Original Research Article

Assessing the impact of precipitation on zooplankton community structure of a tropical river, Niger Delta, Nigeria

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Abstract

Rainfall patterns influencing abundance, diversity and species richness of zooplankton in Mbo River, Nigeria were studied for twelve months using standard analytical methods. The aim was to study rainfall patterns determining zooplankton structure as reference point for the sustainable management of the river in view of the proposed development plans for the river basin. A total of 45 species of zooplankton in eight taxonomic groups were collected as follow: Station I had a higher species richness number (25 species) than Station II (10 species) and Station III (9 species). The results showed that Crustacea was highest constituting 48% in Station I, and 30.8% and 33.3% in Stations II and III respectively. Other taxonomic groups present included Rotifera which contributed to 20.0%, 50.0% and 55.6% in Stations I, II and III, respectively; Molluscs in Station I contributed 8.0% of the species composition but was absent in Stations II and III and Protozoa which contributed 9.1% of the total zooplankton composition in Station I but was not recorded in the other two stations. The maximum diversity per station/month (2.79) was calculated for Station I in September and minimum (0.93) was observed in Station III in July. Seasonally, wet season recorded maximum value of 3.02 while dry season recorded lower values. The significant seasonal variation in zooplankton density (cells/l), diversity and richness was regulated by rainfall.

Keywords: Diversity, Niger Delta, Rainfall, Tropical river, Zooplankton

INTRODUCTION

The increasing water pollution from up-to down-river can be revealed not only by the physico-chemical analyses but also by the indicating plankton especially zooplankton. It is also noted that in relating to increasing pollution, the distribution pattern of zooplankton change in the species composition as well as the diversity of the community. This is attributed to a change in the physico-chemical properties as a result of the deterioration of the water quality. Odiete (1993) noted that plankton growth distribution depended on the carrying capacity of the environment and on the nutrients concentration. The distribution of zooplankton communities depends on many factors, some of which are change of climatic conditions, physico-chemical parameters and vegetation cover (Ekpo, 2013).

The studies revealed that although flood pulse is the affect of heavy rainfall and is a driving force in the ecology of floodplains, in the present study no direct influence of rainfall on the density of different groups of zooplankton could be discerned (Khan et al., 1983; Khan and Ejike, 1984; Akpan and Akpan, 1994 and Essien-Ibok, 2010). This is due to the occurrence of native species as the station is rich in organic and inorganic nutrients along with vegetations which provided shelter against fish predation.

Zooplanktons are microscopic drifting animal-like
organisms found either at or near the surface of water bodies (Ekojo, 2013). Ovie (2011) defined zooplankton as the free-floating, aquatic invertebrates, often described as microscopic because of their usual small sizes that range from a few to several micrometers and are rarely exceeding a millimeter.

The coastal river, Mbo River was chosen for the study because despite its economic and ecological importance and the fact that the area has been chosen by the State Government to be the proposed site for the Deep-sea Port at Ibaka, no published work is available on it as at the inception of the study. This work, therefore, aims to provide a reference point on the effect of precipitation on zooplankton species composition, density, diversity and species richness which will help in the sustainable management of this ecosystem.

MATERIALS AND METHODS

Study Area

The Mbo River (Figure 1) is one of the major rivers in Akwa Ibom State, Nigeria traversing across two local government areas (Urue Offong Oruko and Mbo Local Government Areas) and lies within latitudes 4°30’ to 5°30’ North and longitudes 7°30’ to 8°30’ West on the South Eastern Nigerian coastline. It is a near coastal river located within the Cross River basin and drains into the Cross River Estuary at Ibaka in the Bight of Bonny, with which it maintains a permanent mouth thus exposing the system to tidal ebb and flow. It forms part of the Atlantic Drainage system (Anukam, 1997) east of the Niger which comprises the Cross, Imo, Qua Iboe and Kwa Rivers.

Mbo River which is within the Niger Delta zone of Nigeria is located within the tropical rainforest region characterized by tropical humid climate with distinct dry (November – March) and wet (April – October) seasons (Figure 2). The dry season is characterized by prevalence of dry tropical continental winds from the Sahara Desert while the wet season is typified of moist tropical wind from the Atlantic Ocean. The vegetation cover of the drainage area is dominantly dense Nypa fruticans which seems to have displaced indigenous mangrove trees, Rhizophora racemosa (Orok et al., 2010). Mbo River ecosystem is an important ecosystem. It supports the local economic activities such as agriculture, fishery, eco-tourism and water supply for domestic use. The importance and roles of the ecosystem influences the urbanization and economic activities that converged along the river corridors. The increasing urbanization and socio-economic activities have impacted the ecosystem. The river suffers different impacts of anthropogenic activities along its extension. Non-point impact from the drainage due to surface runoff, washing and spillage from motorized boats, and direct defecation by rural dwellers constitute the main water quality/chemical problems, while loss of habitats as a result of harvesting of mangroves for firewood and riparian degradation constitute the physical problems.

For this survey, three sampling stations within the stretch of the river were recognized (Figure 1). Station III (Ukontenge creek) is located about 1500m upstream of the Mbo Bridge. The average depth at this Station is about 3.5m with an average current velocity of about 51cm sec\(^{-1}\). The fringing vegetation is mainly of red mangrove (Rhizophora racemosa). Human activities at this site are limited to fishing, palm tapping and
occasional bathing. Station II is located between the bridgehead and the defunct Fishing Terminal at Egbughu. The average depth of this site is about 4.1m with an average current velocity of about 45cm sec\(^{-1}\). The fringing vegetation is mainly of *Nypa fruticans* because mangrove species have been felled for construction and firewood for smoking of fish and for domestic use. This station records intense human activities such as domestic chores, intense fishing and faecal discharge which could impact negatively on this location along the river. The human endeavours here also include the use of motorized boats for commercial services. In addition to these, there is a small landing port for medium sized sea-faring boats, with lots of mechanical repairs going on here. Station I is located at 1,000m to the mouth of the river where the river empties into the estuary.

Sampling stations were selected to represent different environmental and ecological variations within the river, so as to better understand the effects of natural and anthropogenic factors on the river’s water quality. Sampling was carried out fortnightly at the three established sites during the mid morning hours between the hours of 8am and 11am.

**Zooplankton Sampling**

Qualitative estimation of plankton was made using a 30cm square mouthed 70mm mesh bolting silk net (Griffin) and collections were made in triplicate. Zooplankton samples for qualitative analysis were obtained by placing the net below the water surface (20cm) and the net towed for 5 minutes until a sufficient quantity of plankton was collected.

Water samples (1,000ml) were collected from approximately 20cm below the water surface mid-stream at each sample site in new, clean 1liter polythene sample bottles, clearly and permanently labeled. The sample was fixed with approximately 5ml of 4% formaldehyde solution and taken to the laboratory for analysis. The sample bottles for plankton were allowed to stand (sedimentation) for 48 hours before decanting the supernatant leaving an aliquot of known volume (10ml). The concentrated samples were homogenized before 1ml of sub-sample from the original stock was collected with sample pipette (Onuoha, 2009). The pipette content was transferred onto a Sedgewick – Rafter counting chamber for species enumeration at a microscope magnification of 400× using the synopsis of Durand and Leveque (1980), Screenivas and Dulthie (1993), Newell and Newell (1977), Egboroge (1973), APHA-AWWA-WPCF (2005) and Onuoha (2009).

**Statistical Analysis**

**Data Transformation**

All the raw data was appropriately transformed to address the normality and homocedasticity requirements of the parametric analysis (Ogbiebu, 2005). Statistical Package for Social Sciences (SPSS) Data Editor was used to compute all measures of central tendencies and dispersion, to characterize the stations in terms of the physico-chemical conditions and fauna abundance, using one way analysis of variance (ANOVA) and the graphics were computed with Microsoft Excel. The biotic community was analyzed using diversity and similarity indices adopted from Ludwig and Reynolds, 1988.

**Community structure assessment**

Shannon – Wiener index of diversity (Shannon and Wiener, 1963) was expressed as:

\[ H_s = \sum \frac{N_i}{N} \log_e \frac{N}{N_i} \]
RESULTS

Species Richness

A total of 45 species of zooplankton in eight taxonomic groups were collected. Of this total, Crustacea was present with the highest percentage of 48.0% in the total zooplankton composition in Station I. In the other two stations (II and III), Crustacea did not dominate as in the first station but rather contributed 30.0% and 33.3% in Stations II and III respectively. Other taxonomic groups present in this study include Rotifera which contributed to 20.0%, 50.0% and 55.6% in Stations I, II and III respectively. Mollusca in Station I contributed to 8.0% of the species composition in this station but was absent in Stations II and III. Protozoa which contributed to 9.1% of the total zooplankton composition in Station I was not recorded in the other two stations. A total percentage of 10.0% and 11.1% were recorded for ciliates in Stations II and III (Figure 4). These were absent in Station I. Polychaetes and Chordata contributed to the percentage composition (4.0% each) only in Station I. Cladocera was scantily recorded in Station II with a percentage contribution of 10.0% of the zooplankton community in this station.

A total of 45 species of zooplankton in 8 taxonomic groups was collected. Of this total, Rotifera presented the highest amount of species richness, which constituted 38% of the total zooplankton species (Table 1). Other taxonomic groups were presented as follows: Crustacea (37.1%), Polychaeta larvae (4.0%), Mollusca (8.0%), Chordata (4.0%) and Protozoa (16.0%). (Figure 3)

In respect to the different stations, Station I had a higher species richness number (25 species) than Station II (10 species) and Station III (9 species). Therefore, Station I made up 56.8% of the species richness,
Table 1. Seasonal variations in zooplankton density (individuals/l) in the two seasons in Mbo River

<table>
<thead>
<tr>
<th>Season</th>
<th>Mean density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet</td>
<td>220.00* (107.51)*</td>
</tr>
<tr>
<td>Dry</td>
<td>121.83b (61.94)b</td>
</tr>
<tr>
<td>LSD</td>
<td>27.03 (9.32)</td>
</tr>
<tr>
<td>P</td>
<td>0.001 (0.0006)</td>
</tr>
</tbody>
</table>

*Means with same letters show no significant difference.

Table 2. Effect of different sampling months on means of total density of zooplankton in Mbo River

<table>
<thead>
<tr>
<th>Months</th>
<th>Zooplankton</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>August</td>
<td>33.8ab (16.3)b</td>
<td>947.1</td>
</tr>
<tr>
<td>September</td>
<td>40.5a (19.3)a</td>
<td>289.8</td>
</tr>
<tr>
<td>October</td>
<td>34.0b (16.6)b</td>
<td>520.2</td>
</tr>
<tr>
<td>November</td>
<td>27.7ac (14.0)cd</td>
<td>215.2</td>
</tr>
<tr>
<td>December</td>
<td>25.0bc (12.7)bc</td>
<td>44.8</td>
</tr>
<tr>
<td>January</td>
<td>23.8cd (11.9)cde</td>
<td>76.9</td>
</tr>
<tr>
<td>February</td>
<td>22.0cde (11.7)cde</td>
<td>141.6</td>
</tr>
<tr>
<td>March</td>
<td>23.3cde (11.7)cde</td>
<td>82.3</td>
</tr>
<tr>
<td>April</td>
<td>23.0cde (11.8)cde</td>
<td>381.3</td>
</tr>
<tr>
<td>May</td>
<td>28.8aded (14.9)aded</td>
<td>498.6</td>
</tr>
<tr>
<td>June</td>
<td>28.5ade (15.1)cde</td>
<td>725.1</td>
</tr>
<tr>
<td>July</td>
<td>31.0ade (13.5)ade</td>
<td>855.3</td>
</tr>
<tr>
<td>LSD</td>
<td>2.58 (0.96)</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>&lt;0.0001 (&lt;0.0001)</td>
<td></td>
</tr>
</tbody>
</table>

*Means with the same letters are not significantly different.

Table 3. Spatial variation in the density of zooplankton in the study sites in Mbo River

<table>
<thead>
<tr>
<th>Station</th>
<th>Mean zooplankton density</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>202.50a (114.12)a</td>
</tr>
<tr>
<td>II</td>
<td>149.75b (70.63)b</td>
</tr>
<tr>
<td>III</td>
<td>160.50b (69.42)b</td>
</tr>
<tr>
<td>LSD</td>
<td>33.11 (11.42)</td>
</tr>
<tr>
<td>P</td>
<td>0.03 (0.002)</td>
</tr>
</tbody>
</table>

*Means with same letters are not significantly different.

followed distantly by Station II with 22.7% and Station III with 20.5%.

The analysis of variance (ANOVA) on the total density or abundance of zooplankton shows that the sampling periods (twice a month) were not significantly different. This means that there was no bias in the sampling periods and that the sampling was homogeneous.

From Table 1 the mean total density in Station I is significantly different (P=<0.03) from that of Stations II and III. It could thus be surmised that in respect to zooplankton density, the variation in data collected was due to samples collected from Station I. Table 1 shows that the highest density for zooplankton was recorded in Station I (202.50 cells/l) while the least was recorded in Station II (149.75 cells/l).

In relation to the monthly density of zooplankton, the highest density was recorded in September (40.5 cells/l) and the least density was observed in February (22.0 cells/l). Zooplankton density in September was significantly different (P=<0.0001) from that of the other months during the sampling period, surmising that the variation in data collected was due to September's abundance.

The results of LSD on the seasonal variation in zoo-
plankton density showed that the variation between the two seasons were significantly different from each other (P=0.001). The mean in the dry season was 44.6% less than that of the wet season (Table 3). This shows that there is seasonal impact on the zooplankton density.

**Diversity**

The highest diversity index of 2.79 was recorded in the month of September in Station I and the least of 0.93 were recorded in July in Station III (Figure 4). Station I recorded the highest diversity value in all the months of the year with the smallest value of 1.98 recorded in March. In March and April, Station III showed the higher values in diversity index than Station II. Station II on the other hand, had higher Shannon-Wiener index values from May to February than Station III.

In respect to zooplankton in the surface water of Mbo River, Station I had higher diversity in the wet season (3.02) than in the dry season (2.69) (Figure 4). The index was slightly higher in the dry season in Station II (1.64) than in the wet season (1.64). Station III had higher...
diversity index in the dry season (1.51) than in the wet season (1.46). It could thus be deduced from this study that in the surface waters of Mbo River, zooplankton had higher diversity, that is, more different species in the dry season than in the wet season in Stations II and III. On the other hand, Station I had higher diversity during the months of rainfall than in the dry season. (Figure 5, 6).

**Correlation of rainfall with total density of zooplankton**

The correlation between rainfall and zooplankton density though a fair one, was not significant (r=0.30; P=0.08). This is an indication that the onset of the rains tends not to have any significant effect on zooplankton density.

**DISCUSSION**

Biogeographically and seasonal differences strongly influence the distribution pattern and constituents of aquatic communities. Because of their dynamic physical nature, the physical and chemical variables, floral and faunal composition of an estuary may vary considerably at spatial scales of metres to kilometers, and temporal scales of days to years (Morissey et al., 1992).

Zooplankton density was highest in September during the wet season. This could be attributed to the high values of phosphate and nitrates which had been recorded in this river for that month (Essien-Ibok et al., 2010). High concentrations of these nutrient elements usually give rise to high abundance of some zooplankton species in aquatic environments (Adesalu et al., 2010; Nwankwo, 2004). Similar regime has also been observed by some workers (Schaefer and Alber, 2007; Balogun and Ladigbolu, 2010 and Ekpo, 2013) where they reported that zooplankton are favoured in nutrient rich environments particularly estuaries. Davies et al., (2009) in their study of the seasonal abundance and distribution of plankton in Minichinda stream, Niger Delta recorded higher quantity volume of plankton in the wet than in the dry season.

The high density of Crustacea observed in this work differs from the results of Green (1960), Jeje and Fernando (1986), Egborge and Tawari (1987) and Akin-Oriola (2003) in which dominance of the Rotifera in Nigerian aquatic ecosystems had been documented. Akin-Oriola (2003) observed that the high population densities of Rotifera have been attributed to their parthenogenetic reproductive pattern and short developmental rates under favourable conditions.

Water level rise in the rainy season also decreased zooplankton density as observed by the negative correlation of zooplankton with rainfall during the wet season. This could be due to the pressure impacted on the cells by the water level. This reduction in density of zooplankton with water level is in accordance with the report of Yakubu (2004) who noted that filling out the river channel results in increase in volume of water flowing through the channel thus affecting the concentration of zooplankton. Zooplankton abundance and population dynamics have been reported to be influenced by repeated environmental fluctuations of which rainfall is a primary steering factor Kizito and Nauwerck (1995), Osore et al., 1997 and Akin-Oriola (2003). The onset of the rains signals a radical change in the physical, chemical, nutrient load, geological and biological characteristics of tropical rivers Lowe-McConnell (1987), Chapman and Kramer (1991) and Akin-Oriola (2003). The input of allochthonous organic materials from the catchment area during rainfall increases growth generally
due to the increased nutrient load.

The highest species diversity and density were observed in Station 1 (upstream). This was in contrast to the observation of Ekpo (2013) in which highest density was obtained downstream. The author attributed downstream high richness to the fact that during connectivity, the zooplankton taxa entered into the floodplain from different habitats along with the native species and survived well in the improved nutritional condition. Station 1 also showed substantially high diversity value. This might be due to the occurrence of native species as the station is rich in organic and inorganic nutrients along with aquatic riparian vegetations which provided shelter against fish predation.

CONCLUSION

The zooplankton community of Mbo River showed a high density and diversity. The assessment of community and ecosystem stability using overall diversity showed Station 1 as the most complex and stable station. The overall diversity may be the product of all spatial and temporal changes affecting the community (Ogbiebu and Oribhabor, 2001) rainfall being the major determinant factor.

REFERENCES

American Public Health Association (APHA) and American Water Works Association and Water Pollution Control.