DIVERSITY AND DISTRIBUTION OF HARMFUL CENTRIC DIATOMS (Baccillariophyceae) IN BONNY ESTUARY, NIGER DELTA, NIGERIA

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ABSTRACT
A survey of algal species in the Bonny Estuary was carried out in seven sampling stations between December, 2017 and May, 2018 to determine the diversity and abundance of harmful centric diatoms in the Bonny Estuary. Plankton samples were collected with 20µm mesh plankton net to provide a quantitative account of harmful algae species, some physico chemical characteristics of water in the Estuary was also determined. The harmful centric diatom recovered were a total of eleven species in four families. Odontella. Aurita recorded the highest percentage abundance (14.57%) followed by Coscinodiscus meneghiniana (13.95%) and the least was Coscinodiscus concinnus with (1.60%).The mean density value recorded ranged between 34.08 x 10ce ll/L and 639.35 x 10cell/L.The Shannon index recorded the highest value of 2.292 in station 4, followed by 2.271 in station 1 while the least value of 2.076 was recorded in station 3.Dominance_D was highest in station 3 with value of 0.1483, followed by 0.1318 in station 6 while the lowest value of 0.1093 was recorded in station 4. The highest Margalef value of 1.441 was recorded in station 1, followed by 1.438 in station 2, while the least value of 1.393 was recorded in station 7. The biotic indices of centric diatom were fairly well distributed in the Bonny Estuary, which shows the centric diatoms are stable. This study therefore, provided information on the diversity and distribution of harmful centric diatoms in the Bonny Estuary

Keywords: harmful algal species, Diatom, diversity, Abundance, Bonny Estuary

INTRODUCTION

More than 400 species and 500 genera of marine phytoplankton have been described. This number is smaller in comparison to fresh water species which is around 15000 (Sournia et al., 1991). However, coastal ecosystems are becoming more vulnerable to harmful algal blooms (HABs), especially in enclosed coastal embayments, as a result of increased nutrient enrichment caused by urbanization, tourism, industrial wastes, desalination plants, agricultural activities and ballast water (Justic et al., 1995; Anderson et al., 2002; Sellner et al., 2003). Marine phytoplankton is the most important component of living organisms in bays, estuaries, creeks, deep oceans and sediments. Organic substances produced by these tiny organisms determine the basic primary productivity of marine habitat.

Diatoms are the most important primary producers in both marine and freshwater environments. Their role in regulating the ocean's silicon cycle is considerable (Yool and Tyrrell (2003). They are commonly used in studies of water quality, because they are sensitive to many environmental conditions related to water acidification, eutrophication and climate change. Diatoms have also been used as valuable indicators in historical assessments of water quality (Dam et al.1994, Schlüter et al 2012).

Diatoms which are algae with distinctive, transparent cell walls made of hydrated silica occur in freshwater and salt water, and in moist vegetation on land (Nabors, 2004). Diatoms are responsible for about 40% of the primary production in marine ecosystems and account for up to 20% of global carbon fixation (Geider et al., 2001). They are the most numerous unicellular algae in the ocean and fresh water environments and are important sources of food and oxygen for heterotrophs in aquatic ecosystems. The cell wall of diatoms consists of two halves made of silica (Dolphine, 2008). Two major groups of diatoms are recognised; centric diatoms (Centrales), cells with radial symmetry, e.g Cyclotella and pennate diatoms (Pennales), cells with bilateral symmetry e.g Synedra (Kadiri and Opute, 2013).

At present, there is no recorded information of harmful centric diatoms in Bonny Estuary. The aim of this study therefore is to provide information on the diversity of harmful centric diatoms in the Bonny Estuary, Niger Delta, Nigeria.

MATERIALS AND METHODS

Study area

The Bonny Estuary is one of the numerous low land coastal waters of the Niger Delta Complex. It is located between latitude 4° 25" and 4° 50" N and longitude 7° 0" and 7°15" E in River State, Nigeria (Figure 1). It is mainly brackish with very little freshwater discharge, mostly from the New Calabar River system. It consists of a main river channel and a large number of associated creeks and creek-lets. The Bonny Estuary is a major shipping route for crude oil and other cargoes, and leads to the Port Harcourt quays, Federal Ocean Terminal, Onne, and the Port Harcourt Refinery terminal jetty, Okirika. The Bonny Estuary (maximum width of 2 km and maximum depth of approximately 15 m near the

mouth) has the largest tidal volume of all river systems in the Niger Delta and it is mostly affected by tidal movement. The salinity fluctuates with the season and the tidal regime is influenced by the Atlantic Ocean (Dangana, 1985).

The climate of the study area is tropical and is marked by two distinct seasons, the dry season (November – March) and the wet season (April – October).

Sampling Stations

Seven sampling stations were established through a reconnaissance preliminary survey of the estuary course at 500m intervals using the ACRC GIS tool. The sampling stations were established based on ecological settings, vegetation and human activities in the area. The stations chosen included Station 1: ((Nembe waterside), Station 2(Ebetu) Station 3(Isaka open river), Station 4 (Isaka main town), Station 5 (Back of Ibeto cement), Station 6 (Macoba), Station 7 (NPA dockyard) as shown in Fig.1.

Figure 1: Map of the study area showing the different sampling stations

Determination of water Quality Variables

Physicochemical parameters: Water temperature., Salinity, pH, Dissolved Oxygen and Total Dissolved Solids (TDS), Electrical Conductivity (µS/cm), Salinity (ppt) were measured in-situ using a water checker at each sampling location according to APHA (2005) Transparency was also measured using a calibrated sechi disc.

Collection of Water samples and Algae

Hundred litres (100 L) of water for quantitative analysis of algae were collected from each of the seven sampling stations using a 20 litre bucket five times into 20µm mesh size plankton net which was held in a vertical position. Net catches were transferred into a 250 ml plastic container and preserved with 4% formalin solution which was concentrated to 10 ml in the laboratory. Two drops of concentrated algal solution were used for each sample mount. Ten mounts were taken and algal cells counted in each mount as described by (Lackey, 1938). Microphotographs of Harmful centric algae were taken by employing a camera that was fixed at the top of the microscope. Various reference materials that included Steidinger *et al*., (1967); Dodge (1982); Taylor (1987); Hallegraeff *et al*., (1995) and Tomas (1997) were used to identify the algae.

Statistical Analysis

Statistical analysis was done using Statistical Package for Social Science (SPSS) 16.0 windows. Analyses of variance (ANOVA) were also employed for the statistical interpretation of data obtained from the study. The community diversity (H′), Equitability (j) and species richness (D″) were

calculated according to (Shannon and Weaver, 1949).

RESULTS

The table 1 below shows the mean value of the physico chemical parameters of the Estuary. Mean values for pH ranged from 7.17 in station 1 to 7.50 in station 7. The pH value in Station 1 was significantly different ($p<0.5$) across stations 2 to 7. Temperature values range from 27.88 in station 2 to 29.28^0C in station 7, station 5 was significantly different across stations ($p<0.5$). Dissolved Oxygen values range from 4.21 in station 5 and 6 to 6.00(mg/l) in station 1 which is significantly different across other stations($p<0.5$). Salinity values range from 19.90 in station 2 to 26.96 in station 3 which is significantly different across the other stations ($p<0.05$). Turbidity values range from 4.28 in station 7 to 7.40(NTU) in station 4. Station 6 is significantly different from other station ($p<0.05$) while total solid dissolved values range from 18.31 in station 2 to 23.05(mg/l) station 3 shows significant difference across other stations ($p<0.05$)

Table 1: Physico-chemical parameters across stations in Bonny Estuary

Station	pH	Temp. .(^{O}C)	DO.(mg/l)	Salinity(ppt)	BOD(mg/l)	Turbidity(NTU)	TDS(mg/l)
1	7.17±0.12^b	28.20±1.02^{ab}	6.00±0.74^a	20.52±1.66^c	2.64±0.14^{bc}	4.78±0.19^{ab}	23.05±3.54^c
2	7.37±0.09^a	27.88±1.12^c	5.70±0.71^d	19.90±1.27^c	2.84±0.32^e	5.18±0.11^d	18.31±4.71^c
3	7.47±0.05^a	28.21±1.07^b	4.87±0.53^e	26.96±4.53^b	2.93±0.21^b	6.90±0.18^b	18.96±4.54^b
4	7.44±0.05^a	28.64±1.08^{ab}	5.64±0.58^c	26.76±4.25^a	3.23±0.22^c	7.40±1.00 ^{a}	19.17±4.62^a
5	7.48±0.06^a	28.48±0.99^a	4.21±0.09^e	25.73±3.77^a	2.92±0.27^d	5.87±1.05^a	18.80±4.56^a
6	7.43±0.10^a	28.51±1.18b^c	4.21±0.35^b	25.48±3.69^a	3.54±0.09^a	4.49±0.75^e	18.71±4.58^{ab}
7	7.50±0.08^a	29.28±1.42b^c	4.77±0.28^b	23.29±2.60^a	2.79±0.09^b	4.28±0.67^c	18.34±4.70^{ab}

*Superscripts of the same alphabet are not significantly different ($P<0.05$)
**Superscripts of different alphabets are significantly different ($P<0.05$)

Table 2 below showed the composition of centric harmful algal species in the Estuary, 4 families and 11species were recorded. The family Triceratiaceae recorded the highest specie of 5 species followed by Coscinodiscaceae with 3 species while the Thalassioneticeae recorded the lowest species of 1.Table 3 below showed the mean density value per litre of the harmful algal centric diatoms.

In Station 1 the highest mean value of 596. 35cell/L (*O.aurita*) was recorded and the least valu e of 119.21cell/L(*O.longicruris*).In Station 2 the hi ghest mean value of 554.13cell/L(*O.longicruris)* th e least value of 17.00cell/L (*C.concinnus).O.sinens is* had the highest mean value of 852.27cell/L,*C.rad iatus* had the least value of 17.00cell/L in station 3.In station 4, *C.meneghiniana* had 698.97cell/L while *C.concinnus* had the least value of 136.13cell/L. Highest mean value of 613.76cell/L was recorded for *C.meneghiniana* while *C.granni* had the lowest mean value of 51.13cell/L in station 5.Mean value of 579.43cell/L was recorded for *C.meneghiniana*, and the least value of 34.08cell/L for *C.granni* in station 6.In station 7 *O.mobilensis* recorded the highest mean value 639.35cell/L while *C.concinnus* recorded the least mean value 68.00cell/L.

Table 2: Harmful Centric Diatoms in Bonny Estuary

Class	***Family***	***Species***
Bacillariophyceae	Triceratiacea	*Odontella aurita* (Lyngbye) C. Agardh
		Odontella longicruris (Greville) Hoban
		Odontella mobiliensis (J.W. Bailey) Grunow
		Odontella sinensis (Greville) Grunow
		Triceratium favus (Ehrenberg)
	Coscinodiscaceae	*Coscinodiscus concinnus* (W. Smith)
		Coscinodiscus granii (Gough)
		Coscinodiscus radiatus (Ehrenberg)
	Stepahnodisceae	*Cyclotella antiqua* (W. Smith)
		Cyclotella meneghiniana (Kützing)
	Thalassionemataceae	*Thalassiosira eccentrica* (Ehrenberg) Cleve

Figure 2 below showed the percentage composition of the harmful centric diatoms. *O. aurita* recorded the highest percentage abundance of 14.57% followed by *C.meneghiniana* with 13.95% while the least percentage abundance recorded was *C.concinnus* with 1.60%.

The table 4 below shows the diversity indices across the station. Dominance_D recorded the highest value of 0.1483 in station 3, followed by 0.1318 in

station 6 while the lowest value of 0.1093 was recorded in station 4. The Shannon index recorded the highest value of 2.292 in station 4, followed by 2.271 in station 1 while the least value of 2.076 was recorded in station 3. The highest value of 0.8246 for evenness was recorded in station 4, followed by 0.8074 in station 1, while the least value of 0.6645 was recorded in station 3. The highest Margalef value of 1.441 was recorded in station 1, followed by 1.438 in station 2, while the least value of 1.393 was recorded in station 7.

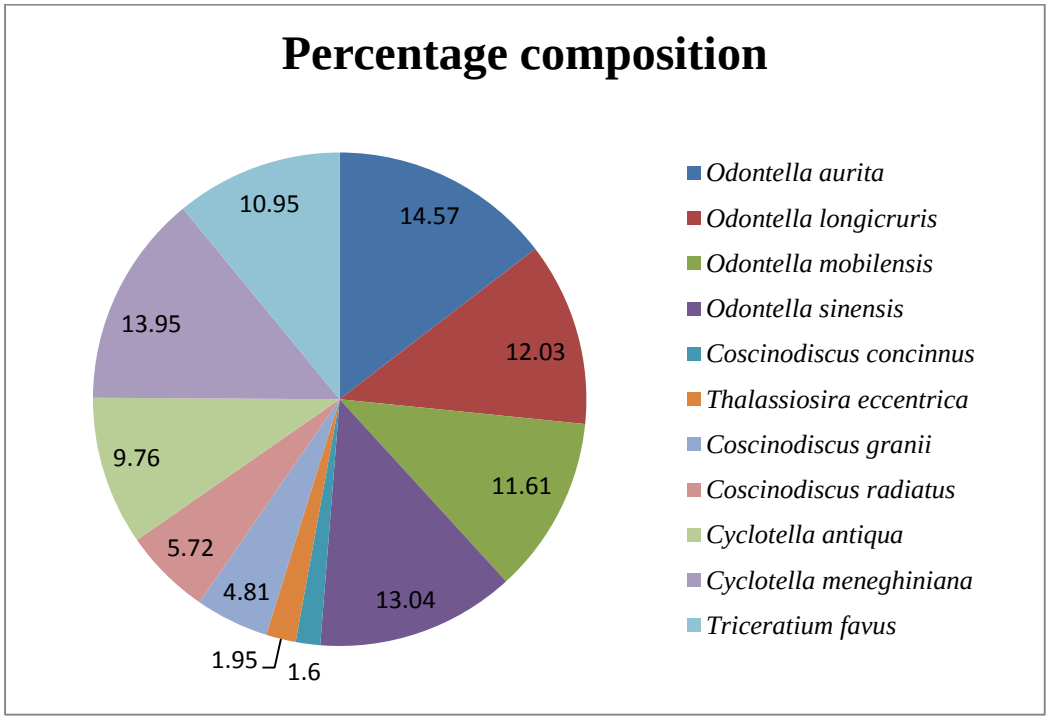

Figure 2: Percentage composition of harmful centric algal species

Table 3: Mean Density Per Litre of Harmful Centric Diatoms in Bonny Estuary

Species /Station	1	2	3	4	5	6	7
Odontella aurita	596.35±85.34^{a}	460.30±187.30^{a}	545.13±33.86^{a}	596.56±255.55^{a}	494.35±187.34^{a}	306.76±306.76^{a}	562.35±119.34^{a}
Odontella longicruris	119.21±51.21^{a}	554.13±42.86^{a}	409.22±170.21^{a}	425.85±255.84^{a}	426.22±153.21^{a}	562.35±119.345^{a}	443.26±170.26^{a}
Odontella mobiliensis	323.84±51.16^{b}	170.42±170.42^{b}	647.43±102.43^{a}	238.59± 238.59^{ab}	392.18±153.17^{ab}	426.01±16.99^{ab}	639.35±42.34^{a}
Odontella sinensis	238.38±68.38^{bc}	494.22±85.21^{abc}	852.27±170.26^{a}	187.42±153.42^{c}	477.26±136.26^{abc}	392.13±119.13^{bc}	545.35±136.34^{ab}
Triceratium favus	255.42±85.42^{ab}	323.68±221.67^{ab}	596.35±85.34^{a}	340.92±0.07^{ab}	477.18± 0.000^{ab}	272.84±0.16^{b}	409.01±0.07^{ab}
Coscinodiscus concinnus	68.13±34.12^{a}	17.00±17.00^{c}	34.08±34.08^{ab}	136.13±33.87^{a}	68.08±0.08^{ab}	0.00±0.00^{c}	68.00±68.00^{bc}
Coscinodiscus granii	289.92±50.92^{a}	187.34±85.33^{a}	34.00±34.00^{a}	221.38±85.38^{a}	51.13±51.12^{a}	170.42±0.00^{a}	221.67±85.33^{a}
Coscinodiscus radiatus	272.84±0.162^{ab}	136.21±34.21^{cd}	17.00±17.00^{d}	289.92±50.92^{ab}	102.25±102.25^{bc}	238.80±0.20^{bc}	341.01±68.00^{a}
Cyclotella antiqua	374.92±34.07^{a}	204.34±68.33^{a}	204.71±34.28^{a}	306.92±34.28^{a}	391.85±33.92^{a}	460.26±289.84^{a}	443.05±153.26^{a}
Cyclotella meneghiniana	323.63±187.63^{a}	289.92±50.92^{a}	460.30±187.30^{a}	698.97±84.97^{a}	613.76±0.23^{a}	579.43±170.43^{a}	442.92±102.07^{a}
Thalassiosira eccentrica	136.13±33.87^{ab}	85.17±51.16^{ab}	221.75±17.24^{a}	0.00±0.00^{b}	0.00±0.00^{b}	34.08±0.00^{b}	0.00±0.00^{b}

Table 3: Diversity Indices of Harmful Centric Diatoms In Bonny Estuary

	STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6	STATION 7
Taxa_S	11	11	11	11	11	11	11
Individuals	2069	2105	2438	2123	2243	2198	2683
Dominance_D	0.1112	0.1161	0.1483	0.1093	0.1292	0.1318	0.1182
Shannon_H	2.271	2.262	2.076	2.292	2.141	2.171	2.209
Evenness_e^H/S	0.8074	0.7999	0.6645	0.8246	0.709	0.7305	0.759
Margalef	1.441	1.438	1.41	1.436	1.426	1.429	1.393

DISCUSSION

The pH values recorded in this study area were well within the preferred pH of 6.5 to 9.0 recommended for optimal fish and aquatic life (Boyd and Lichktopller 1979).The mean temperature values in the study area range from 27.88±1.12 to 29.28±1.42°C across the Stations were observed normal with the reference to the location in Niger Delta region, Alabaster and Lloyd (1980) reported that temperature on natural inland waters in the tropics generally varies between 25°C and 35°C values recorded also agrees with earlier reported works in the Niger Delta water by Abowei (2010) who reported temperature range of between 27°C to 31°C,Omokheyeke *et al.,* (2014) and Jamabo (2008) reported a temperature range between 27ºC and 30ºC in the upper Bonny River of Niger Delta

The Dissolved Oxygen (DO) values in the Stations were higher at the upstream sampled Station than the downstream Station. Similar trend was also reported by Hart and Zabbey (2005) for Woji Creek, Davies *et al* (2008) also made similar report for the Trans- Amadi (Woji) Creek Port Harcourt. They attributed it to the effect of higher temperature and abattoir waste. This is in agreement with the findings of the study. Onwugbuta-Enyi et al, (2008) reported dissolve oxygen value which range from 4.6-11.8 mg/l, this is in contrast with the finding of the study which maybe due to seasons. Water with DO above 6ppm will support fish and

other desirable forms of aquatic biota whereas water with less than 2ppm oxygen will support mainly decomposers.

Salinity values recorded in this study is within the range reported by Chindah and Nduaguibe (2003) of 11.5±1.8 ‰ to 20.3±3.0 ‰ for Lower Bonny River.The recorded higher salinity in the dry season could be as a result of high sunlight intensity that increased the water evaporation rate. Clarke (2005) reported higher salinities in the dry season which is in agreement with the findings of this study. This trend of fluctuation could be attributed to effluent water discharge from several industrial establishments carrying out bunkering activities and domestic activities which are prevalent along the upstream area of the Estuary.

The recorded biological oxygen demand is within the acceptable range for aquatic environments. Vincent-Akpu and Nwachukwu (2016) reported a value of 2.8mg/l in Nembe and 2.50mg/l in Bonny.Davies (2014) reported BOD values of 2.75 to 3.39mg/l in Okpoka Creek which is in agreement with the findings of this study.

Turbidity values in the study area were higher than the the findings of. Davies and Ugumba, (2013) reported turbidity value range from 2.31 to 4.68NTU in Bonny Estaury which is below the values recorded in this study. Wokoma-Aleleye, and Hart, (1999) reported a turbidity value within the range of this study). The observed turbidity level in this study agrees with the range of 2 NTU to 47 NTU reported by Asonye *et al.* (2007) for the turbidity of Nigerian rivers, streams and waterways. Total dissolved solids (TDS) values ranged from 18.31 to23.05mg/l Vincent-Akpu and Nwachukwu (2016) reported TDS values of 13.1mg/l in Nembe and 14.9mg/l in Bonny. The higher total dissolved organic solid concentration recorded in this study might be attributed to high surface runoff, overland flow as well as higher discharge of organic wastes into the river.

The centric harmful algal species composi tion was dominated by Triceratiacea The result was similar with others research indicating that Bacillariophyceae as the dominant genera on water sample (Bazin et al,2014). (Krammer and Lange-Bertalot, 1991) reported 7 centric diatoms which belong to species with widespread distribution in the Holarctic. Onyema et al 2006 investigated the diatoms phytoplankton of an estuarine creek in Lagos and recorded a total 18 species of centric diatoms.

The mean density per litre of harmful centric algal diatoms revealed that the species *C. concinnus* recorded the least density value across the sampling stations. This is contrary to the findings of Linet et al (2013) who recorded low mean density value of *Thalassiosira sp*.in Kenya Coast. *O. aurita* recorded the highest density value across the station (Usup et al 2002) reported the cell densities of HABs species recorded were not high enough ($<10^6$ cells/L for non-toxic production species and $<10^3$ cells/L for toxic production species) to be considered as blooms which is in agreement with the density values of centric diatoms in the study area

Diversity indices are parameters used to indicate the level of stability of an observed community structure, which is closely related to the habitat characteristics occupied by the biota. In this study, the diversity indices of harmful centric diatoms slightly varied across station. The Shannon index recorded the highest value of 2.292 in station 4, followed by 2.271 in station 1 while the least value of 2.076 was recorded in station 3. According to the classification of the Shannon-Wiener index, if the diversity index is lower than 1, then the biota communities would be regarded as unstable, whereas a diversity index of 1-3 would be considered moderately unstable, and a value higher than 3 would signify a stable or prime condition (Mokoginta 2016). It means that diversity index across the stations were considered moderately stable.

Dominance_D index ranges from 0-1, meaning moderately dominance since the value was slightly above 1. The highest value of 0.8246 for evenness was recorded in station 4, followed by 0.8074 in station 1, while the least value of 0.6645 was recorded in station 3. The highest Margalef value of 1.441 was recorded in station 1, followed by 1.438 in station 2, while the least value of 1.393 was recorded in station 7. (Ofonmbuk and Lawrence,2015) reported a higher Margalelf's diversity valve of 2.871 to 3.513 in Qua-iboe river estuary. The low diversity values could be attributed to effects of stress conditions in the environment and also impact by bunker activities which is highly probable in the study area as reported by Adesalu and Nwankwo (2008). Diversity is dependent on key ecological processes such as competition, predation, and succession, and therefore changes in these processes can alter the species diversity index through changes in evenness (Stirling and Wilsey, 2001).

CONCLUSION

The present study revealed the presence of harmful centric diatom in the study area. In this study, the most abundant algal species recorded was *Odontella aurita*, while the least abundant species recorded was *Coscinodiscus concinnus*. All species were well distributed across all stations and the diversity indices showed that the harmful centric diatoms were fairly distributed in the study area and it is therefore recommended that further research should be carried out to provide the interactions of these algal species with environmental gradients in the Bonny Estuary.

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