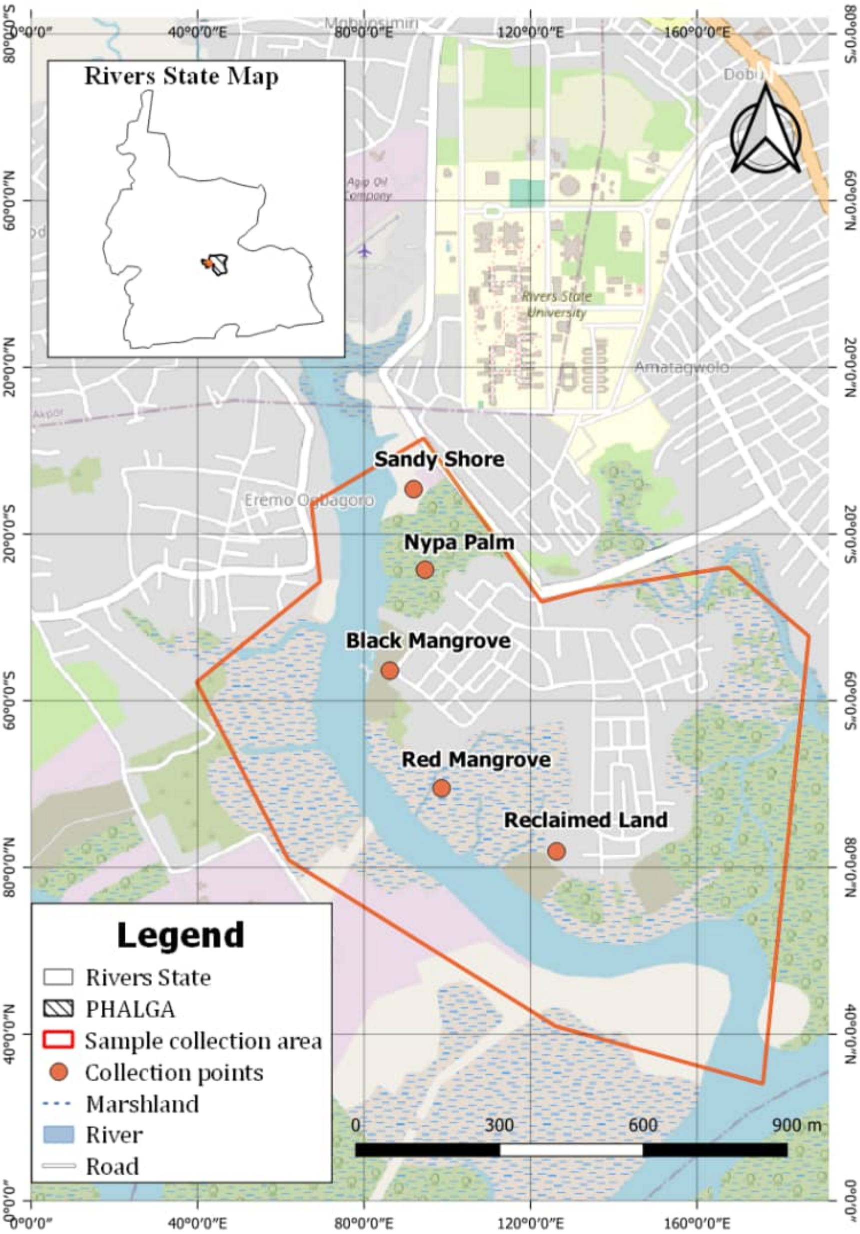

Figure 1. Map of the Study Area at Eagle Island, Rivers State, Nigeria.

Note: The red circle indicates the area of root and soil samples collection.

Table 1. Plant parasitic nematodes of the mangrove plants (*Rhizophora* spp. and *Avicennia* spp) collected at Eagle Island, Niger Delta, Nigeria.

Nematode Genera	Mangrove Species		Total (%)
	***Rhizophora racemosa* (%)**	***Avicennia germinans* (%)**	
Longidorus spp.	322 (14.8)	236 (10.8)	558 (25.6)
Tylenchus spp.	85 (3.9)	58 (2.7)	143 (6.6)
Tylenchorhynchus spp.	210 (9.6)	79 (1.2)	289 (13.3)
Hirschmanniella spp.	210 (9.6)	26 (1.2)	236 (10.8)
Radopholus spp.	104 (4.8)	123 (5.6)	227 (10.4)
Helicotylenchus spp.	255 (11.7)	158 (7.3)	413 (19.0)
Criconema spp.	77 (3.5)	122 (5.6)	199 (9.1)
Dolichodorus spp.	39 (1.8)	39 (1.8)	78 (3.6)
Xiphinema spp.	31 (1.4)	4 (0.2)	35 (1.6)
Total (%)	1,333 (61.2)	845 (38.8)	2,178

2.2. Sampling

The sampling was done in the morning when the tide was low to enable access into the mangrove forest. This is because during high tide the floor of the forest is covered with water. This research is a survey of nematodes of the Eagle Island mangrove swamp in Rivers State. The survey involved the collection of the rhizophere and plant tissues of the mangrove plants to characterize the community status and plant parasitic status of the plants. Soil samples were collected with the aid of a soil auger and were put into waterproof bags and labelled appropriately. With a strong blunt instrument, the content of the auger was scraped into a plastic box while Excess soil was thoroughly shaken off before another sample was taken. A total of 50 soil samples and 15 root samples were collected for analysis. The samples were placed in properly designated polyethene bags placed in a cooler and transported to the laboratory for extraction of nematodes and other physiochemical analysis. Each sampling point was geo-referenced with a handheld Garmin Etrex model GPS [20]. The recorded coordinates were as follows: Sandy shore (4°47.806′ N, 6°58.632′ E), Nypa Palm (4°47.478′ N, 6°58.07′ E), Black Mangrove (4°47.34′ N, 6°58.68′ E), Red Mangrove (4°47.49′ N, 6°58.178′ E), Reclaimed Land (4°47.464′ N, 6°58.418′ E). The reclaimed land was once a thick mangrove forest made up of over four different species of mangrove (red, white, black, and grey) and nypa palm. However, due to the unregulated activities of sand mining companies, all the mangrove trees were cut down, the soil was devastated, and waste soil was dumped on the area. The white sand is pumped from the river and deposited in heaps on the reclaimed site. The sand mining activity involves using several pieces of machinery, such as a swamp bulldozer, which enters the site to clear-cut trees and dump the debris into an open back truck that evacuates the waste. The wheels of the trucks and bulldozers crush any organism in their path, leaving the area devastated. Used oil and grease from the trucks are poured on the soil, leading to contamination. The pumping of sand from the river also brings along coastal waste such as plastic and hospital waste, which are found in large quantities in the area. The few mangrove trees in the region become the point of deposition for soil-based nematodes. The nematode migrates to the neighbouring plants, thus leading to parasitic diversity. Mangrove forests are rich in parasitic activities, which makes them worthy of study.

2.3. Root Collection

Buried roots were pulled out from the ground and cut with a knife while prop roots that grow out of the ground were also cut. The roots of red mangroves are adventitious and grow out of the soil while the roots of the white mangrove and nypa palm grow inside the soil. Of the three species then red mangrove roots are the hardest and grow like a stem, while the nypa palm roots are the lightest and grow tiny. The roots were lifted from the soil using a trowel, so that a sizeable proportion of the root system is unearthed intact [19]. The soil was collected using a soil auger and placed in a bag. Roots were collected at the same time and from the same locations as the soil, and in general, they were, combined in the same sample bag, so that the soil helps preserve the roots. The roots of the red mangrove (*Rhizophora racemosa*), white mangrove (*Avicennia germinans*), and the Nypa palm (*Nypa fruticans*) were collected for the extraction of nematodes. The soil and root samples were then places in cooler filled with ice at 4 °C to preserve the samples.

2.4. Procedure for Nematode Extraction from Mangrove Plant Roots

Firstly, the mangrove root is cut with a knife, and the root samples are placed in waterproof bags, placed in a cooler, and transported to the laboratory for further analysis. Soil particles were gently tapped off the roots and were washed under the tap while the roots were gently dabbed dry with tissue paper. Roots were chopped with a knife and placed in a labelled dish; later, they were placed on tissue paper on a sieve. Then water was carefully poured into the plate, making sure the water went down the gap between the plate and the sieve. This extraction system was set up for 48 h and was constantly checked to ensure that the samples remained wet and did not dry out due to evaporation. The sieves were carefully drained and removed from the plates, while the roots were discarded. The water in the plate was transferred into a labelled beaker. Samples were left to settle for a few hours overnight. The suspension was reduced by decanting through a small aperture sieve and was transferred into a beaker [21]. The nematodes present in the test tube were killed and fixed in hot 4% formaldehyde [19].

2.5. Nematode Extraction

Nematodes were separated from the soil using Baermann's extraction [22] and sieving methods. The soil sample was sieved to remove debris and lumps. A 50 g soil sample was measured; a sieve was lined with tissue paper and placed in a plastic plate. The soil was placed on the tissue paper and was not allowed to spill over the edges. Water was carefully poured into the plate, ensuring that it flowed down the gap between the plate and the sieve. Extract from soil samples was stored for 48 h and was constantly checked to ensure that the samples remained wet and did not dry out due to evaporation. The sieve was carefully drained and removed from the plate, while the tissue and the soil were discarded. The water in the plate was transferred into a labelled beaker. Samples were left to settle for a few hours overnight. The suspension was reduced by decanting through a small aperture sieve and was transferred into a beaker [19]. The extraction apparatus was allowed to stand at normal room temperature for 48 h. Identification was according to Anasari et al. (2020) [23]. The counting of nematodes was done under the dissecting microscope with a counting dish [24].

2.6. Statistical Analysis

Since there were multiple data sets, the data were analyzed using analysis of variance (ANOVA). Logarithmic transformation of the data was performed to meet assumptions of normality and homoscedasticity. Similarly, a post-hoc Tukey's HSD test was done to investigate pairwise mean differences between groups. Duncan's comparison test was carried out to test for the significant difference between the different nematodes. Statistical correlation tests with the correlation matrix were used to determine relationships between nematode and soil parameters. The Shannon diversity index was calculated to assess the species diversity at each sampling site. This index takes into account both species richness (number of different species) and species evenness (relative abundance of each species).

The relative abundance was measured using the formula below:

$$\frac{\text{Species abundance}}{\text{Total abundance}} \times 100$$

The Shannon-Wiener diversity index and Simpson's index of dominance, were used to analyze nematodes community dynamics as shown in Equations (1)–(6).

Shannon-Weaver diversity index:

$$\mathrm{H}^{'} = -\sum(\mathrm{Pi} \times \mathrm{InPi}) \tag{1}$$

Simpson's index of dominance:

$$D = \sum\nolimits_{(\mathrm{Pi})} 2 \tag{2}$$

Where Pi represents the proportion of the i-th taxa in a sample, while response of nematodes to disturbances in the soil and parasitism in plant tissues will be evaluated with maturity index [25]:

$$\text{Maturity Index (MI)} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \frac{\mathrm{V(i)} \times \mathrm{F(i)}}{\mathrm{n}} \tag{3}$$

Where V(i) = coloniser persister value (cp-value) allocated to family; F(i) = the frequency of family i in the sample; and n = total number of individuals in a sample.

$$\text{Hill}^{'}\text{s Diversity N1} = \exp[-\sum(PiInPi)] \tag{4}$$

$$\text{Hill}^{'}\text{s Reciprocal of D N2} = (\sum \mathrm{Pi}^2)^{-1} \tag{5}$$

$$\text{Hill's Evenness } E2{,}1 = \frac{(N2)}{(N1)} \quad (6)$$

Statistical analyses were done with SPSS (Version 25 for Windows) and Microsoft Excel 2016 (Version 8.1 for Windows) as appropriate at $p < 0.05$ level of significance.

3. Results

3.1. Plant Parasitic Nematodes of the Mangrove Plants (*Rhizophora racemosa* and *Avicennia germinans*)

Table 1 shows plant parasitic nematodes of *Rhizophora* spp. and *Avicennia* spp. in the study area. A total of 1,378 nematodes were recovered from the roots of the samples of both mangrove species, comprising 1,333 (61.2%) from *Rhizophora* spp. and 845 (38.8%) from *Avicennia* spp. roots. There was a significant difference in the occurrence of nematodes in both roots of mangrove species. The genus *Longidorus* spp. was significantly ($p < 0.05$) higher than other genera in the roots of both species of mangrove plants, having 558 (25.6%) of the total sum. This was followed by *Helicotylenchus* spp. with 413 (19%), *Tylenchorhynchus* spp. 289 (13.3%), *Hirschmanniella* spp. 236 (10.8%), *Criconema* spp. 199 (9.1%), *Tylenchus* spp. 143 (6.6%), *Dolichodorus* spp. 78 (3.6%), while *Xiphinema* spp. registered the least with 35 (1.6%). The result shows large population of nematodes, making it hot spot for nematodes. The ubiquity of nematodes indicates that they are found everywhere (i.e., soil and water) not only on plants. The parasitic nematode might be a contributing factor to roots rot death in mangroves. But has not been investigated in these areas.

3.2. Trophic Diversity of Soil Nematodes from Eagle Island

Table 2 shows the trophic diversity of soil nematodes in the study area. Out of the total nematodes recovered from the soil in the study, the herbivores, *Longidorus* spp. 673 (17.9), *Criconema* spp. 159 (4.2), *Tylenchorhynchus* spp. 172 (4.6), *Hoplolaimus* spp. 111 (2.9), *Hirschmanniella* spp. 87 (2.3), *Hemicyclophora* spp. 121 (3.2), *Xiphinema* spp. 393 (10.4), *Pratylenchus* spp. 627 (16.7), *Helicotylenchus* spp. 486 (12.9), and *Rotylenchus* spp. 52 (1.4) dominated ($p \leq 0.05$) with 77% of total occurrence (**Figure 2**). This is followed by the bacterivores (10%) and fungivores with 13% which are mostly hyphal feeders. The recovered nematode population was dominated by nematodes of c-p 3, with 69.2% registered, while c-p 5 had 15.4%, c-p 2 and c-p had 7.7% each.

Table 2. Trophic diversity of Soil nematodes identified from Eagle Island, Niger Delta, Nigeria.

Nematode Genera	c-p Value	Feeding Type	FG	FGD	Abundance (%)
Longidorus spp.[c]	5	Herbivores	1d	Plant feeding	673 (17.9)
Criconema spp.[b]	3	Herbivores	1d		159 (4.2)
Tylenchus spp.[d]	3	Fungivores/algivores	2	Associates of plant roots, mosses and algae	343 (9.1)
Tylenchorhynchus spp.[d]	3	Herbivores	1d	Migratory ectoparasites	172 (4.6)
Hirschmanniella spp.[d]	3	Herbivores	1b		87 (2.3)
Rotylenchus spp.[d]	3	Herbivores	1c		52 (1.4)
Hemicyclophora spp.[b]	3	Herbivores	1d	Ectoparasites	121 (3.2)
Xiphinema spp.[c]	5	Herbivores	1d	Pant feeding	393 (10.4)
Pratylenchus spp.[d]	3	Herbivores	1b	Migratory endoparasites	627 (16.7)
Aphelenchus spp.[a]	2	Fungivores	2	Hyphal feeding, fungal feeding	153 (4.1)
Helicotylenchus spp.[d]	3	Herbivores	1c	Ectoparasites or semi-endoparasites	486 (12.9)
Rhabditis spp.[e]	1	Bacterivore	3	Bacterial feeding	387 (10.3)
Hoplolaimus spp.[d]	3	Herbivores	1c	Ectoparasites or semi-endoparasites	111 (2.9)
Total (%)					3,764

Note: a, b, c, d and e= genera with similar alphabets are not significantly different from each other.

3.3. Maturity Index, Diversity, and Evenness of Nematode Fauna in Soil from Eagle Island

Maturity index of soil nematodes in the various sample stations is shown in **Table 3**. *Rhizophora* spp. had (3.25), *Avicennia* spp. (3.58), Sandy shore, (3.59), *Nypa* spp., (3.58), and reclaimed land had (3.39). Shannon diversity index is as follows: Sandy Shore (1.05), *Rhizophora* spp. (0.95), *Avicennia* spp. (1.10), Nypa spp. (0.94) and Reclaimed land (1.09). Evenness in all sample stations is as follows: Sandy Shore

(0.94), *Rhizophora* spp. (0.85), *Avicennia* spp. (0.63) *Nypa* spp., (0.80), and Reclaimed land (0.80). The maturity index of nematode is used in environmental studies to determine how disturbed the underground ecosystem of the mangrove forest is. This depends on the colonizers and persisters in the study areas.

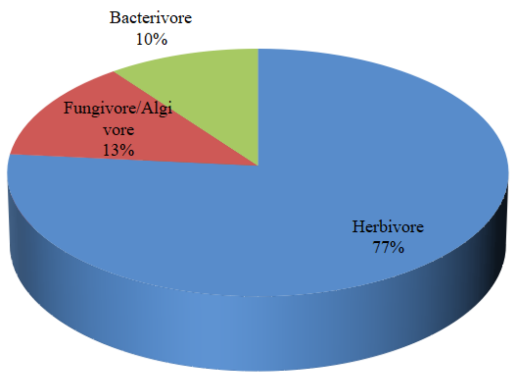

Figure 2. Percentage composition of trophic groups of soil nematodes identified from Eagle Island, Niger Delta, Nigeria.

Table 3. Maturity Index, Diversity and Evenness of Nematode Fauna at Eagle Island, Niger Delta, Nigeria.

	Sandy Shore	***Rhizophora racemose***	***Avicennia germinans***	***Nypa fruticans***	**Reclaimed Land**
Maturity Index	3.59	3.25	3.58	3.58	3.39
Shannon Index (H')	1.05	0.94	1.10	0.94	1.09
Simpson's Dominance	0.37	0.46	0.53	0.46	0.42
Hill's N_0	5	5	5	5	5
Hill'S N_1	2.86	2.56	3.00	2.72	2.97
Hill's N_2	2.70	2.17	1.89	2.17	2.38
Hill's Evenness	0.94	0.85	0.63	0.80	0.80

4. Discussion

A substantial proportion of the world's coastlines in the tropics is occupied by tidal mangrove forest [26]. The coastlines are believed to support estuarine and coastal *Avicennia* and *Rhizophora* trees. The dominant species of mangroves in the study area is the *Rhizophora* species, which makes 60% of the entire population of mangroves. However, two mangrove species were considered in this study to determine the prevalence of plant-parasitic nematodes in both mangrove ecosystems, namely *Rhizophora* spp. and *Avicennia* spp. It was observed that *Rhizophora* spp. had a higher percentage of nematodes, having 61.2% and *Avicennia* spp. having 38.8%. This conforms to the higher prevalence 60% and 40% demonstrated by Balan et al. (2024) [27]. The higher population of nematodes in *Rhizophora* species can be attributed to their ubiquity around the wetland areas of the Niger Delta. The red mangroves have more human-tree contact compared to the *Avicenia* species because of their economic value through their use for firewood production. In the same vein, the adventitious roots of the *Rhizophora* species enable their breathing root system to extend out of the soil, allowing them to contact tidally accumulated plastic waste, which gets stuck to their roots during high tide.

Our observation aligns with the report of Khan (2012) [28] that mangrove ecosystems play host to a significant number of nematodes. However, a higher prevalence of nematodes is observed in *Rhizophora* spp. The region was not as a result of fewer disturbances, as non-significant occurrence of nematodes in disturbed and undisturbed environments has been observed in previous studies [29]. *Rhizophora* species, called the red mangroves, are the most dominant mangrove species in the study area and in the Niger Delta region. It is not surprising that the red mangroves have a higher percentage of nematode prevalence, as they are primarily used for firewood production and are the most exposed to human-mediated perturbations. The dominance of the red mangroves has placed them in all coastal environments where human waste is being deposited by residents living at the water's edge. In contrast, Spedicato et al. 2023 [30] found the *Avicennia* spp. to be higher in prevalence than the *Rhizophora* spp.

The aquatic nature of mangrove flora provides a conducive environment for a varied range of plant nematodes.

However, minimal work has been done on the distribution of nematodes in mangrove ecosystems. Our current study reports the genera *Helicotylenchus, Tylenchus,* and *Hirschmanniella,* which are part of the seventeen important species of plant parasitic nematodes reported by Ferris et al. (2025)[31] from the Sunderban mangrove forest found infesting the mangroves.

A total of 13 genera of nematodes were recorded, with bacteria feeders representing the least number (10%), followed by Fungal/Algal feeders (13%), and the plant feeders representing the highest number (77%). Such occurrences and the variety of plant feeders are quite uncommon in most ecosystems and are clearly related to the absence of man-induced disturbance and the rich food web of the site. In terms of taxonomic groups, among the 13 genera identified, 49% belong to Tylenchoidae, followed by Dorylaimoidae at 28.3%, Rhabditidae at 10.3%, Criconematoidae at 7.4%, and Aphelenchoididae at 4.1%. This is due to the high degree of stability of this region, which has been relatively free of human intervention. This finding is in agreement with earlier reports that populations of dorylaimids in the nematode community are sensitive to disturbance (agricultural practices) and are therefore used as indicators of environmental disturbances[32].

Low Maturity Index (MI) values characterize enriched and disturbed environments, whereas high MI values indicate stable environments. Compared to colonisers, persisters demonstrate a greater sensitivity to pollutants and other disturbances. Consequently, the MI additionally functions to evaluate the influence of various assortments of contaminants, identified and unidentified, encompassing their multifaceted interactions with the abiotic and biotic environment[33]. The contribution of bacterivorous and herbivorous nematodes with high c-p values was high in this study across sample stations. This thereby led to a high Maturity Index (3.5). Our results are in contrast with those of Lucas et al. (2026)[34], where bacterivores and herbivores were absent, but a high proportion of them recorded in our study were reported by Devi and Vaid (2026)[35].

The diversity and evenness of all the samples from Eagle Island were determined by calculating the diversity indices based on the occurrence at the five sample stations (**Table 3**). The diversity indices, Shannon (H') and Simpson (D), indicated mean values of 1.0 and 0.5, respectively. The values concerned were low, indicating low nematode diversity. Pielou's J' or Evenness Index scored a value of 0.8, which is very close to 1. Such a finding suggests that, on average, there is an even distribution of abundances amongst families within the Eagle Island soil. Hill's N_0 Index had a value of 8.0, which indicates that, on average, five nematode families were present within one sample in our study area. Hill's N_1 Index was equal to 2.8, and Hill's N_2 Index had a value of 2.3. Thus, the presence of diverse group of nematode reveal that the study area is disturbed by human activity, which can be used as an indicator of anthropogenic impact. Lastly, the dominance of the herbivorous nematode is an indication of the mangrove forest being a plant-based environment. The herbivorous nematodes thrive on the mangrove root and thus can influence the parasitic dynamics of the ecosystem. Nematode population is also determined by their ability to migrate from the wetland soil into the roots of the mangrove tree. The mangrove soil in the study area is highly impacted by numerous human activities such as sand mining, dredging, marine transportation and commercial activities (i.e., buying and selling of goods), which introduce human waste to the environment. The study implies that there is a high prevalence of nematode population, which might be caused by high anthropogenic activities in the area. A high abundance of herbivorous nematodes was also encountered since the study site is a plant-based ecosystem. Caution should thus be shown to prevent human-parasite contamination, which may lead to public health problems in the area.

5. Conclusion

Maturity and diversity indices focus on information concerning the dynamics, composition, and structure of communities in a particular measurement. When it is assumed that communities with dissimilar composition and structure function differently, soil health can be deduced from such indices. Our findings indicate an average, even distribution among families within the Eagle Island soil, which suggests stability within the community. This study reveals that despite the human disturbances on the surface there is seemingly a form of stability within the soil where the nematode resides. The contribution of bacterivorous and herbivorous nematodes with high c-p values was high in our study. This thereby led to a high Maturity Index (3.5), indicating stability. The red mangroves have a higher prevalence than the Avicennia (black mangrove) species due to their ubiquity in the coastal areas of the Niger Delta. The red mangroves serve as the site for waste deposition in many communities; thus, their roots absorb more microbes and parasitic components than other mangrove species. This study implies that there will be a quick and total recovery of the deforested mangrove ecosystem if human disturbances cease. This study is first of its kind in the Niger Delta, therefore more studies are needed to determine the prevalence of nematode in other mangrove species and other associated species. Mangrove forests can be protected from nematode infestation by preventing waste disposal in the forest. Similarly, defecation and the dumping of human waste in the forest should be stopped to prevent the proliferation of geohelminths.

Author Contributions

Conceptualization, A.O.; methodology, S.O.N.; software, A.O.; validation, A.O., S.O.N., and A.O.N.; formal analysis, A.O.; investigation, A.O. and S.O.N.; resources, A.O. and S.O.N.; data curation, S.O.N.; writing—original draft preparation, A.O.N.; writing—review and editing, A.O., S.O.N., and A.O.N.; visualization, A.O.; supervision, S.O.N.; project administration, S.O.N. All authors have read and agreed to the published version of the manuscript.

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