

IMPACT OF ALUMINIUM EXTRUSION EFFLUENTS ON PLANKTON AND FISH COMPOSITION OF MBAA RIVER, INYISHI, IMO STATE, NIGERIA

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Abstract: The impact of aluminum extrusion effluent on Plankton and fish composition status of Mbaa River in Inyishi, Imo State of Nigeria was studied between June 2022 and April 2023. Three sampling stations were evaluated using plankton and fish composition biomarkers. Algal communities comprised of 6 phyla, 48 species and 4425 individuals. Spatially, the algae were more dominant in SS2 with 2592 individuals constituting 58.56% composition followed by SS3 (1050 individuals and 23.72%) and SS1 (784 specimens with 17.71%). The diatomic group (Chrysophyta) together with the phylum chryptophyta were significantly reduced ($P < 0.05$) in both biomass and diversity at the point source station while green algae (Chlorophyta) and the blue-green algae (Cyanophyta) were significantly more abundant ($P < 0.05$) at the point source than in other sampling stations. Shannon-Wiener's species diversity index was 3.350 at the point source station (SS2), 2.600 at the upstream station (SS1) and 2.750 at downstream station (SS3). Phytoplankton communities of Mbaa River exhibited both spatial and temporal variations. The zooplankton assemblage of the river comprised of 4 orders, 40 species and 2927 individuals. Spatially, zooplanktons were more predominant at the upstream station with 2017 individuals, constituting 69.70% by composition, and significantly higher ($P < 0.05$) than in other stations. Fish assemblages of the river was composed of 19 families, 163 species and 10786 individuals. The most abundant families were the Characidae (19.76% by composition), Mochokidae (16.11%), Schilbeidae (13.57%), and Mormyridae (13.38%). Spatially, fish were more abundant and diverse at downstream location (SS3) with 7065 individuals, equivalent to 0.640 in relative abundance. The point source station was generally sparsely populated by fish both spatially and temporally. Shannon-Wiener's species diversity index was 1.280 (SS1), 0.890 (SS2) and 1.130 (SS3). The study made valuable contribution to knowledge by providing empirical data

for environmentalist working on biodiversity conservation and aquatic ecosystem protection.

INTRODUCTION

The aquatic environment covers 71% of the entire Earth's surface. It comprises of the oceans, the seas, rivers, streams, creeks, lagoons, lakes and pond water (Njoku, 2004). The biotic components of the aquatic ecosystem such as rivers is an indispensable economic resource, such as the fishery upon which millions of artisanal resource producers derive means of livelihood. In Nigeria, the artisanal fisheries sector produces the bulk of fish consumed by the people, serving as source of food, employment, income, raw material and foreign exchange to the rural artisanal populace and the nation. Mbaa River in Inyishi, Imo State is one of such inland freshwater bodies that play indispensable roles in socio-economic lives of the citizens of Imo State. In recent times, however, fertilizer and pesticide runoffs from agricultural lands, oil spillage, and industrial effluents collectively referred to as anthropogenic pollutants have compromised the integrity of most inland water bodies (Njoku & Keke, 2003), including Mbaa river. The resultant effect is that the associated fishery, the biota and the aquatic ecosystem upon which fishers and fishing families depend for livelihood are destroyed. Consumption of fish caught from such polluted water bodies also poses severe danger to consumers. For example, FEPA (1991) reported cases of methyl mercury poisoning of people who ate fish polluted by mercury as a result of accidental discharge from manufacturing industries. In a similar case in Nigeria, 120 people were reported dead after

consuming fish caught from water that received effluents containing high level of ammonia discharge from NAFCON, a fertilizer company in Onne, Rivers State into the Okirika River (FEPA, 1991). The case was also associated with massive fish kills for which compensation was paid for the socio-economic deprivation of the resource dependent communities. One of such potentially endangered inland water ecosystems in Nigeria is the Mbaa river, which receives industrial effluents from Aluminum extrusion industries at Inyishi, Imo State. The river which has its origin at Ugiri flows through Inyisi to Emekuku where it joins the Oramiriukwa river, a distance of about 35km. It is not yet known if the waste is treated before discharge to the river or not. The effect of the effluent on fish populations of the river is also not known.

A second approach to aquatic environment monitoring and evaluation other than the physico-chemical protocol is the biological method. According to Karr (1991), the biological method of aquatic environment monitoring and evaluation is aimed to provide a direct measure of ecological integrity by using the responses of biological organisms to environmental changes. Biological approach allows long term environmental effects to be detected because of the capacity of reflecting conditions that are not present at the time of sampling and analysis. The physico-chemical and biological methods of aquatic environment monitoring and evaluation complement each other in the achievement of a common purpose (Bere and Tundisi, 2010).

Several organisms have been used as bioindicators. They include plankton (Bere and Tundisi, 2010); benthic macro invertebrates (Tiziano et al., 2016) and fish (Tejeda-Vera et al., 2007 and Lopez-Lopez and Sedeno-Diaz, 2015). Furthermore, several authors (Bere and Tundisi, 2010; Rai, 2010; Alloys, 2013; Lopez-Lopez and Sedino-Diaz, 2015; Tiziano et al., 2016; Sharma et al., 2017) are of the view that aquatic environment monitoring and evaluation should be a continuum considering the dynamic nature of the associated ecological factors and the emerging climate change episodes. Several studies have been done in the past on the impact of Aluminium extrusion effluents on Mbaa River. They include the works of Njoku and Igwe (2004) on heavy metals; Ajima et al., (2015) on bioaccumulation of heavy metals; Nwoko and Ezeibe (2015) on heavy metals and physico-chemical factors; Akhionbare et al., (2018) on heavy metals and Ibe (2019) on assessment models and health risk for drinking water. No work has focused on the impact of the anthropogenic pollutants from the aluminium extrusion industries on plankton diversity and fish composition of Mbaa River. This aspect is important because it supports the livelihood of thousands of fishing families in Imo State. The need to ascertain the integrity of the river for domestic use and aquatic life on a continuous basis is also imperative. The present study on “Impacts of Aluminum Extrusion Effluents on Plankton Diversity and Fish Composition of Mbaa River, Inyishi, Imo State, Nigeria” is aimed at closing this gap in knowledge.

MATERIALS AND METHODS

The study area is Inyishi in Ikeduru Local Government Area of Imo State (Fig1). Mbaa River has its source at Ugiri, a community in Isiala Mbano Local Government Area of Imo State from where it flows to other neighbouring communities which include Amaimo, Inyishi and Uzoagba before it joins the Oramiriukwu River at Emekuku as a tributary. Inyishi is located in Ikeduru and lies between latitudes 5:34¹ and 5:38¹ N, and longitudes 7:11¹ and 7:12¹ E. The community has an area of about 1,640 ha. The population of Ikeduru is 206,200 people (Census, 2016). It lies within the rainforest zone of West Africa in South eastern Nigeria. Farming is the basic occupation of the people. Other activities along the shoreline of the river include mining for sharp sand, excavation and lumbering. The shoreline of the river from source at Ugiri to the tributary with Oramiriukwa at Emekukwu is about 35km. The river receives industrial effluents from the aluminum extrusion factory at Inyishi as well as domestic effluents from the adjoining communities and agricultural run offs from the surrounding farm lands. The Aluminum Extrusion Industry Plc, (ALEX) is situated about 4 km along the Atta Amaimo Road in Inyishi village which is 100 meters away from Mbaa river (Akhionbare et al, 2018). The company was established in 1978 and is engaged in the manufacturing of aluminum billet which is processed into aluminum roofing sheets and profiles. According to the description of Akhonbare et al (2018), the Iyi-Afo Inyishi (Mbaa river) joins Onu-Iyide river in Umu-Oziri village, Ikeduru. The rivers are characterized by shallow valleys which are usually filled by flood water during rainy season. The aquifers are

recharged by means of flood infiltration during the rainy season.

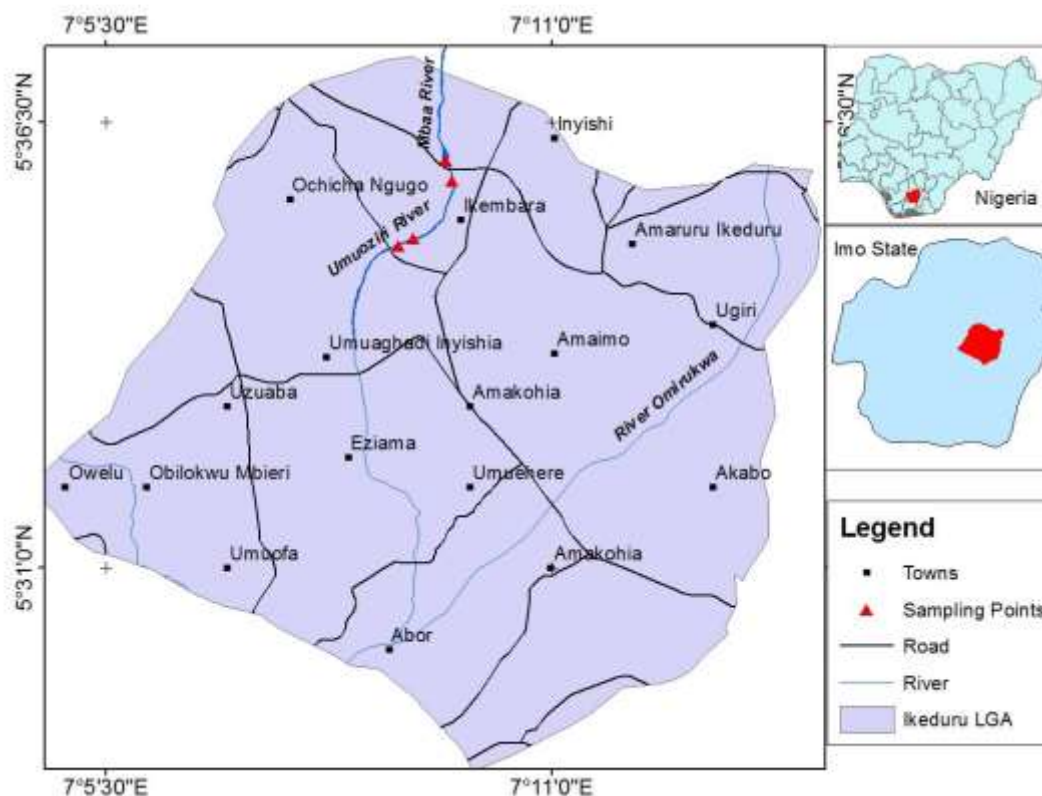


Fig 1: Map of Ikeduru, the Study area showing Mbasa river and the sampling stations. Inset is Map of Nigeria showing the location of Ikeduru. (Source: Akhonbare et al, 2018)

The filtering techniques by Tait (1972), Imoobe (2011), USEPA (2014) and Adeniyi et al (2020) were employed in sampling for plankton.

Sampling was carried out for six months (February – July 2023) covering parts of the wet and dry seasons. Sampling for plankton was done on monthly basis in the mornings between 7.00am and 9.00am at a depth of 20cm below the water surface in accordance with USEPA (2014) procedure. Two plankton nets were

utilized, one for Zooplankton and another for Phytoplankton. Coarse silk bolting Zooplankton net (guage 3) of 0.324mm mesh size with mouth diameter of 50cm was used for sampling the Zooplankton, while guage 21 fine silk bolting hydro bios plankton net of 0.063mm mesh size was employed in sampling for Phytoplankton. Samples were collected by filtering 100 liters of water sample fetched with a bucket through the two plankton nets. This was augmented with plankton tows through the water. The plankton nets were towed through the designated sampling stations for 5 minutes from a motorized canoe at low speed at depths of 20cm.

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The nets were then rinsed into the attached bottles and the contents poured into labeled 1 liter sample bottles and preserved with 4% formaldehyde. The 4% formalin preservative was obtained by pouring 100ml of 40% formaldehyde into 900ml of water sample. In the laboratory, the water volume was reduced to 25ml after sedimentation to concentrate the plankton by siphoning with pipette fitted with a flexible rubber tubing to prevent accident (Adeniyi et al, 2020) and kept in the laboratory for subsequent analysis.

The stratified assessment survey technique (Njoku, 1991) was employed for fish sampling of Mbaa River. A fisherman was engaged to cover the three sampling stations designated on the river using different kinds of fishing gear. These include cast nets, gill nets, and assorted kinds of fishing traps (trigger, basket and wire traps). Both the limnetic and littoral zones of the water body were covered. Fish sampling was carried out on monthly basis for 11 months, between June 2022 and April 2023. After landing the fish were identified with a combination of keys by Daget and Itlis (1965), and Olaosebikan and Raji (2004). After recording the standard length (in centimeters) and weight (in grams), the fish were classified into different taxa and gear categories. Species of each taxa were also identified and enumerated. The diversity of the plankton in terms of species composition was determined by the Shannon – Wiener's Diversity Index (Njoku, 2005) as follows:

$$S$$
$$\text{Species Diversity Index (H}_i\text{)} = \sum_{i=1}^S P_i (\text{Log}_e P_i)$$

Where;

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H_i = The diversity of the i th species in the community of several species

S = Total number of species observed

P_i = Proportion of the i th species in the community

The proportion, (P_i) is given as $N \frac{n_i}{P_i}$

Where;

n_i = Total number of individuals of a particular i th species counted

N = Total number of all species enumerated

The higher the index, the more diverse are the species

b) Species Evenness

After determining the species diversity index, (H_s), the species evenness or uniformity in the community was determined. The ratio of the observed diversity index (H) to the maximum diversity index ($H_{\max}$) is the measure of evenness (E) defined as follows:

$$E = \frac{H(s)}{H(\max)}$$

Where;

E = Species Evenness Index

$H(s)$ Estimate of Shannon-Wiener's diversity Index of the species

$H(\max) = \text{Log}_e S$

S = Total number of species in the plankton community.

c) Simpson's Species Dominance Index

The dominant plankton species in the community was determined using the Simpson's Dominance Index (D) (Njoku, 2005) as follows:

$$D = \frac{(n_i)^2}{N}$$

Where

N = Number of individuals of all species

n_i = Number of individuals of each species

d) Species Similarity Index

The extent of similarity in abundance of various species of plankton in the community was determined using the Jaccard's coefficient of Similarity (Boyd, 1979, Njoku, 2005) as follows:

$$S = \frac{D}{a + b + c}$$

Where; D = Number of taxa present in all stations of the river

a = Number of taxa present in station a, but not in b and c

b = Number of taxa present in station b, but not in a and c

c = Number of taxa present in station c, but not in a and b

Fish composition of the three sampling stations was analyzed according to the diversity of taxa, and relative abundance (percentage composition) of species.

Biodiversity indices, partitioned into four were used to evaluate fish species diversity in the three sampling stations of the river. Ichthyodiversity indices evaluated include:

i. The Shannon-Wiener Species Diversity Index (H_i)

$$S$$

$$(H_i) = \sum P_i (\log_e P_i)$$

This translates to

$$H = \sum (P_i) \times \ln (P_i)$$

Where: P_i = relative abundance of i th species

ii. Species Evenness Index (E)

$$E = \frac{H(s)}{H(\max)}$$

iii. Species (Simpson's) Dominance Index (D)

$$D = \frac{(n_1)^2}{N}$$

iv. Species similarity index (Jaccard's coefficient of similarity (S))

$$S = \frac{D}{a + b + c}$$

RESULTS AND DISCUSSION

A total of 6 taxonomic groups of phytoplankton were identified in the river, and all the 6 groups were present in the three sampling stations, but in varying number of community abundance. The six taxonomic categories include the phyla: Chlorophyta, Cryptophyta, Cyanophyta, Charophyta, Euglenophyta and Chrysophyta. In terms of species composition/distribution, 43 species were present in the upstream station (SS1), 41 in point source station (SS2) and 48 in the downstream location (SS3). The resultant percentage composition where 32.58% (SS1), 31.10% (SS2) and 36.36% (SS3). In terms of abundance of members, the number of individuals was 784 in SS1 with relative abundance of 0.180. A total of 2591 specimens were identified at the point source station (SS2) with relative abundance of 0.590. At the downstream station (SS3), 1050 individuals were identified, comprising of a relative abundance of 0.240. Whereas the number of species and percentage composition of species did not vary between stations, the number of individuals varied quite significantly ($P < 0.05$) between stations, with point source stations (SS2)

recording the highest number of individuals (2591) followed by the downstream station (1050) and the upstream station (784) respectively.

The Phylum Chlorophyta comprised of 11 species including *Chlamydomonas reinhardtii*, *Hematococcus plurialis*, *Scenedesmus obliquus*, *Ulva intestinalis*, *Pediastrum duplex*, *Eudorina elegans*, *Desmococcus olivaceus*, *Volvox globator*, *Chara vulgaris*, *Chara globularis* and *Oedogonium* species. Seven species were found in the upstream station (SS1), 10 in the recipient stream (SS2) and 8 in the downstream station (SS3). The phylum Chryptophyta was made up to 10 species that included *Proteomonas sulcata*, *Plagioselmis prolunga*, *Cryptomonas ovata*, *Cryptomonas phaseolus*, *Rhinomonas reticulata*, *Cryptomonas gracilis*, *Teleaulax amphioxeia*, *Chroomonas* sp, and *Goniomonas avonlea*. The phylum Cyanophyta was represented by *Anabaena flos*, *Gleocapsa* sp, *Geotrichia pilgeri*, *Geotrichia natans*, *Anabaenopsis tangayikae*, *Nostoc entophyllum*, *Nostoc piscinale*, *Oscillatoria broyana*, *Chroococcus turgidus*, *Microcystis elachista* and *Spirulina* species. The phylum charophyta was made up of only 6 species, namely, *Chara conivens*, *Chara crassicaulus*, *Chara fibrosa*, *Chara pedunculata*, *Chara vulgaris* and *Nitella hyaline*. Similarly, the phylum Euglenophyta was sparsely represented by 5 members, including *Euglena viridis*, *Euglena sanguine*, *Euglena gracilis*, *Perenema* species and *Perenema trichophorum*. The Phylum, Chrysophyta (Diatoms) was the most abundant in terms of species composition comprising of 15 species. Member of this community include *Batrachospermum*

globosporum, *Hildenbradia angloensis*, *Thalassiosira occentrica*, *Thalassiosira lentiginosa*, *Thalassiosira lineatus*, *Nitzschia punctata*, *Psammodictyon duriformosa*, *Fragilariopsis ritscheri*, *Navicula symmetrica*, *Cymbella tumida*, *Bacillaria paxillifer*, *Asterionella geyunusae*, *Cyclotella mereghiliana*, *Synedra gouldardi* and *Lemanea* sp.

Phytoplankton is an important biological indicator organism or biomarker for monitoring the health of the aquatic ecosystem and environmental integrity of water bodies (Adaka, et al, 2015). Shugart et al (1992) defined a biomarker as “a xenobiotically induced variation in cellular or biochemical processes, structures or functions in an organism measurable in a biological system or sample”. Bere and Tundisi (2010) identified such biomarker organisms to include phytoplankton, zooplankton, macroinvertebrates and fish. Biological monitoring has gained momentum in aquatic health management in complementing the physical and chemical methods (Bere and Tundisi, 2020; Alloys, 2013). Documented information on phytoplankton studies of Mbaa river was not available for comparison, but the taxonomic groups and species composition of phytoplankton communities of Mbaa river recorded in this study agree with the flora reported for lotic waters of West Africa (Woodhead and Tweed, 1960) and in Nigerian waters (Nwadiaro and Okafor, 2007).

The Green algae (Phylum: Chlorophyta) were predominant in the point source station (SS2) with a total of 1060 cells and 88.48% in composition. This number was significantly higher ($P < 0.05$) than 62 cells (5.18%) in the

upstream station (SS1) and 76 cells (6.34%) in the downstream station (SS3). This same distribution pattern was observed in Blue-green algae (phylum: Cyanophyta) with a preponderance of 436 individual cells, equivalent to 76.90% at the point source station (SS2). This number is also significantly higher ($P < 0.05$) than 62 individuals (10.93%) and 69 individuals (12.20%) recorded at the upstream (SS1) and downstream (SS3) stations respectively. It was however observed that the Phylum, Cryptophyta and the diatomic group, Chrysophyta were sparsely populated in the recipient station (SS2). Chryptophyta was represented by 14 members or 2.97% by composition which is significantly lower ($P < 0.05$) than 152 cells (32.27%) and 305 cells (64.76%) at the upstream (SS1) and downstream (SS3) respectively. Diatoms (Phylum: Chrysophyta) was represented by only 25 members equivalent to 4.40% by composition at the point source stations which was found to be significantly lower ($P < 0.05$) than 206 cells (36.27%) and 337 cells (59.33%) observed in the upstream and downstream stations respectively. The relative abundance of Phytoplankton in the sampling stations were 0.180 (upstream) 0.580 (point source) and 0.240 (downstream). On the whole, the order of abundance/dominance of phytoplankton communities in Mbaa river was Chlorophyta > Euglenophyta > Chrysophyta > Cyanophyta > Charophyta > Cryptophyta.

Generally, the six taxonomic categories of Phytoplankton identified in the river except the members of the phyla, Chlorophyta and Cyanophyta were sparsely populated and less diverse in members at the recipient station

(SS2). The disappearance of three species in the effluent discharge station (SS2) is a clear sign of environmental degradation. According to Bere and Tundisi (2010), a fundamental part of the lotic ecosystem is the Phytoplankton and periphyton community assemblages whose diversity responds very rapidly to aquatic environment pollution, often resulting to changes in both taxonomic composition and species abundance.

The predominance of algae traditionally associated with eutrophication, namely the green algae (Chlorophyta) and the Blue-green algae (Cyanophyta) in the recipient stream further suggests that the integrity of this section of the river has been compromised by anthropogenic wastes which promote eutrophication and algal bloom. These anthropogenic wastes include effluent discharge from the aluminum extrusion plant, agricultural runoff of fertilizers and herbicides from the surrounding farm lands and domestic waste. These wastes result in excessive loads of nutrients such as sulphates, phosphates and nitrates which promote eutrophication. The scanty population of Diatoms (Phylum: Chrysophyta) in the recipient station and the disappearance of numerous species that constitute the diatomic group suggest that this group is sensitive to environmental perturbation and a response to the industrial effluent discharge into this section of the river. Diatoms represent outstanding bioindicators for different degrees of pollution (Bere and Tandisi, 2010). They are excellent indicators of water quality, especially in situations of wide spread increase in eutrophication (Descy and Coste, 1991). Diatoms are the most species-rich group of algae that

responds rapidly to environmental pollution with drastic change in spatial and temporal distribution pattern (Odum, 1985, Njoku, 2014).

The result shows that the Shannon-Wiener's species diversity index ($H_{(s)}$) was 2.60 in the upstream station (SS1), 3.86 in the point source station (SS2) and 2.75 in the downstream station (SS3). The dominance index (D) was 0.16 (SS1), 0.18 (SS2) and 0.13 (SS3). The Shannon-Wiener's species evenness index (E) was estimated as 0.88 for the upstream station, 0.95 for the point source station and 0.79 for the downstream. The Shannon-Wiener's index of 3.86 computed for phytoplankton communities of Mbaa River at the point source station (SS2) was remarkably higher than 2.60 at SS1 and 2.75 at SS3. There were no documented reports on biodiversity of Phytoplankton studies in Mbaa River or in related water bodies for comparison,

but the high diversity index (3.86) computed for phytoplankton at the point source station (SS2) reflects the high diversity of Green-algae (Chlorophyta) and the Blue-green algae (Cyanophyta) observed in this study which created eutrophication conditions in certain shallow areas of this section of the river. This is attributed to the anthropogenic nutrient enrichment of the water from industrial waste discharge into the water together with agricultural run-off of fertilizers and herbicides from the water shed and the catchment areas. This observation is in agreement with the assertions of Botkin and Keller (1985) in chemically polluted aquatic ecosystems.

Table 4.7 Diversity Indices of Phytoplankton of Mbaa River

SPECIES DIVERSITY INDICES	SS1 UPSTREAM	SS2 POINT SOURCE	SS3 DOWN STREAM
Number of Taxa			
Number of Species			
Number of Individuals		1	2
Shannon-Weiner's species diversity index, $H_{(s)}$	2.60	3.86	2.75
Dominance Index (D)	0.16	0.18	0.13
Evenness Index (E)	0.88	0.95	0.79

A total of 4 orders of zooplankton were identified in the river and all were represented in the three sampling stations, but varied in terms of diversity and abundance of species. The 4 zooplankton communities are the Copepoda, with 16 species, 932 individuals and 32.93%

abundance, Cladocera (8 species, 587 individuals with 20.06% abundance). Rotifera was represented by 9 species, 1235 individuals constituting 42.50% abundance); and insecta (insect larvae) with 7 species, 131 individuals, comprising of 4.4% abundance.

In terms of spatial distribution, 621 Copepods were identified at the upstream station (SS1), 178 at the point source station (SS2) and 133 at the downstream station (SS3). For the cladocerans, 375 members were recorded at the point source station, 98 at the upstream and 114 at the downstream. Spatially, 947 rotifers were recorded at the upstream (SS1), 143 at the point source (SS2) and 145 at the downstream (SS3). Out of 131 individuals of the insect order, 78 members were found at SS1, 37 at SS2 and 20 at SS3 respectively. The order, Copepoda was made up of two classes, namely the Calanoida and Cyclopoda. Similarly, the Insecta order comprised of three classes of Ostracoda, Arachnida and the Diptera. The dominant order of Zooplankton communities of Mbaa River is Rotifera > Copepoda > Cladocera > Insecta. The census of Calanoids gave 4 species which include *Pseudodiaptomus* sp, *Tropodiaptomus* *banforanus*, *Thermodiaptomus* *galebi* and *Metadiaptomus* sp. The Cyclopoda were more diverse in number of species and include *Macrocyclus* *albidans* *oligolasi*, *Metacyclus* sp and *Eucyclus* *serrulatus*, *Cyclus* *nigeriae*, *Topocyclus* *confines*, *Afrocyclus* *gibsoni*, *Mesocyclus* *aequatorialis*, *Cryptocyclus* *bicolor* *linjianticus*, *Mesocyclus* *leukarti*, *Ectocyclus* *sphaelaratus*, *Microcyclus* *vericans* and *Thermocyclus* *incises*. Nine rotifers identified include *Branchionus* *falcatus*, *Branchionus* *patulus*, *Branchionus* *calyciflorus*, *Branchionus* *angularis*, *Keratella* *longispina*, *Keratella* *cochlearis* *cochlearis*, *Lecane* *bulli*, *Synchaeta* *longipes* and *Asplanchna* *periodonta*. The community of Insects (larval) was made up of *Ostracoda* (*Stenocypris* *malcolmsoni*,

Acocypris *capillata*, *Cyprina* *globus* and *Cypridopsis* Sp), the Arachnidans (*Unonida* *dentifera* and *Neumaria* sp). One species of the Diptera (*Chaoborus* *anomalous*) was identified.

The observed zooplankton composition of Mbaa River bears close semblance to those of other water bodies in Nigeria. Imoobe (2011) recorded 40 species of zooplankton in Eruvbi River, Edo State, composed of 9 species of Cladocera, 9 of copepoda and 22 species of rotifera, with rotifers as the dominant taxum. Adeniyi et al (2020) recorded a total of 2897 zooplankton species in the lower Niger, consisting of 3 orders with copepod as dominant taxum.

The result shows that all the zooplankton communities including the insect larvae were sparsely populated in the recipient station (SS2) than in other sampling stations. The most predominant zooplankton were the rotifers, made up of 143 individuals at the point source station (SS2), representing 11.58%. This population was significantly lower ($P < 0.05$) than 947 or 76.68% in SS1 and 145 (or 11.74%) in SS3. Other zooplankton communities present include the Copepods, with an overall sample size of 932 members representing 32.93% composition, and distributed as follows: SS1 (621 individuals or 66.13%), SS2 (178 members or 19.10%), SS3 (133 individuals or 14.27%). Others are the Cladocerans, distributed as follows: SS1 (375 members or 63.88%), SS2 (98 members or 16.70%) and SS3 (114 members or 19.42%). Insecta comprised of 78 members equivalent to 58.02% in the upstream station (SS1), 37 members (27.41%) at point source station (SS2) and 20 individuals (14.81%) at the downstream (SS3). The result shows that zooplankton

population at the point source station (SS2) was generally sparse, and significantly lower ($P < 0.05$) than the population of other sampling stations. In terms of relative abundance of Zooplankton at the different stations, it was 0.700 (SS1), 0.16 (SS2) and 0.14 (SS3).

According to John (2000), the ultimate monitor of the aquatic ecosystem is the aquatic life itself. This is why biological markers such as the zooplankton enjoy widespread application in the assessment of ecological changes in lotic ecosystems (Bere and Tundisi, 2010).

The scanty population of Zooplankton communities in the recipient station (SS2), especially the Rotifers and copepods suggest that the integrity of this section of the river has been compromised by industrial effluents and other anthropogenic factors arising from the catchment area of the river. This observation is in agreement with documented literature in other lotic ecosystems. Imoobe (2011) observed Rotifers as the dominant taxum in Eruvbi stream, Odum (1985) was of the view that Zooplankton organisms are very sensitive to aquatic pollution, marked by a drastic reduction in species diversity and abundance. Similarly, Treziano et al, 2016, working on estuarine pollution in Basque coast observed that all the functional Zooplankton categories showed a sharp decline in number of species.

All the 19 fish families were present in the downstream station, 18 in the upstream station while only 13 families were present at the point source station. Six fish families which were absent at the point source station include the Lepidosirenidae, Polypteridae, Pantodontidae, Malapteruridae, Cyprinodontidae, and

Gynnnarchidae. It is believed that these fish taxa were more sensitive and vulnerable to anthropogenic pollution associated with this section of the river which receives industrial effluent from the aluminum extrusion factory. In the upstream station (SS1), 18 families, 60 species and 3,466 individuals were recorded with species composition of 36.80% and relative abundance of 0.368. At the point source station (SS2), there were 13 families, 37 species and 255 individuals with species composition of 22.71% and relative abundance of 0.227. In the downstream location (SS3), 19 fish families, 66 species and 7065 individuals were identified with species composition of 40.49% and relative abundance of 0.405.

Another important observation on spatial distribution pattern of fish populations of Mbaa River is the variations in species biodiversity among the three sampling stations as reported above. The remarkable decline in the number of individuals at the point source station implies that the environmental conditions in this station was not conducive for aquatic life and biodiversity development. The analysis of relative abundance of fish taxa showed that the family, Characidae was the most abundant with 2,174 members and 19.76% composition followed by Mochokidae with 1,772 members and 16.11% composition. The third taxa in terms of relative abundance of members is the family, Schilbeidae with 1493 individuals and 13.57% abundance. This is followed by the family Mormyridae with 1,472 individuals and 13.38% abundance. The usefulness of fish as bio-monitor in the assessment and monitoring of the health status of aquatic ecosystems such as Mbaa River

have been emphasized (USEPA, 2003), Treziano et al, 2016, Bere and Tundisi, 2010). According to Lopez-Lopez and Diaz (2015), the sensitivity of fish to a variety of aquatic pollutants qualifies them as biomarkers in the identification of disruptions in the aquatic ecosystem. This is evident in the observed scanty population of fish and low biodiversity of species at the point source station which receives industrial effluents from the aluminum extrusion plant. The scanty population of fish and sharp decline in biodiversity and abundance at the point source station is a clear response to environmental degradation. Lopez-Lopez and Diaz (2015), reported that environmental stress from degraded habitats generally result to changes in the number of species richness and abundance. This view was also corroborated by Kumar (2022) who made similar observation in river karamana, India which was polluted with industrial waste discharges.

Shannon Weiner's diversity index, $H(s)$ was 1.28 in the upstream station (SS1), 0.89 in the point source station (SS2) and 1.13 at the downstream station (SS3). The Shannon-Weiner's dominance index (D) was 0.75 (SS1), 0.13 (SS2) and 0.97 (SS3). Similarly, the Evenness index (E) was estimated as 0.29 for upstream stations (SS1), 0.24 for the point source station (SS2) and 0.36 for the downstream station (SS3). The low diversity index of 0.89 and dominance index of 0.13 estimated for the recipient station (SS2) as against those of upstream station (1.28 and 0.75) and downstream station (1.15 and 0.27) respectively gives further credence to the suggestion that the quality of water at the point source station has been comprised to the extent

that it could not support ecosystem biodiversity. According to Odum (1985), diversity indexes are useful for comparing communities in the aquatic ecosystem and that species diversity indexes decrease with increasing loads of aquatic pollution.

The values computed in this study agree with values of estimations in similar tropical environmental conditions. Odum (1971) states that the values of Shannon-Weiner's diversity index usually range from 0.0 to 5.0, and that the higher the value the healthier and conducive the aquatic ecosystem. Adebayo et al (2020) computed Shannon-Weiner's diversity index of 1.80 and evenness index of 0.234 for the fish populations of Ere River. In Oramirukwa River, Okorie (2015) estimated a diversity index of 1.305 while Nwadiaro and Okafor (2007) estimated a Shannon-Weiner's species diversity index of 1.359 for the Ichthyofauna of Otamiri River. Similarly in Lake Oguta, Nwadiaro (2007) recorded species diversity index of 0.892 for the fish populations of Lake Oguta.

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