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DIVERSITY INDICES OF SELECTED BIOTA IN SOMBREIRO RIVER, RIVERS STATE, SOUTH-SOUTH NIGERIA

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Abstract
An investigation aimed at ascertaining the species richness, evenness and diversity of phytoplankton, epipelic algae, zooplankton and benthic macro faunal communities of Sombreiro River was carried out over a 24 month period across 10 stations. Samples were collected once monthly and preserved in the field before transporting to the laboratory, where samples were identified and enumerated to the species level using relevant identification keys. Field and laboratory methods followed standard procedures and data generated were subjected to specific ecological statistical analyses using analytical tools fit for natural communities. Margalef's index for species richness, evenness index and Shannon – Weiner diversity index for phytoplankton varied from 5.638 – 7.423, 0.717 – 0.882 and 1.331 – 1.664 respectively. Those of epipelic algae are 8.796 – 9.302, 0.489 – 0.709 and 0.560 – 0.922 respectively, those of Zooplankton respectively fluctuated from 1.852 – 4.297, 0.748 – 0.921 and 0.920 –1.399 and finally benthic macro fauna values ranged from 0.944 – 2.055, 0.905 – 0.991 and 0.452 – 0.673 respectively. Species richness/ diversity data except for phytoplankton showed that more species were recorded in the lower zone followed by the middle zone and then the upper zone. This is in total agreement with the generally held consensus that diversity decreases as pollution increases and vice versa.

Key words: Species diversity, evenness, species richness, natural communities

Introduction
The variety and heterogeneity of organisms or traits at all levels of the hierarchy of life, from molecules to ecosystems is represented by biodiversity (Morris *et al*., 2014). Their presence or absence, abundance, diversity and distribution could give an insight into the anthropogenic activities prevalent in any given ecosystem. Empirical studies on biodiversity in natural communities require the use of relevant statistical tools to analyze data obtained from the field. Ecological statistics tools used in characterizing species abundance relationships are diverse and takes into cognizance how the total abundance of species are distributed among the various species and the total number of individuals encountered (Ogbeibu, 2014). The way the species are distributed is expressed as evenness, with high values indicating relatively equal numbers of individuals per species and low values signifying that one or a few species dominate. The total number of species is expressed as richness, which according to Magurran, (2004) is the most commonly applied and simplest metric used to represent diversity. Das (2021) opined that among several indices for estimating diversity, the Shannon- Weiner Diversity Index is unarguably the best choice, while Mulya *et al*., (2021) opined that Margalef's index is the best index for species diversity measurement in mangrove communities. The magnitudes of these three indices generally tend to reduce with increasing environmental contamination (Johnston& Roberts, 2009) and as such can be used as ecological indicators (Chariton *et al.,*2016). Determining these values (richness, evenness and diversity) in selected biota of the Sombreiro River is the aim of this investigation.

Materials and Methods
The study area was demarcated into three blocks – lower, middle and upper blocks. Two stations (1 and 2) were established in the lower block representing the non- oil production activity zone while four stations each were established in the middle (Stations 3 – 6) and upper blocks (Stations 7 – 10). While the middle block – "legal oil production activity zone" (houses a well head and flow station) the upper block – the "illegal oil production activity zone" houses local/artisanal refineries.

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While the stations in the middle and upper blocks were test stations, stations 1 and 2 in the lower block served as control.
Standard methods (APHA, 2005) were adopted for sampling and laboratory analysis of all parameters and this lasted for 24 months. Phytoplankton and epipelic algae (flora), zooplankton and macro - faunal benthos (fauna) were deployed for this investigation.
The geographic coordinates of the study area spread from N 4˚ 34.692' to 4˚ 43.329' and E 6˚ 48.037'to 6˚ 46.476'.
Being natural communities ecological statistical tools as given by Ogbeibu, (2014) and specified below were utilized in characterizing species abundance relationships of the phytoplankton, epipelic algae, zooplankton and macro-benthic fauna communities.

1) Margalef's index (d) was used to obtain the estimate of species richness and is given by;

$$d = \frac{S-1}{Log\ N}$$

Where; S = Total number of species

N = Total number of individuals of all species

Log N = Natural or Naperian logarithm

2) Shannon- Weiner Diversity Index (H) given by,

$$H = \frac{N \log N - \varepsilon fi \log fi}{N}$$

Where,

N = total number of individuals of all species

Fi = number of individuals of eachspecies

3) Evenness Index (E) given by

$$E = \frac{H}{H_{max}} = \frac{H}{\log\ S}$$

Where,

H = observed diversity

S = number of species

Results and Discussion
Presented in Fig. 1 are the Species Richness, Evenness and Diversity Indexes of phytoplankton for all the Stations throughout the period of study. Phytoplankton species richness during the period of the study varied from 5.638 in Station 1 to 7.423 observed in Station 7. Similarly, Evenness and Diversity Indexes fluctuated from 0.717 to 0.882 and 1.331 to 1.664 obtained from Stations 5 and 10 respectively.

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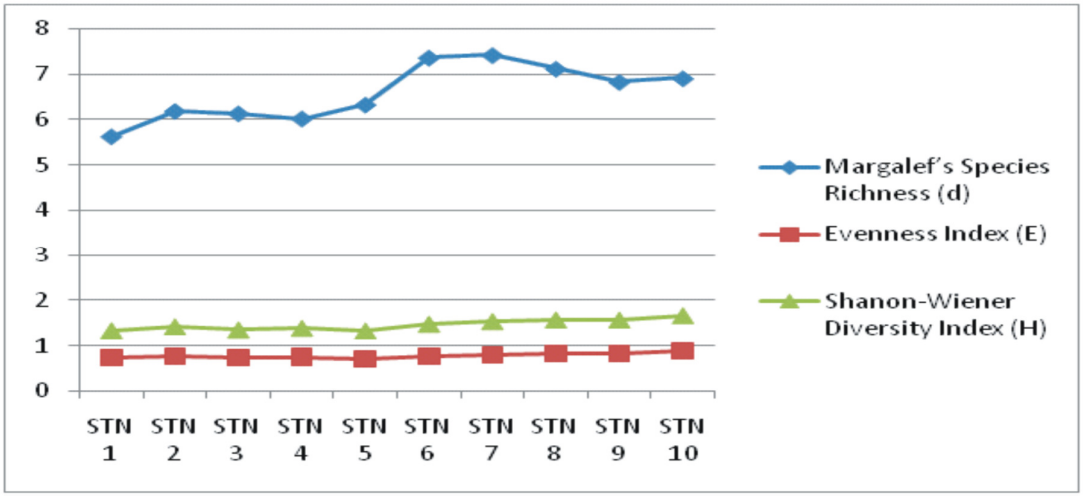

Fig. 1: Phytoplankton species richness, evenness and diversity Indices

Figure 2 shows the Species Richness, Evenness and Diversity Indexes of epipelic algae obtained for the entire study. Epipelic algae species richness during the period of the study varied from 8.796 in Station 1 to 9.302 gotten in Station 10. Similarly, while Evenness values fluctuated from 0.489 to 0.709 (obtained in Stations 6 and 5 respectively) that of Diversity index varied from 0.560 gotten in Station 6 to 0.922 obtained in Stations 5.

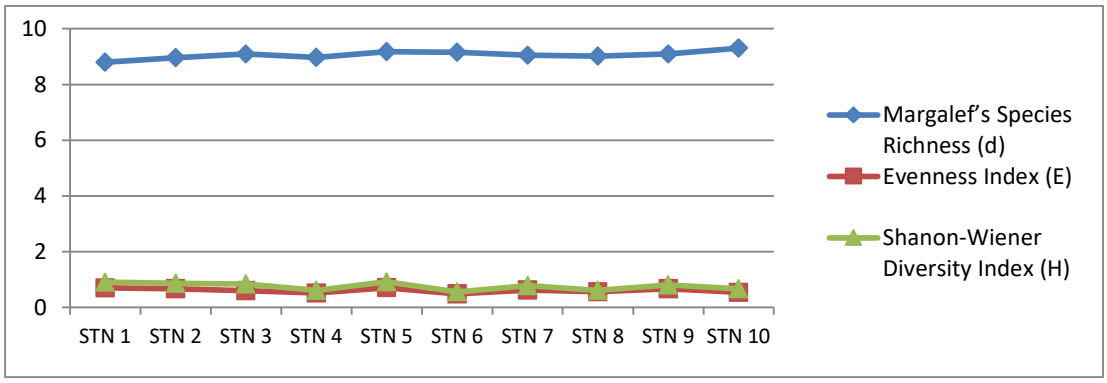

Fig 2: Epipelic algae species richness, evenness and diversity indices

Figure 3 shows the Species Richness, Evenness and Diversity Indexes of zooplankton obtained for the entire study. Zooplankton species richness during the period of the study varied from 1.852 in Station 6 to 4.297 obtained from Station 2. Evenness values however, fluctuated from 0.748 to 0.921 obtained in Stations 6 and 5 respectively while that of Diversity index varied from 0.920 obtained from Station 6 to 1.399 obtained in Stations 5 (see Fig. 3).

The Species Richness, Evenness and Diversity Index of benthic macro fauna obtained for the entire study are as shown in Fig. 4. Benthic macro fauna species richness during the study fluctuated from 0.944to 2.055 obtained in Stations8and 9 respectively. Evenness values fluctuated from 0.9051 obtained from Station 3 to 0.9915 obtained in Station10, and that of Diversity index was from 0.4516gotten in Station 5 to 0.6731 obtained in Stations 9, see Fig. 4.

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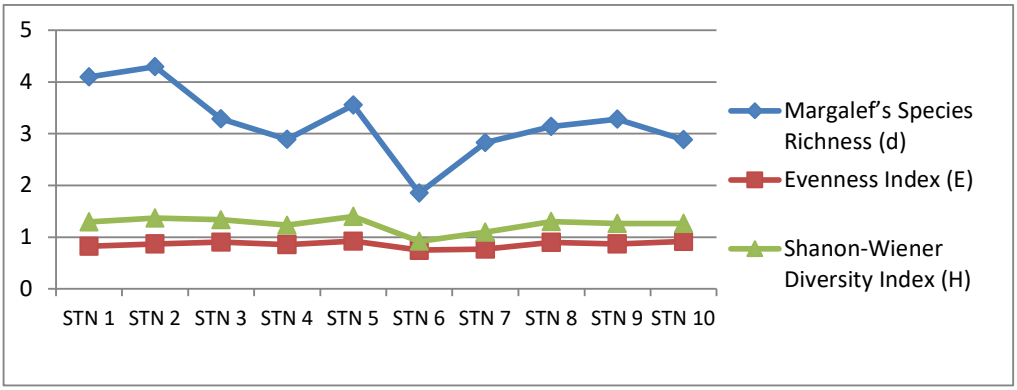

Fig. 3: Zooplankton species richness, evenness and diversity indices

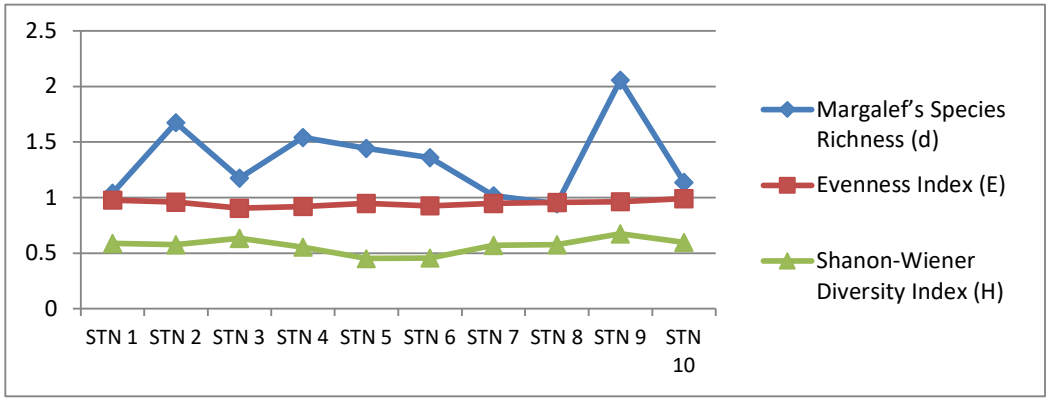

Fig. 4: Benthic macro- fauna species richness, evenness and diversity indices

Phytoplankton diversity index for the study area fluctuated from 1.331 to 1.664, which compares favourably with the 0 922 to 1.573 reported by Ezekiel *et al.*,(2011) in the fresh water axis of Sombreiro River, and the 0.88 – 2.07 in the Bonny Estuary by Aguonu *et al.,* (2011), but higher than the diversity range of 0.208 – 0.595 in the Elechi Creek by Ogamba*et.al*., (2004) and lower than the range of 1.479 – 4.165 reported by Edoghotu, (1998) for Oginigba Creek in Port Harcourt and the 3.8 – 50 observed in the lower Bonny Estuary by Chindah and Braide (2004)**.** The species Richness (a measure of the total number of species) in this investigation varied from 5.638 – 7.423 as opposed to the 4.705 – 5.096 and 3.823 – 5.965 as reported by Ezekiel *et al.,* (2011), and Ogamba *et al*., (2004) respectively. Similarly, Evenness (which measures how the number of individuals are distributed among the species) in this study fluctuated from 0.717 – 0.882. This is comparable to the evenness range of 0.659 – 0.955 gotten by Ogamba *et al*., (2004) in the Elechi Creek but slightly lower than the range of 0.922 – 0.973 gotten in the Sombreiro River by Ezekiel *et al.,* (2011).

Epipelic algae species diversity in this study was low and varied from 0.560 – 0.922, lower than the investigation of Sahin *et al*., (2010) who reported a maximum diversity value of 2.26. Wokoma (1999) re-counted a diversity of 0.97 – 3.77 for periphyton in the Elechi Creek, and observed that all the lowest diversity values were recorded in Station 5 (the most impacted) and the highest at station 1 (the control Station). The evenness value ranged from 0.489 – 0.709 and is also lower than the 0.31 – 1 reported by Wokoma (1999), however the species richness was high varying from 8.796 – 9.302.

Species richness or diversity was highest in the lower zone (station 1 – 37 species and station 2- 38 species with a mean of 37.5 species) with no oil production activity, while the middle and upper zones had a uniform mean

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number of species of 26.75 each (middle zone's stations 3, 4, 5 and 6 had 30, 27, 33 and 17 species respectively and upper zone's stations 7, 8, 9 and 10 had 26, 28, 29 and 24 species respectively).

The Shanon – Weiner Diversity Index (H) recorded for Zooplankton in the study area varied from a low of 0.920 to a high of 1.399 which is generally lower than the range of 3. 4578 – 3.4798 reported by Sulehria *et al.,* (2013) for epiphytic rotifers of a flood plain. The observed values of this investigation compares favourably with 1.074 – 1.204 reported by Ezekiel *et al.,* (2011) also in the Sombreiro River and the 0.87 – 1.61 recorded by Aguonu *et al.,* (2011) in the Bonny Estuary. It is however higher than the range of 0.4503 – 0.6541 recorded by Vaidya and Yadav, (2008) in the fresh water bodies of Kathmandu valley. They added that the observed low diversity was as a result of the water quality of the investigated water bodies which were found to be deteriorated due to the discharge of untreated effluents, solid wastes and poor conservation practices.

The evenness values ranged from 0.748 – 0.921 which is comparable to the evenness range of 0.6146 –0.9602 reported by Vaidya and Yadav, (2008), as well as that of Ezekiel *et al.,* (2011) which varied from 0.870 – 0.978. Margalef's species richness fluctuated from 1.852 – 4.297 and is in close affinity with the reported range of 2.256 – 2.345 as observed by Ezekiel *et al.,* (2011) and the mean value of 2.9139 recorded by Sulehria *et al*., (2013), but higher than the 0.86 – 2.48 reported by Aguonu *et al.,* (2011).

The diversity index of macro benthic fauna in Sombreiro River varied from 0.452 – 0.673, this is below the mean value of 0.956 reported by Ezekiel *et al.,*(2011) in the fresh water region of Sombreiro River as well as that of Das (2021) who recorded a Shanon – Wienner diversity index of 0.74 for macro-invertebrates in the tidal mud flat of Hana Char. Species richness and evenness values in this study varied from 0.944 – 2.055 and 0.905 – 0.991 and both compares favourably with the reported mean values of 1.339 and 0.986 (Ezekiel *et al.,* 2011) respectively. Nkwoji *et al*., (2010) also reported low values for Margalef's species richness and Shanon – Wienner diversity index.

The phytoplankton species richness, evenness and diversity index were fairly distributed in the Stations. This shows that the phytoplankton community was stable in the Stations of the study area. Minimal variations in the density of phytoplankton as reflected by Shannon – Weiner (H), Pielou's Evenness (E) and Margalef's Species Richness (d) is attributable to uniform chemical and physical conditions in the river. A comparison of the diversity indices used in this study showed that Shanon – Weiner index produced low result ranging from1.331 – 1. 664 in all the Stations while that of Margalef was quite high fluctuating between 5.682 – 7.423 and is more reflective of the observed data, bringing out the differences between the Stations. Therefore, the Margalef index is more suitable to interpret the diversity pattern of phytoplankton in Sombreiro River.

The high species richness value of epipelic algae in relation to the low diversity and evenness values is indicative of the fact that only a few opportunistic species accounts for the abundance (total individuals) of epipelic algae in the study area, and is indicative of a single (few) species dominance – a feature of stressed or polluted environments. This position is further amplified by the presence of the genus Phormidium in all the Stations of the study area as a consequence of the suggestion of Sen*et al.*, (1990) that Phormidium species are indicators of pollution and are more prolific in polluted regions.

The zooplankton community structure as exemplified by the ecological indices (diversity index, species richness and evenness) showed stability in the study area. However, the conclusion of Aguonu *et al.,* (2011) that copepods (are known to) constitute a major food source for most commercial fish species and dominate the zooplankton communities of water bodies that serve as natural breeding grounds for most aquatic fauna is at variance with outcome of this study. The zooplankton community of the study area was dominated by Protozoa and Rotifera, indicating that the Sombreiro River is no longer playing its role efficiently as a natural breeding ground for aquatic fauna. This observation is thought to be a response by the zooplankton community to environmental stressors – in this case total hydrocarbon content (THC).

The low population density and diversity of benthos in the sediments of the study area is indicative of an environment under stress, and the dominance of the community by polychaetes suggests that they are either adapted to or are favoured by the stressor – petroleum hydrocarbon. This explains why there was a near absence of crabs, mudskipper and periwinkle in the mudflats of the Sombreiro River.

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Generally, species richness/ diversity of the biological data except phytoplankton showed that more species were recorded in the lower zone followed by the middle zone and then the upper zone. This is in total agreement with the generally held consensus that diversity decreases as pollution increases and vice versa (Wu, 1982).

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