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Research Article

Seasonal Variation and Abundance of Harmful *Bacillaria paxillifera* Species (Müller, 1786) in Bonny Estuary, Rivers State, Niger Delta, Nigeria

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Abstract

Background and Objectives: Harmful algal species are natural phenomena that have occurred throughout history in water bodies. Estuaries form an integral part of inshore waters, despite extreme conditions, they are fertile, highly productive and essential ecosystem. This study examined the seasonal variation and abundance of harmful *Bacillaria paxillifera* species in the Bonny Estuary. **Materials and Methods:** Plankton samples were collected with 20 µm mesh plankton net to provide a quantitative account of the algal species, the physico chemical characteristics of the estuary was also determined by using a horiba water checker. **Results:** Mean density value per liter of *Bacillaria paxillifera* spp. ranged from 165.52 (cell L^{-1}) in station 4-336.14 (cell L^{-1}) in station 1. The monthly distribution of the species showed that highest density value per liter was recorded in the month of April and least density value per liter was recorded in the month of February. Seasonal distribution revealed that the species decreased across season from dry to wet. Correlations matrix between physico chemical parameters, nutrients and total biomass of the species also revealed that pH, total dissolved solids, dissolved oxygen, salinity and nitrate correlated positively with total biomass while, temperature and phosphate showed negative correlation with total biomass. **Conclusion:** Therefore, there is need for further research to provide information on prediction of possible bloom of this species in Bonny estuary.

Key words: Abundance, variation, correlation, algal species, Bonny Estuary

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Phytoplankton are free floating tiny floral components that are widely distributed in the marine and estuarine environments. They play an important role to make the estuarine ecosystem more productive. These microscopic organisms are vital and important as a primary producer and source of food supply to the aquatic body. Phytoplankton are also one of the initial biological components from which energy is transmitted through the food chain to higher organisms[1].

Estuaries and their associated river systems form an integral part of inshore waters. Despite extreme conditions, estuaries are fertile, highly productive and essential ecosystem for fisheries in the tropical region[2]. The abundance, distribution and species composition data of phytoplankton are important for the study of estuarine ecosystems. It is reported that phytoplankton species undergo spatiotemporal distribution changes due to the various effects of hydrographic factors on individual species[3].

The production of phytoplankton is largely dependent on the nutrient concentrations and light availability in the photic zone[4]. In addition to light and oxygen, phytoplankton requires basic simple inorganic chemical nutrients, like Phosphate Nitrate (NO_3^-), PO_4^-, Carbon Dioxide (CO_2) and some diatoms require a form of Silicon (SiO_4^-) for their growth and sustenance[5]. The changes in the structure of the phytoplankton community can be influenced by their surrounding environment in ways which favour or disfavour their continued persistence[6]. Phytoplankton community and size composition are also known to be related to nutrient availability[7]. Nutrient enrichment can be predicted to alter phytoplankton community composition[2,8,9].

Harmful Algal Blooms (HABs) are commonly occurring phenomena. These events have increased in frequency, duration and geographic distribution over the past 2 decades, however, resulting in increased public health and economic effects. Among the 5,000 species of phytoplankton that exist[10], about 300 species can occur in such high numbers that they obviously discolor the surface of the sea and about 40 species are capable of producing potent toxins that can be transferred to humans through fish and shellfish[11].

The genus *Bacillaria* was revised by Jahn and Schmid[12], with recognition of additional species. *Bacillaria paxillifera* var. *czarneckii* was described from material from the Mississippi, but also documented in Europe. *Bacillaria kuseliae* and *B. urve-millerae* were described from Germany and Australia, respectively such taxa vary in the raphe flanges arrangement, the shape of the valve and the form and number of the plastid.

Nonetheless, several studies have shown that physical and chemical factors have a significant influence on plankton populations in mangrove waters relative to the coastal nearshore climate, resulting in seasonal changes in the composition and densities of plankton organism[13]. Thus, the estimation of those physical parameters and inorganic chemicals is also essential for studying the community structure of phytoplankton in an aquatic environment. The aim of this study was to examine the seasonal variation and abundance of *Bacillaria paxillifera* species in Bonny estuary.

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 4°25"-4°50"N latitude and 7°0"-7°15"E longitude in River state, Nigeria (Fig. 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, Okrika, Nigeria. 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[14]. The climate of the study area is tropical and is marked by 2 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 500 m intervals by using the ACRC GIS tool. Sampling was carried out between December, 2017-November, 2018. The sampling stations were established based on ecological settings, vegetation and human activities in the area. The stations chosen included station 1 (Ebetu) station 2 (Isaka open river), station 3 (Isaka main town) and station 4 (back of Ibeto cement) as shown in Fig. 1.

Determination of water quality variables

Physicochemical parameters: Temperature, salinity, pH, dissolved oxygen and Total Dissolved Solids (TDS) electrical conductivity (μS cm^{-1}) and salinity (ppt) were measured *in situ* by using a horiba water checker at each sampling location. Transparency was also measured by using a calibrated secchi disk.

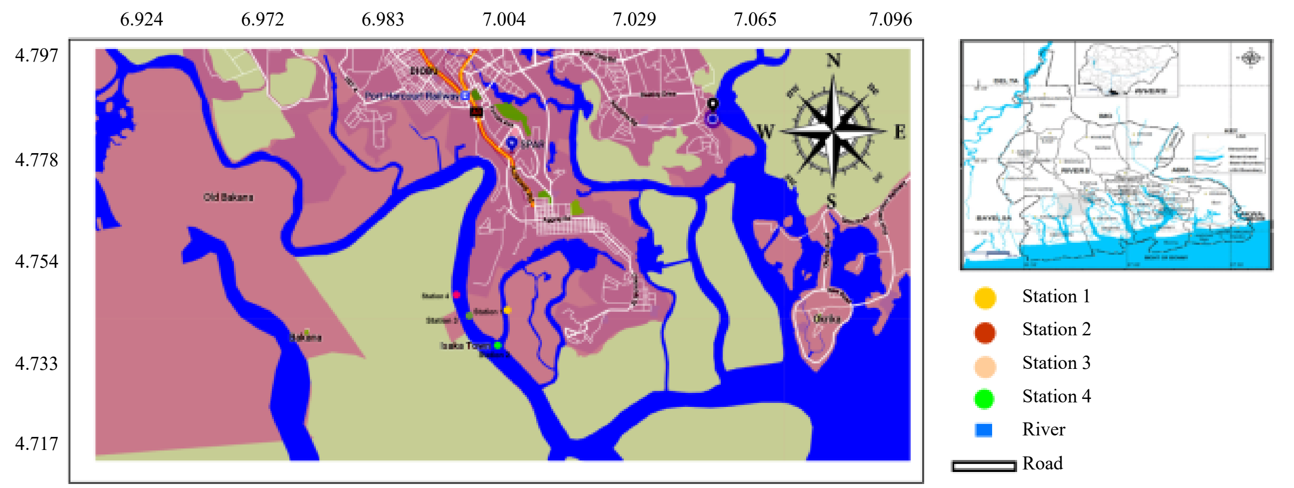

Fig. 1: Map of the study area showing the different sampling stations

Source: Field Survey, 2018

Collection of water samples and algae: Surface water samples for quantitative analysis of algae were collected from 4 sampling stations by filtering 100 L of surface water, using using a 20 L bucket for 5 times into 20 µm mesh size plankton net which was held in a vertical position. Net catches were transferred to a 250 mL plastic container and stored in the laboratory with a 4% formalin solution concentrated at 10 mL. For each sample brace, two drops of concentrated algal solution were used. Ten mounts were taken and algal cells were counted as described in each mount[15]. 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 Hallegraeff *et al.*[11], Steidinger *et al.*[16], Dodge[17], Taylor[18] and Tomas[19] were used to identify the algae.

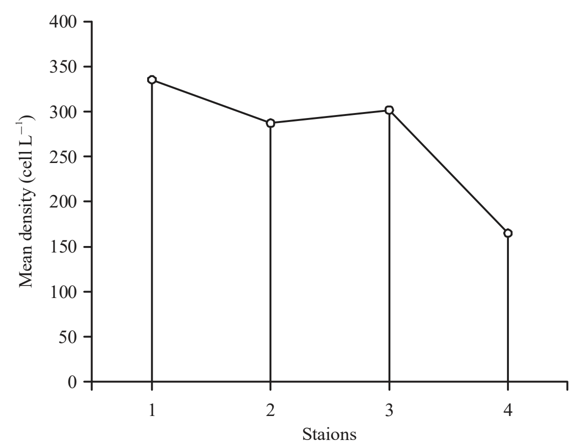

Fig. 2: Mean cell density value per liter of *Bacillaria paxillifera* species in Bonny Estuary

Statistical analysis: Statistical analysis was done by using Statistical Package for Social Science (SPSS) 16.0 windows. Analysis of variance (ANOVA) was also employed for the statistical interpretation of data obtained from the study. Pearson correlation 'r' was used to check the affinities of various physicochemical parameters, nutrients and its correlation with species abundance were carried out by using Pearson correlation at 0.05 and 0.01 significant levels.

RESULTS

Physico chemical parameters and nutrients: The Table 1 shows the mean value of the physico chemical parameters of the Bonny estuary. The pH values ranged from 7.11±0.07 to 7.32±0.20 in station 1 and 4, respectively there was significance difference between station 1 and 4 ($p<0.05$). Dissolved oxygen range from 3.89±0.16 to 4-4.64±0.36 mg L^{-1} in station 4 and 1, respectively. Station 4 is significantly different across the stations ($p<0.05$). Phosphate (PO_4) values ranged from 2.90±0.22 to 9.48±1.06 in station 1 and 4, respectively. There is significant difference between stations 3 and 4 ($p<0.05$). Nitrate (NO_3) values ranged from 0.53±0.04 to 2.62±0.92 in station 2 and 1, respectively. Station 1 is significantly difference across the stations ($p<0.05$).

Monthly and seasonal abundance of *Bacillaria paxillifera* Spp.: Figure 2 showed the mean density value per liter of *Bacillaria paxillifera* spp. the values ranged from 336.14 (cell L^{-1}) in station 1 while the lowest density value was 165.52 (cell L^{-1}) in station 4.

Table 1: Environmental parameters of Bonny Estuary across stations

Parameters	Station 1	Station 2	Station 3	Station 4
pH (ionic concentration)	7.11±0.07[b]	7.26±0.05[ab]	7.26±0.05[ab]	7.32±0.20[c]
Temperature (°C)	29.48±0.82[a]	28.97±0.56[a]	28.95±0.58[a]	28.96±0.50[a]
Dissolved oxygen (mg L^{-1})	4.64±0.36[ab]	4.46±0.28[ab]	4.39±0.35[ab]	3.89±0.16[a]
Salinity (ppt)	16.20±0.98[a]	19.40±2.40[a]	19.47±2.29[a]	18.24±2.22[a]
Total dissolved solids (mg L^{-1})	17.44±2.33[a]	18.34±2.24[a]	18.33±2.31[a]	17.16±2.44[a]
PO_4 (mg L^{-1})	2.90±0.22[a]	3.70±0.25[a]	6.71±0.53[b]	9.48±1.06[c]
NO_3 (mg L^{-1})	2.62±0.92[b]	0.53±0.04[a]	0.66±0.06[a]	0.71±0.06[a]

Superscripts of the same alphabet are not significantly different across the column (p<0.05), Superscripts of different alphabets are significantly different (p<0.05), PO_4: Phosphate, NO_3: Nitrate

Table 2: Correlation matrix of physicochemical parameters, nutrients and biomass of *Bacillaria paxillifera* spp. in Bonny Estuary

Parameters	pH	TDS	DO	Temperature	Salinity	PO_4	NO_3	Total biomass
pH (ionic concentration)	1.000							
Total dissolved solids	0.107	1.000						
Dissolved oxygen	0.145	0.344**	1.000					
Temperature	-0.214**	0.097	-0.009	1.000				
Salinity	0.431**	-0.063	0.034	0.035	1.000			
PO_4	0.162*	-0.568**	-0.272**	-0.117	0.113	1.000		
NO_3	0.125	0.334**	0.437**	0.073	0.017	0.087	1.000	
Total biomass	0.332	0.435	0.564	-0.297	0.063**	-0.271	0.220	1.000

**Correlation is significant at p<0.01(level) 2 tailed, *Correlation is significant at p<0.05(level) 2 tailed

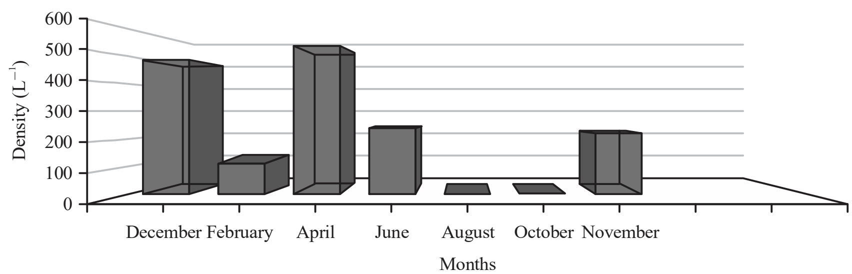

Fig. 3: Monthly distribution of *Bacillaria paxillifera* spp. in Bonny Estuary

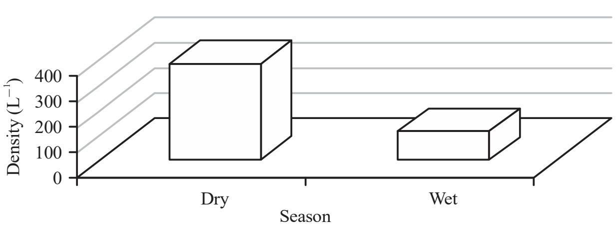

Fig. 4: Seasonal distribution of *Bacillaria paxillifera* spp. in Bonny Estuary

The monthly distribution of *Bacillaria paxillifera* spp. in Fig. 3 showed that the highest density value per liter was recorded in the month of April while, the least density value per liter was recorded in the month of February. The seasonal distribution of *Bacillaria paxillifera* spp. in Fig. 4 showed that the species decreased across season from dry to wet.

Correlation matrix of environmental parameters with *Bacillaria paxillifera* spp.: Correlations matrix between physico chemical parameters, nutrients and total biomass of *Bacillaria paxillifera* spp. is shown in Table 2. The pH correlated positively with phosphate (0.162), nitrate (0.125) and total biomass (0.332). Phosphate was significantly different at p<0.05. Total Dissolved Solid (TDS) correlated negatively with phosphate (-0.568) and positively correlated with nitrate (0.334) and total biomass (0.435). Phosphate and nitrate were significantly different at p<0.01. Dissolved oxygen correlated negatively with phosphate (-0.272), but correlates positively with nitrate (0.473) and total biomass (0.564). Phosphate and nitrate were significantly different at p<0.01. Temperature correlated negatively with phosphate (-0.117), total biomass (-0.297) and positively correlated with nitrate (0.073). Salinity correlated positively with phosphate (0.113), nitrate (0.017) and total biomass (0.063) with no significant difference. Phosphate correlated positively with nitrate (0.087) and negatively with total biomass (-0.271) with no significant difference while nitrate was positively correlated with total biomass (0.220) with no significant difference.

DISCUSSION

The physico chemical and nutrient parameters in the study area showed that pH, salinity and phosphate increased across the stations, however, temperature, dissolved oxygen and nitrate decreased across the stations from the upstream to the downstream of the sampling stations. The pH values recorded in this study ranged from 7.11±0.07 to 7.32±0.20 were within the preferred pH recommended for aquatic life[20]. The mean temperature values in the study area range from 28.95±0.58 to 29.48±0.82°C were observed normal with the reference to the location in Niger Delta region. Abowei[21] reported the temperature range of between 27-31°C, Omokheyeke[22] and Jamabo[23] reported, a temperature range between 27 and 30°C in the upper Bonny river of Niger Delta.

Dissolved oxygen values recorded the range from 3.89±0.16 to 4.64±0.36 mg L^{-1}. Similar trend was reported by Hart and Zabbey[24] and Davies *et al*.[25] made similar report in Niger Delta waters. Salinity values ranged from 16.20±0.98 to 19.47±2.29 mg L^{-1}. This is also within the range reported by Chindah and Nduaguibe[26] for lower Bonny river. Total Dissolved Solids (TDS) values ranged from 17.16±2.44 to 18.34±2.24 mg L^{-1}. Vincent-Akpu and Nwachukwu[27] reported TDS values of 13.1 mg L^{-1} in Nembe and 14.9 mg L^{-1} 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.

Phosphate (PO_4) values ranged between 2.90±0.22 to 9.48±1.06 mg L^{-1}. Falomo[28] reported a mean phosphate of 1.4 mg L^{-1} in Okrika creek central Bonny estuary while, Ebere[29] recorded (4.95-14.73 mg L^{-1}) at polluted sites in the upper Bonny estuary, Davies[30] reported a value of 0.73 mg L^{-1} in Bonny estuary. Phosphorus stimulated algae growth that Praveena *et al*.[31] attributed the higher values of phosphate in the coastal waters of Port Dickson, Strait of Malacca, Malaysia to anthropogenic impact thus this could be the possible reason for the higher phosphate values in Bonny estuary. Nitrate values ranged from 0.53±0.04 to 2.62±0.92 mg L^{-1}. Nitrates values recorded was in agreement with Vincent-Akpu and Nwachukwu[27], who reported a value of 4.6 mg L^{-1} in Bonny and 3.3 mg L^{-1} in Nembe. The range of nitrate recorded in this study was below the statutory limit of 25-50 mg L^{-1} given by the EEC[32] and 20 mg L^{-1} USEPA[33]. Nitrate does not pose a health threat, but it is readily reduced to nitrite by the enzyme nitrate reductase which is widely distributed and abundant in both plants and micro-organisms[34].

The mean cell density value per liter recorded highest value in station 1 (fishing activities and ferry terminal) followed by station 3 (dominated by domestic activities and waste) while station 4 (back of a cement factory) recorded the least mean density values, which could be a factor for high density of the species in station 1 and 3, respectively. All environmental factors except temperature and phosphate showed a positive correlation with total biomass of the algal species. The algal species decreased across season from dry to wet season. The mean density per litre of *Bacillaria paxillifera* spp. values ranged from 165.52±42.96 to 336.14±64.66 cell L^{-1} in station 4 and 1, respectively. This revealed that the species recorded the least density value in station 4. This is in contrary with the findings of Linet *et al*.[35], who recorded low mean density value of *Thalassiosira* sp., in Kenya Coast. *Bacillaria paxillifera* dominated the entire population in the lower Gulf and the off-shore stations of Peninsular Malaysia[36]. Usup *et al*.[37] reported the cell densities of harmful algal species recorded were not high enough (<10^6 cells L^{-1} for non-toxic production species and <10^3 cells L^{-1} for toxic production species) to be considered as blooms which is in agreement with the density values of *Bacillaria paxillifera* spp. in the study area.

The concentration of phytoplankton is correlated with seasonal flow variations. The peak in the dry season and diminish in the floods[38]. The result of this study showed that the species decreased across season from dry to wet. Seasonal variations in pennate diatom (algal) abundance with higher values in the dry season have also been reported by Ogamba *et al*.[39] and Emmanuel and Onyema[40]. The results also showed that variations occurred between seasons and in some algal species. The dry seasons had significantly higher mean algal abundance than the wet season during the sampling period. Abdullahi and Indabawa[41] also recorded higher algal cells in the dry season than in the rainy season which is in agreement with the findings of this study. Abubakar[42] reported that in tropical regions the dry and rainy seasons showed distinct fluctuations with an abundance of phytoplankton. Swann[43] reported that algae is one of the causes of turbidity. The recorded high rainy season turbidity was probably due to the high natural erosion and run offs from the surroundings. This might be responsible for the low algal abundance in the wet season. The monthly variation of population composition and significant difference with season may be due to the fluctuations of physico chemical parameters of the water as suggested by Iqbal *et al*.[44].

Coastal waters are characterized by a high degree of spatial and temporal variability of environmental parameters[45]. Correlations matrix between physico chemical parameters, nutrients and total biomass of *Bacillaria paxillifera* spp. revealed that pH, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), salinity and nitrate showed a positive correlation while temperature and phosphate showed a negative correlation with total biomass. Pennate diatoms like *Bacillaria paxillifera* showed a strong positive relation with salinity and a negative correlation with nutrients. This is supported by the study of Sahu *et al.*[46] who showed that high salinity supported high pennate diatom abundance. Admiraal *et al.*[47], Polat and Isik[48] and Alp and Sen[49] on the other hand showed a negative correlation between pennate diatom abundance and nutrients.

Coastal water's nutrient enrichment is generally the main driving factor in the succession and composition of phytoplankton communities[50]. As expected, nitrate and phosphate levels both significantly affected algal growth. The results of this study is contrary to the findings who found that algal growth has a significant effect on both nitrate and phosphate levels[51-53]. This result of this study is in agreement with the study by Tubea *et al.*[54], who found that algal growth was not significantly affected by phosphate levels. The results of this study are also contradictory to the findings of Pietilainen and Niinioja[55], who found that algal growth was not affected by nitrate levels. However, their study was conducted over the summer when the algae were in the logarithmic phase of growth. According to Abubakar[42], who stated that, if nitrogen is present in very high concentrations and phosphorus is not, the algae will proliferate until it has used up all of the phosphorus even if there is still an ample supply of nitrogen. Regardless of the significance of the interaction between the variables, it can be concluded that if only one nutrient is substantially increased the other nutrient will limit the growth. Twomey *et al.*[56] reported that, high nitrate concentrations enhance the phytoplankton growth and there was a positive correlation between NO_3 and the total counts of phytoplankton ($r = 0.66$) which is in agreement with the finding of this study thought with a weak correlation ($r = 0.222$).

CONCLUSION

The present study revealed the seasonal abundance of harmful *Bacillaria paxillifera* spp. in the study area. Mean density value per liter was highest in station 1 due to the industrial activities in the area. Abundance decreased from dry to wet season. pH, total dissolved solids, dissolved oxygen, salinity and nitrate correlated positively with total biomass while temperature and phosphate showed negative correlation with total biomass, it is, therefore, recommended that further research should be carried out to provide information on prediction of possible bloom of this species in the Bonny estuary.

SIGNIFICANCE STATEMENT

This study discovered the presences of harmful *Bacillaria paxillifera* spp., it's seasonal abundance and distribution in the Bonny estuary, Niger Delta, Nigeria. This can be beneficial for monitoring programmes to mitigate the possible occurrence of this species forming bloom. This study will help researchers to uncover the critical areas to enhance ecosystem-based management strategies for harmful algal blooms through the rapid detection of harmful algal species, that many researchers have not able to explore in this region. Thus, there is need to adequately plan monitoring programmes to develop early warning systems and models for short term forecast of harmful algal blooms.

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