



OCCURRENCE AND ABUNDANCE OF PHYTOBENTHOS IN THE INTERTIDAL ZONE OF THE CALABAR RIVER, NIGERIA

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ABSTRACT

An investigation was conducted on the occurrence and abundance of phytobenthos in the intertidal mudflats and sandbars of the Calabar River, Nigeria, for three month (May – July 2021). Total of 12 samples (6 each from mudflats and sandbars) were collected on bi-weekly basis for the three months and used for this study. The Samples were collected during lowtides when the mudflats and sandbars were exposed, by scrapping about 1cm² of the surface layers of the mudflats and sandbars using a hand trowel at Nsidung beach located between Latitude 4° 57' 0" - 4° 58' 30" N and Longitiude 8° 18' 0" - 8° 19' 30' E. The collected samples were stored in 250ml amber glass bottles, preserved in 10% formaldehyde solution and transported to the Biological Oceanography Laboratory, University of Calabar Nigeria for analysis. In the laboratory samples were analysed by addition of 1-3mls of Lugols iodine solution and subjected to microscopy using x10 objectives. The present study is aimed at identifying **i)** the different species of the phytobenthos in the mudflats and sandbars, **ii)** the commonest and most abundant phytobenthos in the mudflats and sandbars, **iii)** the month of high abundance of the phytobenthos in the mudflats and sandbars, and **iv)** to assess which of the two ecotones has higher abundance of the phytobenthos in the Calabar River, Nigeria, during the period of study. Phytobenthos cells were identified using standard schemes and atlases and data analysed empirically and statistically. Phytobenthic cells abundance in each of the two ecotones were recorded during each month of sampling. The intertidal mudflats were richer in phytobenthos with 903 (86.91%) cells than the sandbars with 136 (13.09%) cells. The month of May was generally richer in phytobenthos in both ecotones with 344 cells (mudflats) and 58 (sandbars). This was followed by June with 317 cells in the mudflats and 46 cells in the sandbars and July with 242 cells in the mudflats and 32 cells in the sandbars. The Bacillariophyceae were the most abundant phytobenthos with 394 (43.63%) cells in the mudflats and 59 (43.38%) cells in the sandbars, with the least abundant being the Rhodophyceae with 52(5.76%) cells in the mudflats and 7 (5.15%) cells in the sandbars.

The present study strongly recommends further studies of the mudflats and sandbars of the Calabar River, particularly the rate of primary productivity, to enhance the ecological understanding of the primary productivity of these very important ecotones.

KEYWORDS: Abundance, Phytobenthos, Intertidal Zones, Calabar River, Nigeria

INTRODUCTION

The majority of the phytobenthos in the different aquatic habitats comprise of various types of planktonic algae – the phytobenthos (Castro & Huber, 2005).

These play an important role in the food web of the aquatic habitats, particularly as a source of food to other species, typically zooplankton, fin and shellfishes (Hansen *et al.*, 2001).

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The littoral and intertidal zones are synonymous and are periodically exposed to air by falling tides and submerged by rising water levels. Included in this general area are a variety of distinctive ecosystems such as rocky shores, sandy beaches and mudflats, each supporting specially adapted assemblages of species (Lalli & Parsons, 1997). Rocky intertidal areas support a preponderance of epifauna, whereas, the soft-substrate, sand and mud communities have higher proportions of infaunal species (Castro & Huber, 2005; Job *et al.*, 2011).

The intertidal regions mark the transition from land to sea, although they make up only a very small part of the total aquatic environment of the world (Prasad, 2000), which support rich and diverse communities of aquatic plants and invertebrates as well as birds and inshore species of fish (Hansen *et al.*, 2001). In its general ecological perspective, an intertidal zone is an area submerged by water at high tide, but exposed at low tide (Olaniyan, 1978; Lalli & Parsons, 1997; Castro & Huber, 2005; Guoying *et al.*, 2009).

In intertidal ecosystems, particularly shallow aquatic environments, benthic fauna and flora are intimately associated with bottom sediment and exposed to large environmental fluctuations determined by the alternation between emersion and immersion conditions (Costa *et al.*, 2002). The intertidal zone has expanse of mudflats and sandbars as parts of the ecosystem of river systems, estuarine and marine environment (Mann, 2000). These zones are of ecological importance as they provide micro habitats to diverse groups of phytobenthos and other intertidal entities (Job *et al.*, 2011; Costa-Boddeker *et al.*, 2017). The dominant primary producers of the intertidal zone, particularly the mudflats and sandbars are the episamicroflora which according to Olaniyan (1978), Goldman & Horne (1983), Lalli & Parsons (1997), Mann (2000), Edu *et al.*, (2007) and Job *et al.* (2011), are generally species of benthic diatoms, flagellates and dinoflagellates specially adapted to grow on the sediment and sandbar particles. Their productivity has been reported to inversely correlate with the grain size making up the zones, coupled with nutrient and water retention capacities (Castro & Huber, 2005).

The productivity of intertidal sandbars has been reported to be low especially in the absence of a cover of marsh grasses or seagrasses (Lalli & Parsons, 1997). The productivity of the intertidal sandbars has been documented to be about $10\text{gm}^{-2}\text{yr}^{-1}$, whereas that of the intertidal mudflats is of the order of $230\text{gm}^{-2}\text{yr}^{-1}$ (Moul & Mason, 1957; Goldman & Horne, 1983; Castro & Huber, 2005).

The varied grain sizes, nutrients and water retention capacities of mudflats and sandbars create disparity conditions in the types of microfloral species and abundance that occur in these two euphotic ecological zones. Hence, it becomes imperative to investigate these euphotic ecological zones in order to provide the species of the phytobenthic communities inhabiting them.

Studies of the different ecotones in an ecosystem such as the occurrence and abundance of phytobenthos in the intertidal zone of the Calabar River, Nigeria, is important because the results are expected to contribute to the existing literature on the Calabar River. Again, the results of the present study are expected to provide information on the species composition of the phytobenthos inhabiting the mudflats and sandbars of the Calabar River in addition to indicating which of the ecotones is richer in phytobenthos than the other. The results of the present study are also expected to add to already existing literature of the two habitats such as those of Job *et al.* (2011).

Studies on the occurrence and abundance of phytobenthos in the intertidal mudflats and sandbars of the Calabar River are scarce, although, Edu *et al.* (2007) studied the microflora of the mangrove swamp of the Cross River Estuary, Nigeria, while Job *et al.* (2011) studied the microflora of the mudflats and sandbars of the Calabar River, Nigeria. None of these authors reported on the phytobenthos of the mudflat and sandbars of the Calabar river, Nigeria, which the present study is designed.

MATERIALS AND METHODS

Description of study area

The Calabar River, Nigeria lies geographically between latitude $04^{\circ}54'N$ and longitude $08^{\circ}16'08''E$, located in the Cross River System, South Eastern Nigeria (Figure. 1).

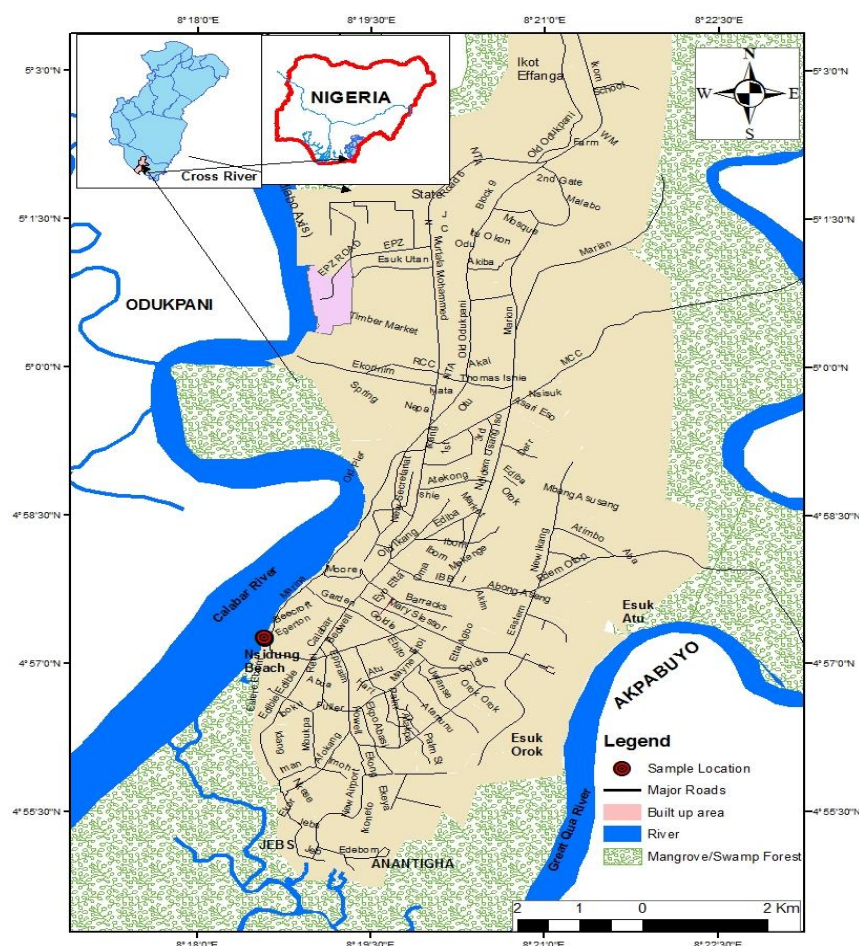


Fig. 1: Section of Cross River Estuary system, showing sampling location at Nsidung Beach (Job *et al.*, 2011 & Job *et al.*, 2015)

The Calabar River takes its rise from the Oban Hills in Akamkpa, Nigeria and flows southwards through the high rainforest of the Southeast coast of Nigeria before discharging into the Cross River Estuary at Calabar (Akpan, 2002)

The river lies in the humid tropical rainforest belt. The zone is characterized by a long wet season between April and November and a relatively short dry season from December to March. The coastal shoreline is characterized by thick vegetation changing from freshwater to swamp ecology to mangrove swamp towards the estuary. On the banks of the Calabar River, *Nypafruticans* (Nypa palm) has been reported to dominate the environment (Asuquo, 1999).

The Calabar River, from its source, cuts through black shales, siltstone, clayey and silt deposits, and also alluvial deposits before entering the Cross River at Alligator Island (Asuquo, 1999). The river is a tidal river, devoid of strong ocean waves. However, it is influenced by wind-induced waves and shock waves from the South-west trade winds.

The Calabar River has a semi-diurnal tidal range of between 1.50 – 2.50m (Asuquo and Tambe, 2010) and experiences both flood and ebb tidal stages, with the flood direction being northwards and southwards in the ebb direction (Asuquo, 1999). Calabar, as any typical tropical city in Nigeria, has a sub-equatorial climate (Job *et al.*, 2011), with two distinct seasons (rainy season and dry season). Longer rainy season and shorter dry season are known in the area with a high relative humidity especially in the wet season with an average temperature of 23.7°C (Asuquo, 1999, Job *et al.*, 2019; Job & Akpan, 2021).

The vegetation is generally rainforest, close to the mangrove belts. Mangrove with major species such as *Avecinia africana*, *Rhizophora racemosa* are also the constituents of the vegetation in the area especially bordering the Great Kwa and Calabar river flood plains (Holzloechner *et al.*, 2002). The nypa palm (*Nypafruticans*) and *Pandanus* sp constitute among the other trees and shrubs of mix vegetation of the area (Holzloechner *et al.*, 2002). The activities of the people living around the area include fishing, farming, hunting, wood logging, sand mining and boat building (Holzloechner *et al.*, 2002; Job *et al.*, 2021).

FIELD STUDIES

Collection and preservation of samples

Surface layers of about 1cm² of the intertidal mudflats and sand-bars were collected by scrapping method using a hand trowel during low tides at Nsidung Beach, Calabar, Cross River State, Nigeria, following the methods employed by Moul & Mason (1957), Lukatelich & McComb (1980) and Job *et al.*, (2011).

Samples were stored in 250ml amber glass bottle and preserved in 10% formaldehyde solution and stained with 1-2mls of Lugol's iodine solution prior to laboratory analysis. Samples were collected twice a month and pooled into a single monthly sample.

Laboratory studies

Analysis of samples

In the laboratory, 1g of the sample was taken from the bulk sample for analysis. The measurement of the 1g sample was done using an electronic weighing balance (Model kw3366 3XMICRO. AAA. RO3) (Great Britain).

The two sample sources (the mudflats and sandbars samples) were separately analyzed using 1g at a time until all the bulk samples are completely analyzed.

Prior to analysis, the 1g sample was spread in a petri dish with the addition of 1ml of tap water (to ease the spreading of the sample). The samples were subjected to microscopy on addition of 1-3mls of Lugol's iodine solution using an inverted microscope (Model: Olympus CH00545, Tokyo, Japan) of x10 and x40 objectives, following Hargrave (1969), Hodgkiss & Songhin (2004) and Job *et al.* (2011).

Identification of phytobenthos

Identification of the phytobenthos was based on morphological features of the phytobenthic species. Identification schemes of Edmonton (1959), Prescott (1970), Olaniyan (1978), Sharma (1986) and

Needham & Needham (1962) were used for the identification. Phytobenthos were identified to the nearest possible taxon.

DATA ANALYSIS

Data obtained were analyzed empirically to determine abundance (numerical and relative) of the phytobenthos families in the mudflats and sandbars and statically, using the Chi square to test if there was any significant relationship in the abundance of the phytobenthos between the two ecotones during the period of study.

Determination of numerical and relative abundance of the phytobenthic species

Individual species (n) in each sample was enumerated under each family. The total number of all individuals (N) in a particular family was determined and used for the calculation of relative abundance according to the formula:

$$\%Ra = n(100)/N \text{ (Job } et al., 2011).$$

Where %Ra is the relative abundance of each of the phytobenthos in the sample per month.

n is the number of individual species,

and N, the number of all individuals in a particular phylum.

RESULTS

Species composition of the Phytobenthos

Altogether, 21 species of Phytobenthos, spread into 5 major families were identified during the period of study. These were BACILLARIOPHYCEAE (*Thalassiosira*gravid, *Nitzchiapungens*, *Skeletomacostatum*, *Chaetonemalacinosus*, *Ceratium*tripos, *Eucampia*zodiacusand *Bidulphi*apelagica), CHLOROPHYCEAE (*Cladophoralimicola*, *Vauchenasp*, *Closterium*gracile and *Netrium*digtus), CHRYSOPHYCEAE (*Dinobryon*sertularia, *Dinobryon*divergens, *Dinobryon*socialeand *Ceratium*hirudinea), RHODOPHYCEAE (*Bostrychia*radicansand *Bostrychia*binderi) and EUGLENOPHYCEAE (*Euglena* gracilis, *Euglena* acusand *Euglena* rubra) (Table 1).

Table1: Phytobenthic species composition in the mudflats and sandbars of the Calabar River, Nigeria (May – July 2021) (Pooled data)

Phytobenthos Species	Abundance/month Mud flats			Abundance/month Sand Bars		
	May	June	July	May	June	July
BACILLARIOPHYCEAE						
<i>Thalassiosira gravida</i>	47	43	29	5	9	-
<i>Nitzschia pungens</i>	23	14	17	-	3	8
<i>Skeletonema acostatum</i>	11	8	-	-	-	3
<i>Chaetoneum ciniosus</i>	28	23	16	9	7	-
<i>Ceratium tripos</i>	9	11	15	-	4	3
<i>Eucampia zodiacus</i>	16	15	-	4	-	1
<i>Bidulphia pelagica</i>	18	24	17	3	-	-
Abundance(n)	162	138	94	21	23	15
CHLOROPHYCEAE						
<i>Cladophor alimicala</i>	27	16	31	9	4	3
<i>Vauchena sp</i>	14	20	12	-	1	-
<i>Closterium gracile</i>	29	-	16	6	2	-
<i>Netrium digitus</i>	18	15	-	4	-	-
Abundance (n)	88	51	59	19	7	3
CHRYSTOPHYCEAE						
<i>Dinobryon sertularia</i>	17	13	11	3	5	-
<i>Dinobryon divergens</i>	13	18	21	-	2	3
<i>Dinobryon sociale</i>	16	10	16	7	-	1
<i>Ceratium hirudinea</i>	-	14	-	1	-	1
Abundance (n)	46	55	48	11	7	5
RHODOPHYCEAE						
<i>Bostrychia radicans</i>	9	-	5	-	1	-
<i>Bostrychia binderi</i>	11	18	9	3	-	3
Abundance (n)	20	18	14	3	1	3
EUGLENOPHYCEAE						
<i>Euglena gracilis</i>	10	17	11	-	6	-
<i>Euglena acus</i>	-	13	9	3	-	5
<i>Euglena rubra</i>	12	16	-	1	-	-
<i>Tracheloronas superbus</i>	6	9	7	-	2	1
Abundance (n)	28	55	27	4	8	6

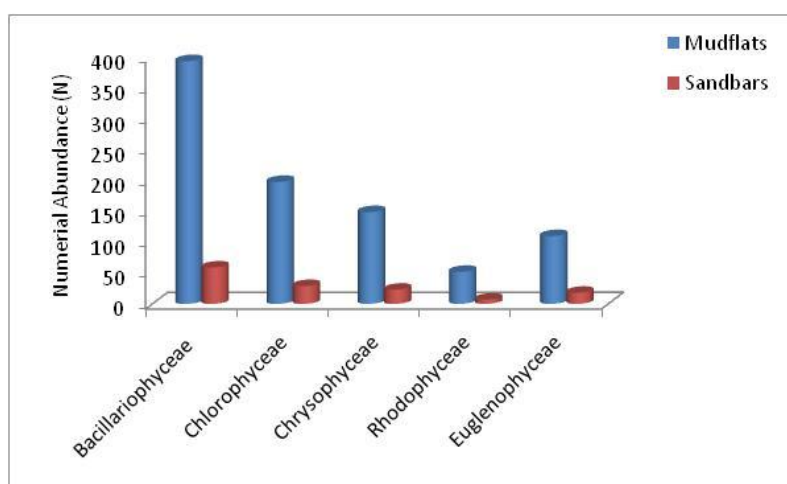
Numerical and Relative abundance of the Phytobenthos

The numerical and relative abundance of major Phytobenthos families identified in the mudflats and sandbars are presented in Table 2. Total of 394(43.63%) of Bacillariophyceae were in the mudflats, with 59(43.38%) recorded in the sandbars. Chlorophyceae had 198(21.93%) cells in the mudflats, with 29(21.32%) cells in the sandbars; Chrysophyceae were observed to have 149(16.50%) cells abundance in the mudflats, with 23(16.91%) in

the sandbars; Rhodophyceae had 52(5.76%) cells abundance in the mudflats and 7(5.15%) in the sandbars, while Euglenophyceae were observed to have cells abundance of 110 (12.18%) in the mudflats and 18(13.24%) in the sandbars. The numerical abundance of the cells of each of the major Phytobenthos families is depicted in Figure 2. The mudflats were generally richer with phytobenthos than sandbars. There was significant relationship in the abundance of the phytobenthos ($p < 0.05$) in the mudflats and sandbars.

Table 2: Summary of the numerical and relative abundance of the major phytobenthos identified in the mudflats and sandbars of the Calabar River, Nigeria (May – July, 2021) (Pooled data)

Major microflora families	Mudflats		Sandbars	
	N	%n	N	%n
Bacillariophyceae	394	43.63	59	43.38
Chlorophyceae	198	21.93	29	21.32
Chrysophyceae	149	16.50	23	16.91
Rhodophyceae	52	5.76	7	5.15
Euglenophyceae	110	12.18	18	13.24
Total abundance (N)	903	100.0	136	100.0

**Fig.2: Numerical abundance of the major phytobenthos cells in the mudflats and sandbars of the Calabar River Nigeria during the period of study (May–July, 2021) (Pooled data).****Monthly abundance of the major phytobenthos families**

The monthly abundance of the major phytobenthos families is presented in Table 3. In the mudflats, the month of May recorded high abundance of 344

phytobenthos cells with 317 in June and 242 in July, while in the sandbars, total of 58 phytobenthos cells were recorded in May with 46 in June and 32 in July. These are illustrated in Figure 3

Table 3: Monthly abundance of the major phytobenthos in the mudflats and sandbars of the Calabar River Nigeria (May – July, 2021)

	Mudflats			Sandbars		
	May	June	July	May	June	July
Bacillariophyceae	162	138	94	21	23	15
Chlorophyceae	88	51	59	19	7	3
Chrysophyceae	46	55	48	11	7	5
Rhodophyceae	20	18	14	3	1	3
Euglenophyceae	28	55	27	4	8	6
Total abundance (N)	344	317	242	58	46	32

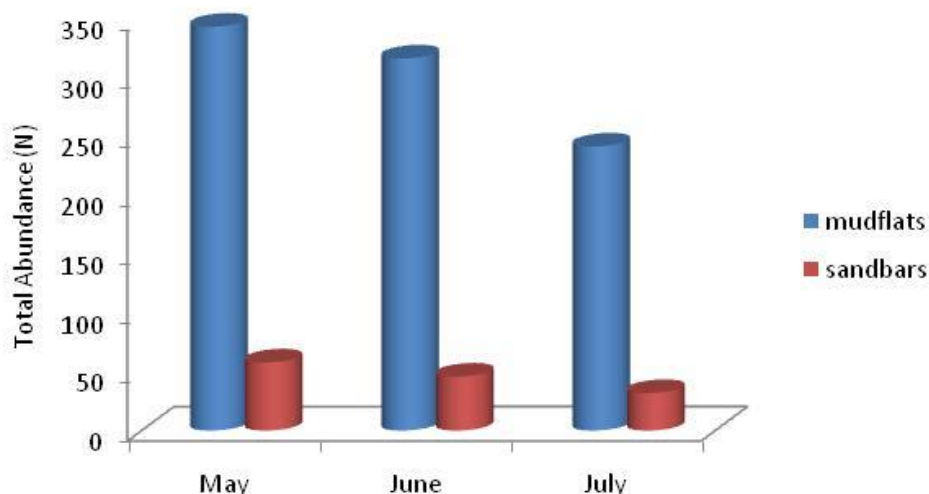


Figure 3: Numerical abundance of the major phytobenthos in the mudflats sandbars of the Calabar River Nigeria during the period of study (May–July, 2021)

Abundance of the phytobenthos in relation to the ecotones

Total of 903 (86.91%) of the phytobenthos were recorded in the mudflats with 136 (13.09%) in the sandbars (Table 4, Figure 4).

Table 4: Summary of the Phytobenthos abundance in the mudflats and sandbars of the Calabar River, Nigeria. (Pooled Results)

Ecotones	Abundance
Mudflats	903 (86.91)*
Sandbars	136 (13.09)*
Total Abundance (N)	1039 (100.0)*

*Numbers of parenthesis represent relative abundance of the phytobenthos

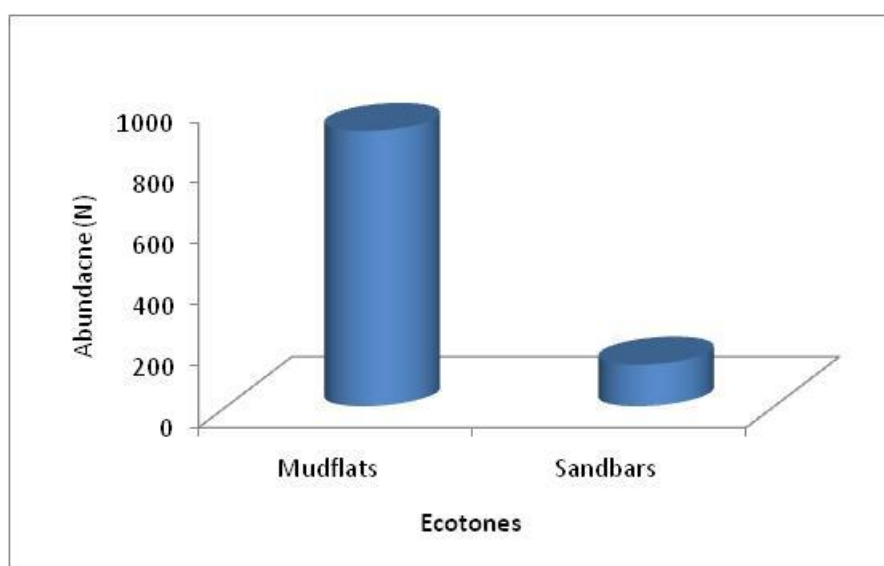


Figure 4: Abundance of the phytobenthos in the mudflats and sandbars of Calabar River, Nigeria, during the period of study

DISCUSSION

Phytobenthos play important role in detritus-based food webs in nearshore environment (Edu *et al.*, 2007). Microbial activities may lead to the enrichment of soil nutrients in the aquatic ecotones such as the mudflats and sandbars (Job *et al.*, 2011; Job *et al.*, 2015; Job *et al.* 2019).

Phytobenthos population was found to be higher in the mudflats than in the sandbars. Mudflats are generally known to have higher water and nutrient retention capacity, than sandbars (Pamatma, 1968; Gross, 1977; Lalli & Parsons, 1997; Mann, 2000; Castro & Huber, 2005; Job *et al.*, 2011). In the presence of solar radiation, coupled with the rich nutrient load in the mudflat than in the sandbars, rapid multiplication of phytobenthos cells are encouraged in the former than in the latter, hence, the higher abundance of the phytobenthos in the mudflats than in the sandbars. Sandbars are known to possess poor retention capacity for water and nutrients for the phytobenthos to utilize for primary productivity (Mann, 2000). This ultimately results in the building up of higher standing crop of the phytobenthos in the mudflats than in the sandbars (Edu *et al.*, 2002; Job *et al.*, 2011).

The results obtained in this study are in agreement with those of Job *et al.* (2011) who reported high abundance of microflora in the intertidal mudflats of the Cross River Estuary, Nigeria, and attributed it to the higher water and nutrient retention capacity of the mudflats than the sandbars. Pamatina (1968) also reported high abundance of benthic phytobenthos in the mudflats of Aberdeenshire, Scotland, and related it to the higher retention capacity for water and nutrients by the mudflats than the sandbars.

Again, Sharp *et al.*, (1982), reported that the building up of higher standing crop of phytobenthos in the intertidal mudflats, rather than in the sandbars, is as a result of nutrients entrapment capacity by the mudflats than the sandbars and that such nutrient entrapment and retention had caused an increase in the standing crop of phytoplankton generally in the subtidal mudflats of Delaware estuary in the United States of America. Also, the association of higher numbers of phytobenthos in nutrient-rich waters, derived from river discharges, has previously been reported in the sediment of Marion Lake in Oregon, located in Linn county of the United State of America (Hargrave, 1969). Similar high abundance of phytobenthos has also been reported in the sediment of River Pamlico, North Carolina (Lukatelich & McComb, 1986), Sharp *et al.* (1982) had also previously documented that nutrient-rich sediments and intertidal mudflats provide a suitable habit for phytobenthos, which, according to Pennock (1985), Mann (2000), Castro & Huber (2005), Edu *et al.* (2007), Job *et al.* (2011), is one of the factors that influences and regulates phytobenthos biomass in intertidal mudflats and sandbars.

Also as previously documented in Job *et al.* (2011), eutrophication is a common phenomenon which undoubtedly is a key factor stimulating microbial growth. This, according to Mann (2000), Prasad (2000) and Casto & Huber (2005) involves the entrapment of water molecules rich in both inorganic and organic nutrients. The fine silty nature of mudflats plays a vital role in nutrient entrapment for enhancement primary productivity (Job *et al.*, 2011). This provides the driving force for the phytobenthos to multiply rapidly in their numbers in the mudflats than in the sandbars (Pennock, 1985; Mann, 2000; Castro & Huber, 2005; Job *et al.*, 2011).

CONCLUSION

The results of the present study revealed differential abundance of phytobenthos population in the intertidal mudflats and sandbars of the Calabar River, Nigeria. The two ecotones are interconnected by nature and receive flushing at the same time during high tides, but due to their differential capacities to retend water and nutrients, their phytobenthos building capacities also differ. This might have been the premise for the observed high abundance of the phytobenthos population in the mudflats than in the sandbars.

The month of May was observed to have the highest number of phytobenthos in the mudflat with a total of 344 cells, followed by June with 317 cells and July with a total of 242 cells of the phytobenthos. In the sandbars, the month of May was also observed to have high abundance of the phytobenthos with 58 cells followed by June, with 46 cells and July with 32 cells, an indication that in May, nutrients entrapment and retention were high for the phytobenthos to make use of in building and multiplying their cells.

To therefore ecologically understand the dynamics of the two ecotones, it is strongly recommended that further studies be conducted on their primary productivity levels.

CONFLICT OF INTEREST

The Authors declare no conflict of interest

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