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WATER QUALITY ASSESSMENTS: A CASE STUDY OF PLANKTON AND MACROBENTHIC INVERTEBRATES OF PORTO-NOVO AND PARTS OF GULF OF GUINEA

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ABSTRACT

Aspects of physico-chemical characteristics, plankton and macro invertebrates of Porto-Novo and Gulf of Guinea were studied in September 2012 with a view to determine the quality of water using plankton indices. Standard methods were used to determine the physico-chemical parameters. The mean water quality parameters studied were temperature (36.71°C), pH (7.63), transparency (1.97m), total dissolved solids (10.0mg/L), dissolved oxygen (4.73mg/L) and salinity (38.58‰) for Gulf of Guinea. Five divisions; Cyanophyta, Bacillariophyta, Chlorophyta, Euglenophyta and Pyrrhophyta were recorded for both bodies of water with diatoms and dinoflagellates dominating the spectrum. The phytoplankton ofPorto-Novo recorded abundance of *Gomphonema* spp., *Fragilaria crotonensis*, *Synedra*sp. and *Nitzschia* sp.(diatoms) while that of Gulf of Guinea recorded *Ceratium* spp. and *Gonyaulax spinifera* (dinoflagellates). For the zooplankton, *Acartia clausii* (a copepod) and *Penilla avirostris* Dana (Cladocera) were the highest in both occurrence and abundance especially at Porto-Novo. The population of benthic fauna was low (20 individuals) dominated by bivalve, *Tivela tripla.*

Key Words: Microalgae, zooplankton, benthos, Porto-Novo, Gulf of Guinea

INTRODUCTION

The tropical coastlines support a diverse array of microalgae and macro-benthic communities that play important roles in ecosystem processes such as recycling nutrients, detoxifying pollutants, dispersion and burial and secondary production (Gray, 1997; Snelgrove, 1997). Additionally, these organisms provide food for humans and are considered an important source of food for fishes and birds (Snelgrove, 1999; Thrush and Dayton, 2002). According to Campbell (2008), water bodies can be fully characterized by three major components: hydrology, physico-chemistry and biology while Chapman and Kimstach (1996), stated that water quality can be described through a range of quantitative and qualitative measurements such as physico-chemical and biological tests, species inventories and biotic indices. Among marine organisms, marine algae are rich sources of structurally diverse bioactive compounds with various biological activities (Al Hafedh *et al*., 2014). Algae are widespread everywhere on earth where there is light to carry out photosynthesis and have the potential to produce a number of valuable compounds like Polyunsaturated Fatty Acids (PUFAs), pigments and antioxidants for pharmaceuticals, biomedical and nutraceutical products. Microalgae form an essential component of the marine food chain and provide nourishment to many marine species and they also play an important role in regulating the amount of carbon in the atmosphere. The microalgae make up the baseline of many food webs in aquatic environment and globally an important primary producer. According to Falkowski and Raven (2007), phytoplankton are currently responsible for about 50% of global primary production while Meehl *et al*. (2007) stated that the climate change over the next century is expected to modify ocean ice cover, temperature, precipitation and circulation, altering the environmental conditions that influence phytoplankton standing stock and primary production (Sarmiento *et al*., 2004). According to Khatri (1987), the quality of the environment can be assessed based on the distribution pattern of the plankton.

Macrobenthic organisms play a vital role in the circulation and recirculation of nutrients in aquatic environments. They constitute a link between the unavailable nutrients in detritus and useful protein materials in fish. Most benthic organisms feed over a wide range of fishes and are used for the classification of biological status of the water bodies. In Africa and particularly in Nigeria, there is a gradual buildup of literatures in macro-invertebrate studies and their use as bioindicators in recent times (Ikomi *et al*., 2005; Arimoro and Osakwe, 2006; Arimoro *et al*., 2007a and b; Edokpayi *et al*., 2000; Ogbeibu and Orhibhabor 2002; Edema *et al*., 2002). In this report, the plankton and macro benthic invertebrates' community and species in coastal waters of Porto-Novo creek and Gulf of Guinea were investigated. Observation of species composition and abundance provide insight into the trophic status of these water bodies.

MATERIALS AND METHODS

Description of sampling stations

Porto - Novo Creek

The creek is colonized by a recognizable riparian mangrove swamp community which takes account of the mangrove roots, mudflats and mud banks. The mangroves swamp promotes the deposition of silt by reducing the rate of water with their prop root system and the mangrove species are dominated by few genera of *Rhizophora racemosa* (Red mangrove), *Rhizophora harrisonni*, *Avicennia germinans*, *Phoenix reclinata*, *Raphia hookeri*, *Acrosticum aureum*, *Paspalum orbiculare*, and *Dryopteris*. The riparian vegetation is also dominated by *Cocos nucifera* trees. Three sampling stations (Fig. 1) were chosen for Porto-Novo creek to reflect differences in biological characteristics which exist in the same body of water using Global Positioning System. Station 1 with coordinates N06^{o}25.172′, E002^{o}51.534′while station 2, N06^{o}26.070′, E002^{o}50.888′is a confluence and 3 N06^{o}24.436′, E002^{o}53.842′respectively is farther down.The opening of the creek to Festac creek at Ibafon and Lagos harbour gives Porto-Novo creek its characteristics features.

Gulf of Guinea

Twelve sampling stations (Fig. 1) were chosen for Gulf of Guinea using Global Positioning System (Table 1).

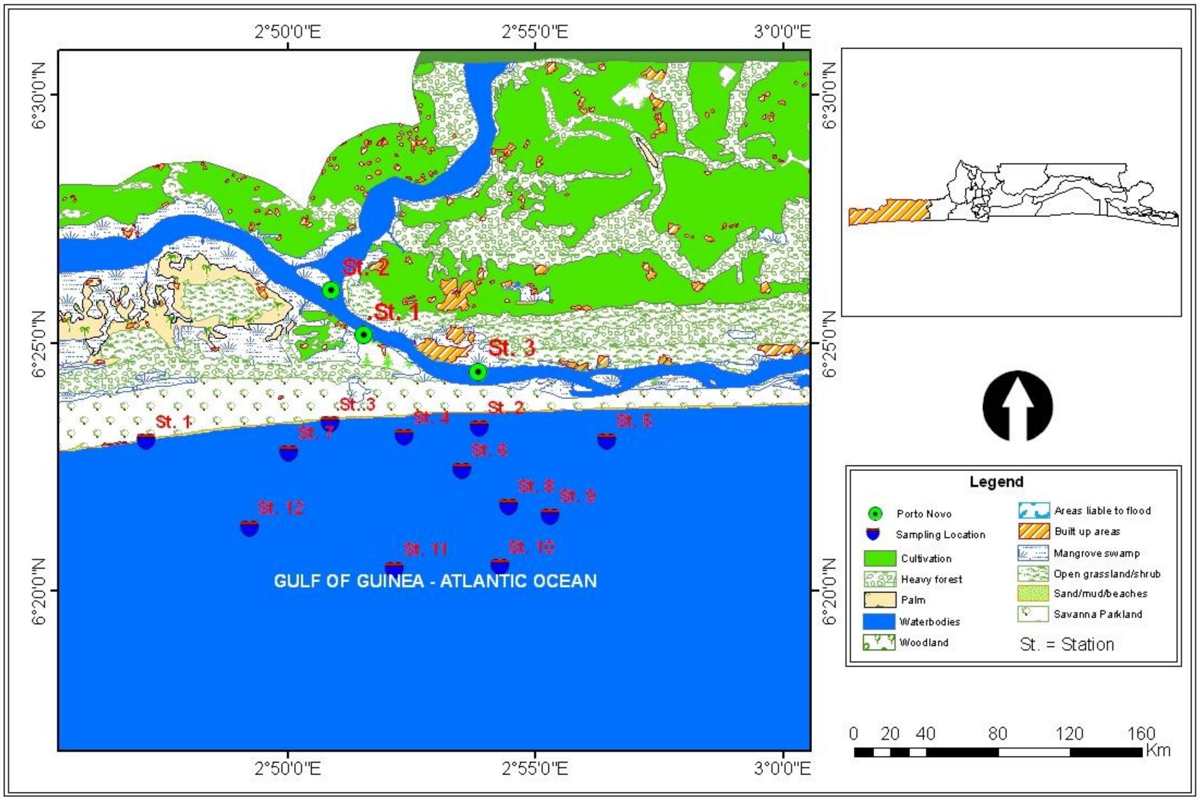

Fig. 1: Different sampling stations at the Porto-Novo and Gulf of Guinea

Table 1: Sampling Coordinates for Gulf of Guinea

S/N	Location	Latitude (N)	Longitude (E)
1	Station 1	06º23'0.9''	002º47'8.6''
2	Station 2	06º23'17.5''	002º53'51.7''
3	Station 3	06º23'22.3''	002º50'51.9''
4	Station 4	06º23'6.5''	002º52'21.5''
5	Station 5	06º23'1.7''	002º56'26.8''
6	Station 6	06º22'25.8''	002º53'31.1''
7	Station 7	06º22'47.2''	002º50'1.6''
8	Station 8	06º21'42.4''	002º54'28.3''
9	Station 9	06º21'30.8''	002º55'17.9''
10	Station 10	06º20'29.4''	002º54'17.3''
11	Station 11	06º20'25.9''	002º52'9.1''
12	Station 12	06º21'16.2''	002º 49'13.4''

Collection and analysis of samples
For water chemistry, surface water samples were collected into a well labeled dark bottle for dissolved oxygen analyses while *in-situ* analysis of surface water samples were done for Temperature, Conductivity, pH, Salinity, Total dissolved solids and transparency using handheld thermometer, conductivity and pH meter, refractometer and Secchi disc respectively.

Plankton
For plankton, surfacewater samples were collected directly into already labelled 500ml plastic using water sampler (this method was used in order to have record of all plankton including nanoplankton that may be present in this water body), also plankton net (55µm) was tied to Ship and hauled for 10mins at low speed for Gulf of Guinea samples while engine boat was used atPorto-Novo. Samples collected were fixed with 4% unbuffered formalin. Samples were then taken into the laboratory where it was allowed to settle for 24h and then decanted to a known volume in appropriately labelled plastic container. Taxonomic keys employed in identification of plankton taxa include Hustedt (1930–1937); Whitford and Schumacher (1973);Krammer and Large-Bertalot (1986); Olaniyan (1968, 1969, 1975); Wiafe and Frid (2001).

Macro-benthos
Macro-benthos were extracted by sieving from sediment samples collected by lowering a Van Veen Grab at each sampling point for bottom sediment collection. Grab samples were initially washed on deck through sieves of 0.5mm mesh and the retained materials were preserved in formalin (4 %) for further sorting in the laboratory. The identification of the species was according to taxonomic keys provided in Oyenekan (1975); Edmunds (1978); Schneider (1990); Yankson and Kendall (2001).

Community structure analysis
To obtain the estimate of species diversity, three community structure indices were used: Margalef’s diversity index (d), Shannon-Weaner Index (H^1) (Shannon and Weaver 1963) and Species Equitability (j) or Evenness (Pielou 1975).

RESULTS

Physico-chemical analysis results
Results for the surface water physico-chemical parameters at Porto-Novo were presented in Table 2 while Table 3 shows the results for Gulf of Guinea. The pH of the water bodies was essentially neutral while the salinity concentration confirmed the brackish and marine nature of the two water bodies.

Table 2: Physical parameters values at the Porto-Novo creek

Parameter	Station 1	Station 2	Station 3
Surface water temperature (^oC)	32	31.9	31.7
Transparency (m)	0.78	0.39	0.39
Total Dissolved Solids (Mg/L)	0	0.02	0.04
pH	9.4	9	8.6
Salinity (‰)	16	16.7	15.8
Dissolved Oxygen	3.5	4.1	3.9

Table 3: Physical parameters values at the Badagry Off-Shore parts of Gulf of Guinea

	Station											
Parameter	1	2	3	4	5	6	7	8	9	10	11	12
Surface water temperature (ºC)	36.9	36.6	36.6	34.5	35.5	35.7	37.6	37.3	37.5	37.5	37.4	37.4
Transparency (m)	2.00	1.20	1.36	1.50	1.65	1.60	1.62	2.10	2.20	2.80	2.95	2.68
Total dissolved solids (mg/L)	106.0	112.0	154.0	135.0	167.0	175.0	112.0	109.0	187.0	174.0	154.0	101.0
Ph	7.56	7.67	7.64	7.69	7.5	7.55	7.58	7.61	7.66	7.68	7.7	7.69
Salinity (‰)	35	40	40	40	37	38	37	38	40	39	40	39
Dissolved oxygen (mg/L)	4.0	4.5	4.0	5.0	5.0	5.2	5.1	4.3	4.5	5.0	5.0	5.2

Phytoplankton in Porto-Novo

Total phytoplankton abundance and species composition for Porto-Novo is presented in Table 4. Four divisions; Bacillariophyta, Chlorophyta, Cyanophyta and Euglenophyta were represented (Fig. 2). Out of the 67 algal taxa identified, 51 were diatoms species belonging to 24 genera with *Synedra* sp. as the frequent taxon dominating the phytoplakton spectrum**.**Green algaerecorded 13 taxa belonging to 7 genera while blue green and euglenophytes were represented by 1 and 2 taxa belonging toone genus each of*Oscillatoria* and *Trachelomonas* respectively (Table 4).Highest Margalef value (4.60) was recorded at Station 3 while 0.93 (highest value) was recorded at Station1 for species evenness (Table 4).

Phytoplankton in Gulf of Guinea

Total phytoplankton abundance and species composition is presented in Table 5. Four divisions; Bacillariophyta, Chlorophyta, Pyrrhophyta and Euglenophyta were observed (Fig. 3). Out of the 47 algal taxa identified, 32 were diatoms species belonging to 20 genera.Green algae recorded five taxa belonging to five genera while dinoflagellates and euglenophytes were represented by seven and three taxa belonging to four and two genera respectively (Table 5).Higher cells/ml of Euglenophytes were recorded at Station 1 which is not too far from the settlement which could probably due to organic wastes from the houses around this station. Highest species evenness value (0.98) recorded at Station 2 was dominated by species of *Ceratium*, *Gonyaulax*, *Gymnodinium* and *Peridinium* (dinoflagellates) while the lowest value (0.35) observed at Station 1 was dominated by species of the Euglenophytes (*Euglena* and *Phacus*). Highest values (3.02, 2.33) of Margalef and Shannon-Weaner indices were recorded at Stations 4 and 5 respectively while lowest values (0.71, 0.63) were recorded at Stations 10 and 1 respectively (Fig. 4).

Table 4: Phytoplankton composition and abundance (per/ml) in Porto Novo

	Phytoplankton	Station		
		1	2	3
	Division: Bacillariophyta			
	Class I: Bacillariophyceae			
	Order I: Aulacoseirales			
	Family : Aulacoseiraceae			
1	*Aulacoseira granulata* var. *angustissima* f. *spiralis* (Hust) czar. Et Reinke	5	_	_
2	*Aulacoseira* sp.	5	_	5
	Order II : Thalassionematales			
	Family:Thalassionemataceae			
3	*Thalassiothrix nitzschioides* (Grunow) Van Heurch	5	_	_
4	*Thallassiothrix* sp.	_	7	_
	Order III :Cocconeidales			
	Family :Cocconeidaceae			
5	*Cocconeis disculus* (Schum.) Cleve	_	_	20
6	*Cocconeis* sp.	_	15	_
	Order IV :Stephanodiscales			
	Family: Stephanodiscaceae			
7	*Cyclotella* sp.	_	3	_
	Order V: Bacillariales			
	Family: Bacillariaceae			
8	*Bacillaria paxillifer* (O.F. Muller) Hendey	_	45	_
9	*Nitzschia acicularis* W. Smith	_	_	10
10	*N. fonticola* Grun.	_	_	10
11	*N. ignorata* Krasske	_	1	_
12	*N. obtusa* W.Sm	_	2	_
13	*N. sigma* (Kutzing) W. Smith	_	_	10
14	*Nitzschia* sp.	3	69	5
	Order VI: Fragilariales			
	Family:Fragilariaceae			
15	*Fragilaria crotonensis* Kitton	_	75	27
16	*Fragilaria* sp.	_	16	_
17	*Synedra nana* Meister	_	_	8
18	*Synedra* sp.	3	75	80
19	*Ulnaria ulna* (Nitzsch) Ehrenberg	_	73	_
	Order VII : Naviculales			
	Family I : Naviculaceae			

Table 4 Cont'd

20	*Diploneis domblittensis* (Grunow) Cleve	_	1	_
21	*Navicula exigua* (Greg.) O.Muller	_	1	_
22	*Navicula* sp.	_	12	5
23	*Pinnularia acrosphaeria* Brebisson	_	4	_
24	*P. maior* (Kutzing) Rabenhorst	_	1	_
25	*P.interrupta* W.Smith	_	3	_
26	*Pinnularia* sp.	_	_	15
27	*Pleurosigma* sp.	_	_	5
	Family II: Eunotiaceae			
28	*Eunotia sudetica* (O.Muller) Hustedt	_	5	_
29	*Eunotia* sp.	_	5	_
	Family III: Catenulaceae			
30	*Amphora aequalis* Krammer	_	3	_
31	*A. normannii* Rabenhorst	_	1	_
	Family IV: Gomphonemataceae			
32	*Gomphonema. amoenum* Lange-Bertalot	_	91	_
33	*G. angustum* Agardh	_	78	_
34	*G. clavatum* Ehrenberg	_	68	5
35	*G. curtum* Gurtelansicht	_	_	20
36	*G. grovei* M. Schmidt	_	_	5
37	*G. subclavatum* Grunow	_	1	_
38	*Gomphonema* sp.	_	_	10
39	*Gyrosigma obtusatum* (Sulliv.) Boyer	_	21	_
40	*G. wansbeckii*(Donkin) Cleve	_	10	_
	Family V: Neidiaceae			
41	*Neidium* sp.	_	_	10
	Order VIII: Cymbellales			
	Family : Cymbellaceae			
42	*Cymbella silesiaca* Bleisch	_	4	_
43	*Cymbella* sp.	_	_	10
	Order IX: Mastogloiales			
	Family: Mastogloiaceae			
44	*Mastogloia* sp.	_	2	_
	Order X : Tabellariales			
	Family :Tabellariaceae			
45	*Tabellaria fenestrata* (Lyng.) Kutzing	_	53	5
46	*Tabellaria* sp.	_	_	40
	Order XI:Melosirales			
	Family :Melosiraceae			
47	*Melosira granulata* (Ehr.) Ralfs	6	_	4

Table 4 Cont'd

48	*Melosira moniliformis* (O. F. Muller) C. Agardh	_	_	5
49	*Melosira* sp.	15	13	15
	Order XII:Chaetocerotales			
	Family:Chaetocerotaceae			
50	*Terpsinoe americana* (Bail.) Ralfs	_	3	_
	Order XIII:Surirellales			
	Family: Surirellaceae			
51	*Surirella* sp.	_	_	5
	Division: Chlorophyta			
	Class I: Chlorophyceae			
	Order I: Desmidiales			
	Family I: Closteriaceae			
52	*Closterium lunula* Nitzsch	_	1	_
53	*C. moniliferum* Ehrenb.	_	4	_
54	*C. peracerosum* Gay	_	42	_
55	*C. peracerosum* var. *elegans* G. S. West	_	_	10
56	*C. setaceum*Ehrenb.	_	_	3
57	*Closterium* sp.	_	3	_
	Family II: Desmidiaceae			
58	*Cosmarium* sp.	_	_	5
59	*Euastrum bidentatum*Nageli	_	1	_
60	*Euastrum* sp.	_	1	_
	Family III: Microsporaceae			
61	*Microspora* sp.	_	6	_
	Order II: Oedogoniales			
	Family: Oedogoniaceae			
62	*Oedogonium* sp.	_	3	_
	Class II: Trebouxiophyceae			
	Order: Chlorellales			
	Family: Chlorellaceae			
63	*Apatococcus lobatus* (Chodat) B. Petersen	_	_	3
	Class III: Zygnematophyceae			
	Order: Zygnematales			
	Family: Zygnemataceae			
64	*Mougeotia* sp.	_	39	_
	Division: Cyanophyta			
	Class: Cyanophyceae			
	Order I: Oscillatoriales			
	Family I: Oscillatoriaceae			

Table 4 Cont'd

65	*Oscillatoria limosa.*	5	6	_
	Division: Euglenophyta			
	Class: Euglenophyceae			
	Order: Euglenales			
	Family: Euglenaceae			
66	*Trachelomonas hispida*	_	1	_
67	*Trachelomonas* sp.	3	_	_
	Total number of species (S)	9	43	28
	Total number of individuals (N)	50	868	355
	Margalef Index (d)	2.04	6.21	4.60
	Shannon-Weiner (H^1)	2.04	2.97	2.89
	Species evenness (j)	0.93	0.79	0.87

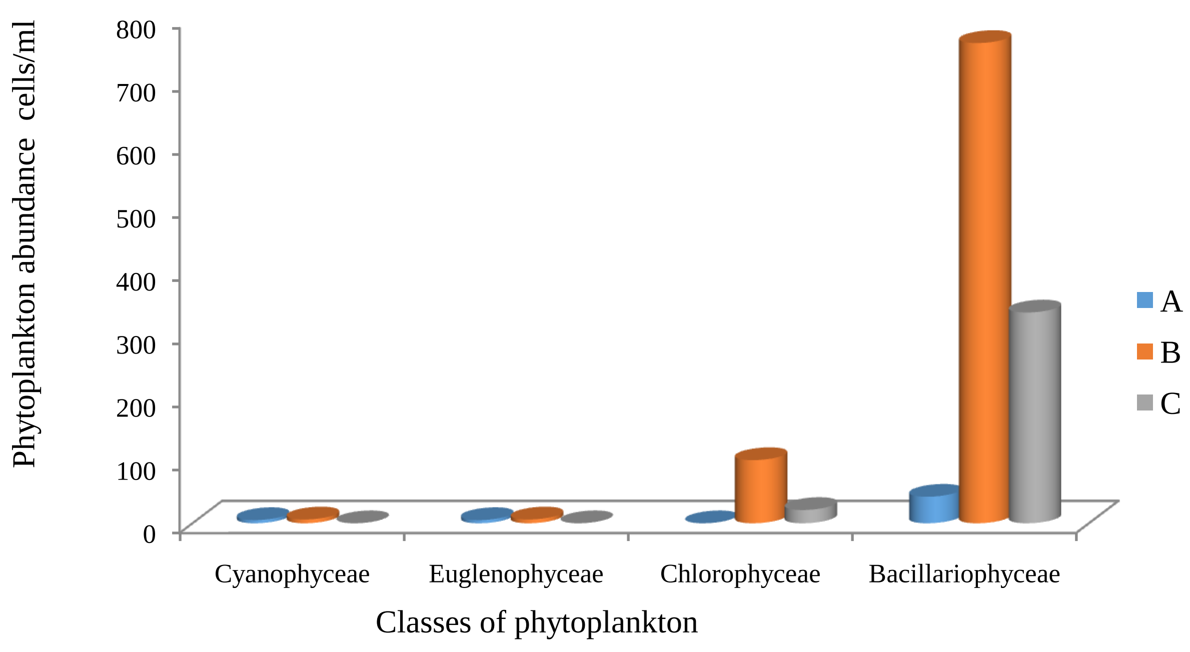

Fig. 2: Relationship between different classes of phytoplankton at Porto-Novo creek

Table 5: Phytoplankton composition and abundance at Badagry Off-Shore parts of Gulf of Guinea

		Station											
	Phytoplankton	1	2	3	4	5	6	7	8	9	10	11	12
	Division: Bacillariophyta												
	Class I: Bacillariophyceae												
	Order I: Aulacoseirales												
	Family : Aulacoseiraceae												
1	*Aulacoseira* sp.	_	_	_	_	3	_	5	_	_	_	3	_
	Order II:Bacillariales												
	Family :Bacillariaaceae												
2	*Nitzschia acicularis*W. Smith	_	_	_	_	_	2	_	_	_	3	_	_
3	*Nitzschia* sp.	_	_	_	2	_	_	_	_	_	_	_	_
	Order III:Biddulphiales												
	Family :Biddulphiaaceae												
4	*Biddulphia aurita* (Lyngbye) Brebisson	_	_	_	2	_	_	_	_	_	_	_	_
5	*Biddulphia* sp.	_	_	_	_	_	_	_	2	_	_	_	_
	Order IV:Chaetocerotales												
	Family:Chaetocerotaceae												
6	*Chaetoceros coaractatus* Lauder	_	_	2	_	_	_	_	_	_	_	_	_
7	*C. decipiens* Cleve	_	_	5	_	_	_	_	_	_	_	_	_
8	*Hemiaulus hauckii* Grunow from Hustedt	_	_	_	1	_	2	_	2	_	_	_	10
9	*Terpsinoe americana* (Bail.) Ralfs	2	_	_	_	_	_	_	_	_	_	_	_
	Order V:Cocconeidales												
	Family:Cocconeidaceae												
10	*Cocconeis scutelum*Ehr.	_	_	2	_	_	_	_	_	_	_	_	_
11	*Cocconeis* sp.	_	_	_	_	5	_	_	_	_	_	_	_
	Order VI: Fragilariales												
	Family:Fragilariaceae												
12	*Fragilaria crotonensis* Kitton	_	_	_	2	_	3	_	_	_	_	_	_
13	*Synedra* sp.	2	_	_	_	_	1	_	_	_	_	_	_
	Order VII: Naviculales												
	Family: Naviculaceae												
14	*Diploneis interrupta* (Kutzing) Cleve	_	_	_	_	_	_	_	_	1	_	_	_
15	*Navicula radiosa* Kutz	1	_	_	_	_	_	_	_	_	_	_	_

16	*Pinnularia macilenta*(Ehr.) Ehrenberg	_	_	_	_	3	_	_	_	_	_	_	_
17	*Pinnularia* sp.	_	7	_	_	_	_	_	_	_	_	_	_
18	*Pleurosigma angulatum* (Quekett) W. Smith	_	_	_	_	6	_	_	_	_	_	_	_
19	*P. salinarum* Reimer	_	_	_	2	_	_	_	_	_	_	_	_
	Order VIII: Tabellariales												
	Family:Tabellariaceae												
20	*Tabellaria fenestrata* (Lyng) Kutzing	_	_	_	_	_	_	_	_	_	4	_	_
21	*T. flocculosa* (Roth.) Kut.	_	_	_	_	_	_	_	2	_	_	_	_
	Order IX : Thalassionematales												
	Family:Thalassionemataceae												
22	*Thalassiothrix frauenfeldii* Grunow	_	_	3	_	8	_	_	_	_	_	_	_
23	*T. nitzschioides* (Grunow) Van Heurch	_	_	_	_	_	_	_	_	_	_	5	_
	Class II: Coscinodiscophyceae												
	Order I:Coscinodiscales												
	Family:Coscinodiscaceae												
24	*Coscinodiscus centralis* Ehrenberg	_	_	3	3	7	_	3	_	1	2	_	_
25	*C. jonesianus* Greville Ostenf	_	_	_	_	5	_	5	_	_	_	_	_
26	*C. oculus iridis* Ehr.Hustedt	_	_	_	_	_	_	_	_	_	_	_	_
27	*Coscinodiscus* sp	_	_	_	_	5	_	6	_	_	_	_	5
28	*Hyalodiscus* sp	_	_	2	_	_	_	_	_	_	_	_	_
29	*Rhizosolenia* sp	_	_	2	9	_	_	_	_	6	3	_	_
30	*Stephanopyxis palmeriana* (Greville) Grunow	_	_	9	_	_	_	_	_	_	_	_	_
	Order II:Melosirales												
	Family:Melosiraceae												
31	*Melosira granulata* (Ehr.) Ralfs	_	_	_	_	_	2	_	_	_	_	_	_
32	*Melosira* sp	_	_	_	_	8	_	_	1	_	_	_	_
	Division: Pyrrhophyta												
	Class: Dinophyceae												
	Order: Gonyaulacales												
	Family: Ceratiaceae												
33	*Ceratium furca* (Ehr.) Clap et Lachum	_	_	_	_	_	2	_	_	_	_	_	_
34	*C. hirundinella* (OFM) Schrank	_	13	_	_	5	_	_	_	_	_	_	_
35	*C. massilense* Gourret	_	13	_	_	_	_	_	_	1	_	_	_
36	*C. tripos* (O. F. Muller) Nitzsch	_	_	3	2	_	_	_	_	_	_	3	_
37	*Gonyaulax spinifera* (Clap and Lachm)	_	10	_	_	2	_	_	_	_	_	_	_
38	*Gymnodinium* sp.	_	9	_	2	_	1	_	_	_	_	_	2
39	*Peridinium* sp	2	_	_	2	_	_	_	_	_	_	_	_

	Division: Chlorophyta												
	Class I : Chlorophyceae												
	Order: Chlamydomonadales												
	Family: Cylindrocapsaceae												
40	*Cylindrocapsa conferta* W.West	_	_	_	_	_	4	_	_	_	_	_	_
	Class II: Trebouxiophyceae												
	Order: Chlorellales												
	Family: Chlorellaceae												
41	*Gloeotila* sp	_	_	_	9	_	4	_	4	_	11	_	_
	Class III: Zygnematophyceae												
	Order: Desmidiales												
	Family: Closteriaceae												
42	*Closterium kutzingii* Breb.	-	_	_	_	_	_	_	_	_	1		
	Family: Desmidiaceae												
43	*Hyalotheca* sp	_	_	_	_	_	15	_	_	_	_	_	_
44	*Pleurotaenium ovatum* Nordst.	_	_	_	2	_	_	_	_	_	1	_	_
	Division: Euglenophyta												
	Class: Euglenophyceae												
	Order: Euglenales												
	Family: Euglenaceae												
45	*Euglena* sp	60	_	15	_	_	10	_	_	_	_	_	_
46	*Phacus viridis* Ehr.	3	_	_	_	_	_	_	_	_	_	_	_
47	*Phacus* sp	_	_	2	_	_	1	_	2	_	2	_	_
	Total number of species (S)	6	5	11	12	11	12	4	6	4	8	3	3
	Total number of individuals (N)	70	52	48	38	57	47	19	13	9	27	11	17
	Margalef index (d)	1.18	1.01	2.58	3.02	2.47	2.86	1.02	1.95	1.37	2.12	0.83	0.71
	Shannon-Weiner (H^1)	0.63	1.58	2.10	2.22	2.33	2.07	1.36	1.71	1.00	1.77	1.07	0.92
	Species evenness (j)	0.35	0.98	0.88	0.89	0.97	0.83	0.98	0.95	0.72	0.85	0.97	0.84

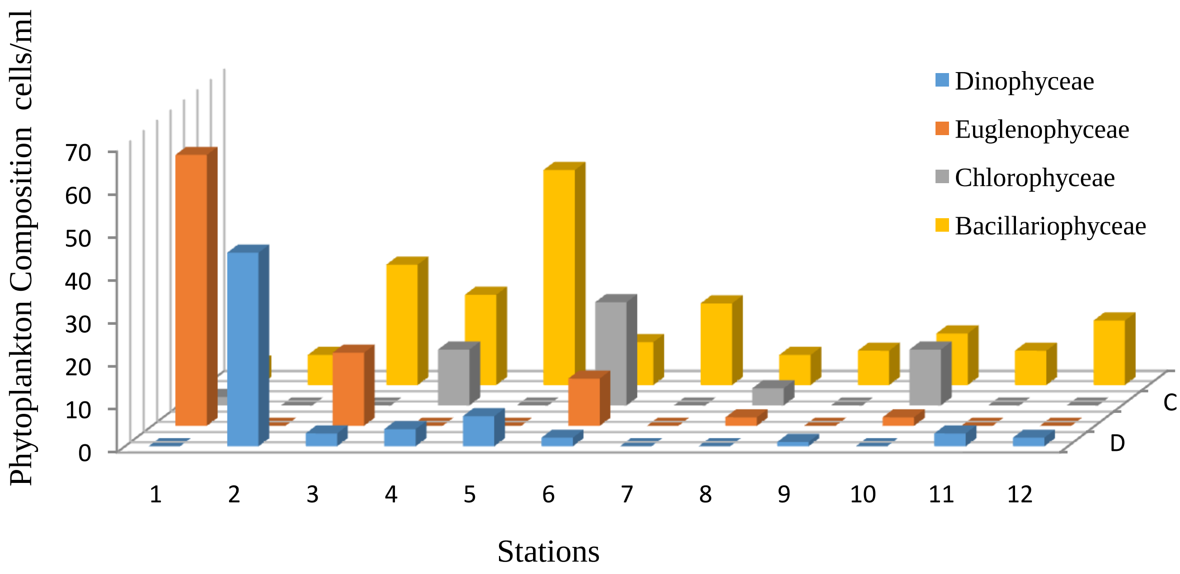

Fig. 3: Relationship between different classes of phytoplankton at Badagry off-shore (Gulf of Guinea**)**

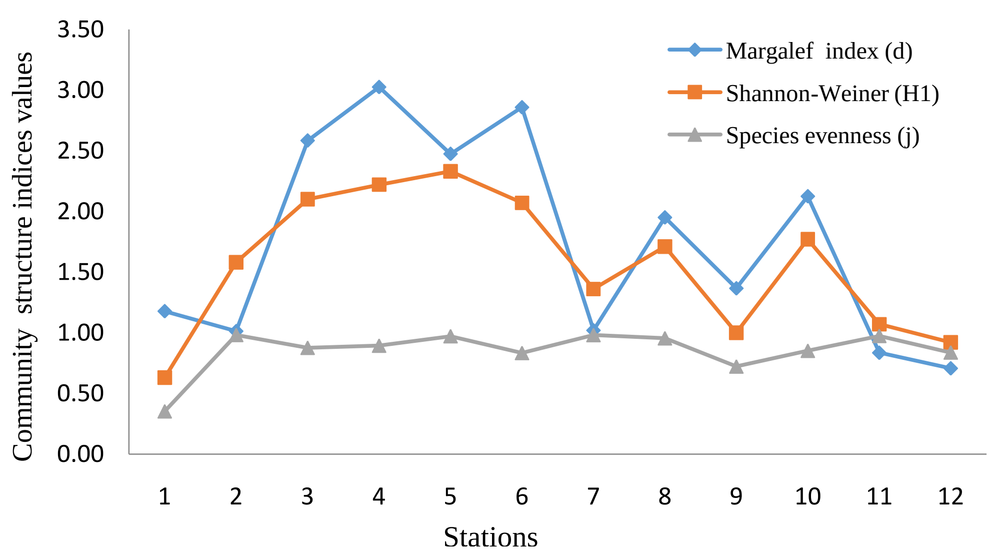

Fig. 4 : Phytoplankton Community structure analysis at Gulf of Guinea)

Zooplankton in Porto-Novo

The zooplankton composition is represented by two ordersCalanoida and Cladocera from only one major group, arthropoda. (Table 6).The order, calalnoida accounted for 74.28% with *Acartia clausii* being the dominant species; cladocera recorded 5.07% and ably represented by *Penilla avirostris* while the juvenile stages of some zooplankton recorded 20.65%. Percentage composition of different zooplankton classes and variations in diversity indices are represented in Fig. 5 and 6.Generally, the species diversity was low and the low species richness and diversity observed in the study site could be a pointer to the status of the environment. Community structure analysis results show an evenly distributed organism at station 2 (Table 6).

Table 6: Species composition of zooplankton (cells per ml) at Porto- Novo creek

	Stations		
	1	2	3
Phyllum: Arthropoda			
Class: Crustacean			
Sub-class 1: Copepoda			
Order: Calanoida			
Family:Paracalanidae			
Acartia clausii Geisbrecht	680	600	480
A. discaudata Geisbrecht		250	
Eucalanus attenuatus Dana	40		
Sub-class 2: Branchiopoda			
Order: Cladocera			
Penilla avirostris Dana	80	10	50
Juvenile stages			
Zoea larva	40	120	280
Megalop larva			40
Copepod Nauplii larva		50	40
Total number of species (s)	4	5	5
Total number of individual (N)	840	1030	890
Margalef Species Diversity (d)	0.45	0.58	0.59
Shannon-Weaver (H^1)	0.21	0.54	0.62
Species Evenness (j)	0.15	0.34	0.38

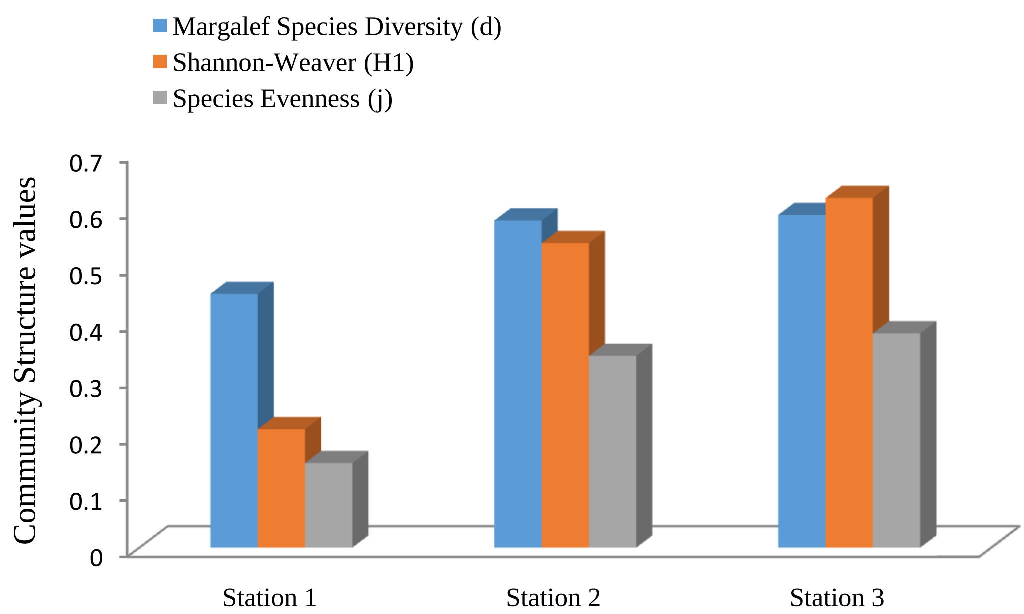

Fig. 5: Relationships between community structure analysis at Porto-Novo

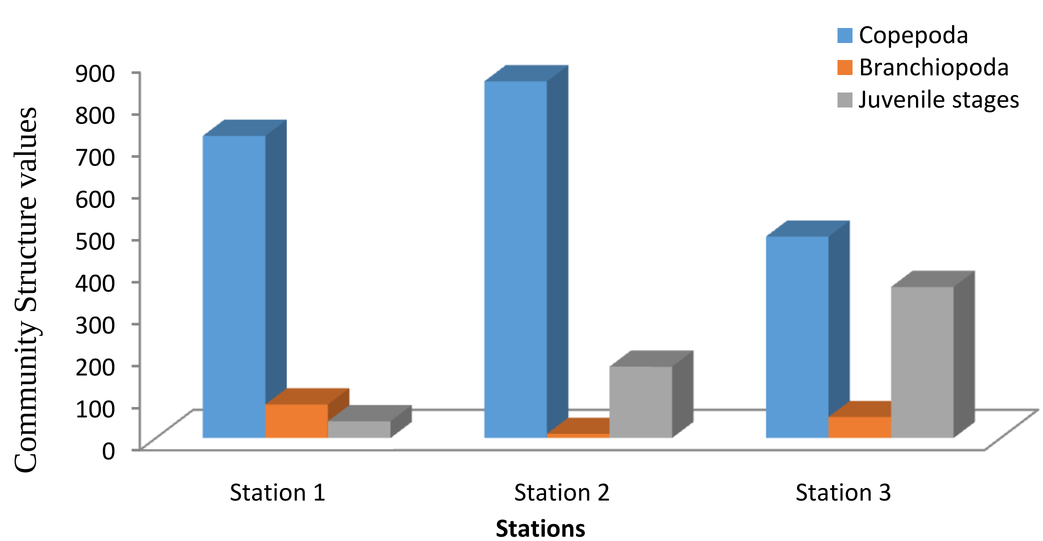

Fig. 6: Relationships between zooplankton subclasses and juvenile stages at Porto-Novo

Zooplankton in Gulf of Guinea

The values for zooplankton was high values as presented in Table 7 and community structure analysis resultsarepresented in Fig. 7. More zooplankton were recorded as compared to Porto-Novo creek. Comparison between zooplankton and phytoplankton is presented in Fig. 8. The abundance of phytoplankton probably support the array of zooplankton identified, since phytoplankton are the primary producers that zooplankton feed on (food chain).

Macro benthic invertebrates

Faunal composition, abundance and distribution at Porto-Novo creek

The macro benthic invertebrates were represented by 9 taxa, belonging to 3 groups (Table 8). The dominant group was the Bivalvia accounting for 73.6% while the Gastropoda and Crustacea groups accounted for 24.50% and 1.90% of the total individuals respectively (106 individuals/m^2) (Fig. 9). The dominant taxon was *Mactra glabrata* accounting for 20.8% of the total individuals recorded, *Turritella annulata* was least represented with 0.9% of the total individuals recorded (Fig. 10). The Shannon-Wiener Index (Hs)was highest at station A (0.79) and lowest at station B (0.70). Margalef Index (d) was highest at station A (1.64) and lowest at station C (1.42) while the Equitability Index (j) was highest at station C (0.96) and lowest at station B (0.90) (Table 8).

Table 7: The zooplankton composition and abundance at different stations at Gulf of Guinea

	Stations											
Zooolankton	1	2	3	4	5	6	7	8	9	10	11	12
Phyllum: Arthropoda												
Class: Crustacean												
Sub-class : Copepoda												
Order I: Calanoida												
Acartia tonsa Dana	_	_	_	_	_	_	_	_	_	_	4	_
Acartia sp.	_	3	_	_	5	_	10	_	_	_	3	3
Aetideopsis sp.	_	_	_	_	_	_	_	_	_	_	3	_
Aetideus sp.	_	_	_	_	_	_	_	_	_	_	3	_
Balanus nauplii	_	_	_	_	_	_	_	_	_	_	_	_
Calanus sp.	_	_	_	_	_	_	5	_	_	_	_	3
Centropages sp.	_	_	_	_	_	_	4	_	_	_	2	_
Cirripedia	_	_	_	_	_	_	_	_	_	_	_	5
Colobonema sp.	_	_	_	_	_	_	_	_	1	_	_	_
Conchopsis navicula Haeckel	_	_	_	_	_	_	2	_	_	_	_	_
Corycaeus sp.	_	_	_	_	_	_	_	_	2	_	_	_
Eucalanus bungi Giesbrecht	_	_	_	_	_	_	5	_	_	_	_	_
Eucalanus sp.	_	3	_	_	_	_	_	_	_	_	_	_
Euchaeta sp.	_	_	_	_	2	_	10	_	_	_	_	_
Hippopodius sp.	_	_	_	4	_	_	_	_	_	_	_	_
Jelly fish	_	3	_	_	_	_	2	_	_	_	_	_

Lucifer sp.	_	_	_	_	5	_	4	_	_	_	6	10
Microstella sp.	_	2	_	_	_	_	_	_	_	_	_	_
Muggiaea atlantica Cunningham	_	3	_		54	_	5	_	_	_	_	_
Mysis	_	_	_			_	_	_	_	_	2	1
Oithona nana	_	11	4	_	/	_	6	_	_	_	_	_
Paracalanus sp.	6	35	_	_	_	_	6	_	_	_	_	3
Parafavella sp.	_		2	_		_		_	_	_		
Penaeidea	_	_	_	_	_	3	_	_	_	2	_	4
Penilia sp.	_	_	_	3	_	_	_	_	_	_	5	6
Phractopelta sp.	_	_	_	_	_	2	_	_	_	_	_	_
Rhabdonella lohmanni	_	_	_	_	2	_	_	_	_	_	_	_
Scolecithricella minor (Brady)	_	2	_	_	_	_	_	_	_	_	_	_
Unidentified sp.	_	_	_	_	_	_	_	3	20	35	_	_
Temora sp.	_	8	_	_	_	_	8	_	_	_	10	_
Phyllum: Chodata												
Class: Larvacea												
Oikopleura sp.	_	_	_	_	_	_	2	_	_	_	_	_
Juvenile stages												
Zoea larvae	_	2	_	_	3	_	_	_	_	_	_	_
Nauplii larvae	1	2	_	2	_	_	_	_	_	3	2	3
Fish egg	_	20	_	_	_	_	3	_	_	_	_	_
Copepod nauplii	_	_	_	_	_	_	_	_	_	_	_	2
Cypris larvae	_	_	_	_	2	_	2	_	_	_	_	_
Primitive pluteus-type larva	_	_	_	5	_	_	_	5	_	_	_	_
Total number of species	2	12	2	4	7	2	15	2	3	3	10	10
Total number of individuals	7	94	6	14	26	5	74	8	23	40	40	40
Margalef index (d)	0.51	2.42	0.56	1.14	1.84	0.62	3.25	0.48	0.64	0.54	2.44	2.44
Shannon-Weiner (H^1)	0.41	1.93	0.63	1.33	1.83	0.67	2.57	0.66	0.47	0.46	2.15	2.14
Species evenness (j)	0.59	0.78	0.91	0.96	0.94	0.97	0.95	0.95	0.43	0.42	0.93	0.93

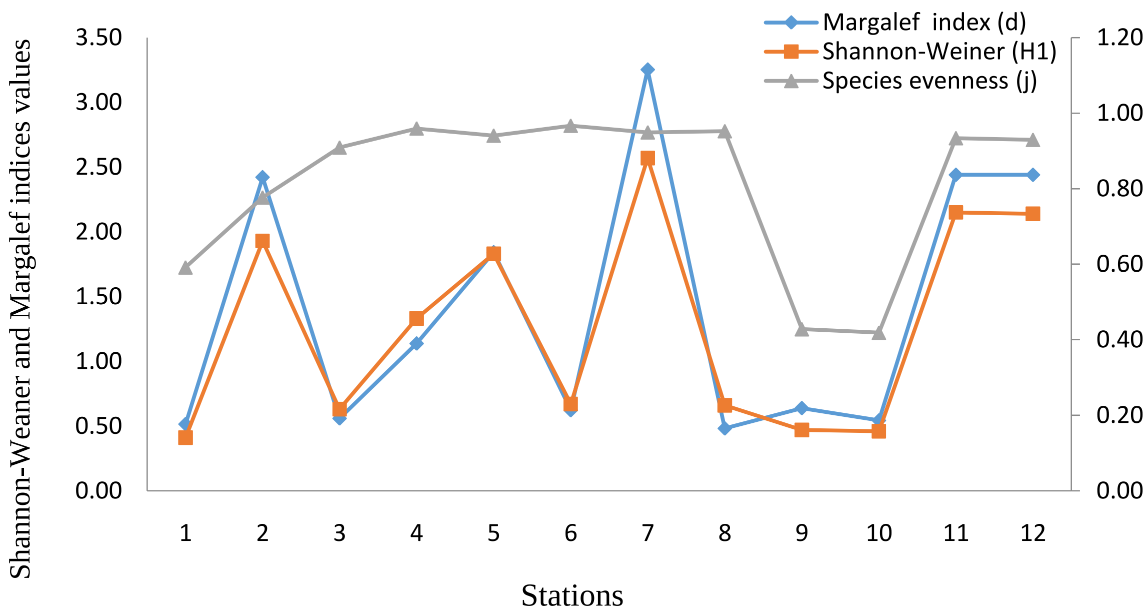

Fig. 7: Zooplankton Community structure analysis relationship at Gulf of Guinea stations

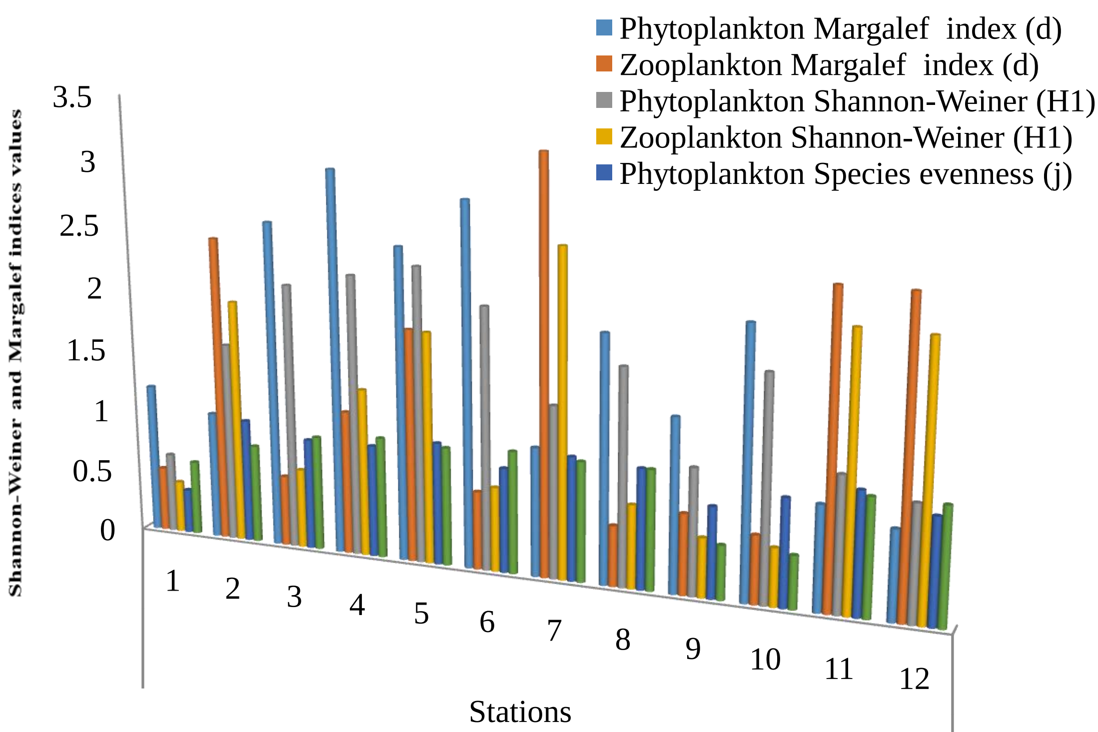

Fig. 8: Comparison between phytoplankton and zooplankton community structure analysis at Gulf of Guinea

Table 8: The distribution, occurrence and diversity indices of macro-benthic invertebrates community at Porto- Novo Creek (September 2012)

Macro-benthic invertebrate	Station A	Station B	Station C
BIVALVIA			
Perna perna	4	-	-
Mactra glabrata	9	7	6
Pitaria tumens	8	-	5
Macoma cumana	6	7	8
Tivela tripla	-	10	8
CRUSTACEA			
Tetraclita squamata	2	-	-
GASTROPODA			
Turritella annulata	-	1	-
Typanotonus fuscata	8	6	3
Pachymelania aurita	2	2	4
Total species diversity (S)	7	6	6
Total abundance (N)	39	33	34
Log of Species diversity (Log S)	0.85	0.78	0.78
Log of abundance (Log N)	1.59	1.52	1.53
Shannon-Wiener Index (Hs)	0.79	0.70	0.75
Margalef Index (d)	1.64	1.43	1.42
Equitability Index (j)	0.93	0.90	0.96

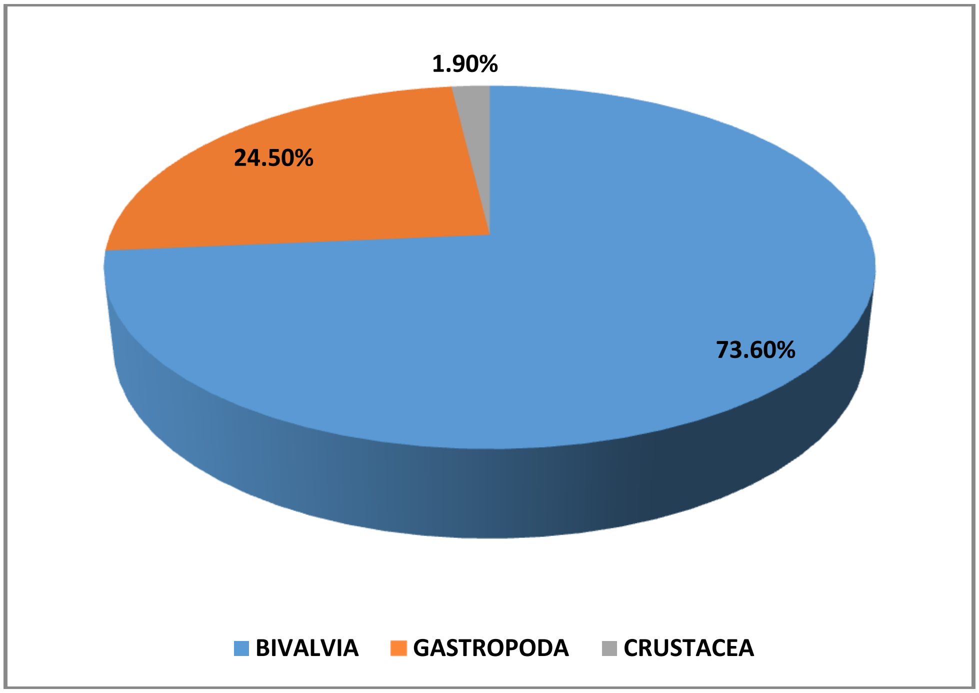

Fig. 9: The percentage contribution of the major Macro-benthic invertebrate groups at Porto-Novo Creek

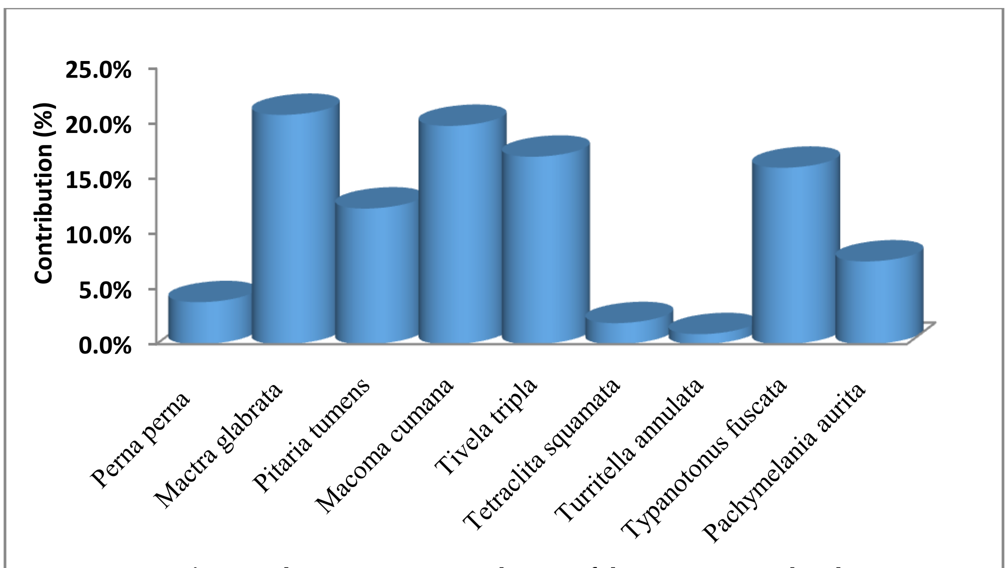

Fig. 10: The percentage contribution of the major Macro-benthic Invertebrate taxa at Porto-Novo Creek

Faunal composition, abundance and distribution at Gulf of Guinea

The spatial distribution, species composition and diversity of macro-benthic fauna of part of Gulf of Guinea were represented by 12 taxa, belonging to 3 groups (Table 9). The dominant group was the Bivalvia accounting for 95.6% while the Gastropoda and Polychaeta groups accounted for 2.9% and 1.5% of the total individuals respectively (136 individuals/m^2) (Fig.11). The dominant taxon was *Tivela tripla* accounting for 33.09% of the total individuals recorded while *Cardium costatum*, *Nereis lamellosa* and *Lumbrineris* spp. were least represented with 0.74% each of the total individuals recorded (Fig. 12). The Shannon-Wiener Index (Hs) was highest at Station 5 (0.65) and lowest at Station 12 (0.15). Margalef Index (d) was highest at Station 11 (1.44) and lowest at station 12 (0.00) while the Equitability Index (j) was highest at Stations 3 and 10 (0.99) and lowest at Station 12 (0.00).

DISCUSSION

The present observation that diatoms dominate the phytoplankton community confirms earlier reports made by Chindah and Pudo (1991) in Bonny River, Erondu and Chindah (1991) in the new Calabar River, Niger Delta, Adesalu (2008) in Lekki lagoon; Adesalu and Nwankwo (2005, 2008) in Olero and Abule eledu creek respectively, Adesalu *et al*. (2008, 2014) in Ogbe and Ipa-Itako creeks and Nwankwo (1986, 1991) in the Lagoons of South western Nigeria. Both phytoplankton and zooplankton communities have been successfully used in coastal water quality monitoring and as bioindicators of pollution (Webber *et al*., 2005). The abundance of phytoplankton over the zooplankton in this study support Ward and Montague(1996) who stated that zooplankton grazing not only reduces phytoplankton biomass, (through food chain) but removes other suspended particles from the water by concentration into much denser faecal pellets which then fall to the benthos.

The prevalence of pennate forms may be highlighting the shallow nature of Porto-Novo creek and the dominance of crustaceans and diatoms in the plankton was similar to observation made in coastal waters of South Western Nigeria (Nwankwo 1996, 1998; Akpata *et al*., 1993, Nwankwo *et al*., 2015). The preponderance of some algal species with environmental significance is noted, for instance, *Ulnaria ulna* formoderate organic pollution (Nwankwo 1996; Nwankwo*et al*., 1994, 2015) and *Oscillatoria limosa* (Nwankwo and Akinsoji 1989) was reported as opportunistic species found in moderately to heavy organically impacted environments. The abundance of dinoflagellates was in consonance with oceanic waters that are dominated by diatoms and dinoflagellates. According to Marques *et al*. (2003) knowledge of the structure of the benthic macro invertebrate community provides precise and local information on recent events, which can be seen in their structuring.

The use of invertebrates and fish as bioindicators of water quality has been advocated by several researchers (Victor and Ogbeibu, 1985; Ofojekwu *et al.*, 1996; Edokpayi and Osimen, 2001; Adakole and Annune, 2003). However, in Porto-Novo creek, the macro-benthic abundance and composition were relatively low and according to Chukwu and Nwankwo, (2003), any ecological imbalance arising from severe alterations of factors such as water quality, immediate substrates for occupation and food availability may affect the macro-benthos.

Table 9: The distribution, occurrence, and diversity indices of macro-benthic invertebrate community at the parts of Gulf of Guinea (September 2012)

	ST. 1	ST. 2	ST. 3	ST. 4	ST. 5	ST. 6	ST. 7	ST. 8	ST. 9	ST. 10	ST. 11	ST. 12
BIVALVIA												
Macoma cumana		6	3	5	6		7	4	4	4		2
Tivela tripla	5	5	4	3	4	3	5	3	7	6		
Codokia eburnea	1							2	1		2	
Donax acutangulus						2				4		
Cardium costatum											1	
Diplodonta diaphana	2					2				5	3	
Mactra glabrata		2										
Tellina nymphalis					4		2				2	
Pitaria tumens		4			3		2					
POLYCHAETA												
Nereis lamellosa		1										
Lumbrineris spp.				1								
GASTROPODA												
Mitra fusca				1	1		1		1			
Total species diversity (S)	3	5	2	4	5	3	5	3	4	4	4	1
Total abundance (N)	8	18	7	10	18	7	17	9	13	19	8	2
Log of Species diversity (Log S)	0.48	0.70	0.30	0.60	0.70	0.48	0.70	0.48	0.60	0.60	0.60	0.00
Log of abundance (Log N)	0.90	1.26	0.85	1.00	1.26	0.85	1.23	0.95	1.11	1.28	0.90	0.30
Shannon-Wiener Index (Hs)	0.39	0.63	0.30	0.51	0.65	0.47	0.61	0.46	0.47	0.60	0.57	0.15
Margalef Index (d)	0.96	1.38	0.51	1.30	1.38	1.03	1.41	0.91	1.17	1.02	1.44	0.00
Equitability Index (j)	0.81	0.91	0.99	0.85	0.93	0.98	0.87	0.96	0.79	0.99	0.96	0.00

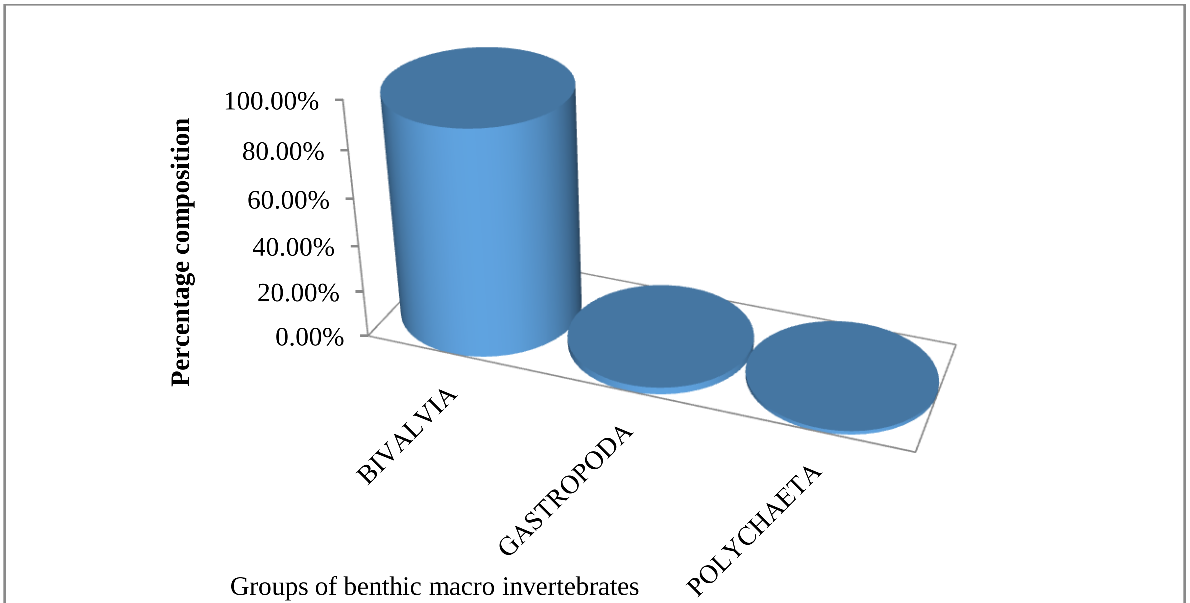

Fig.11: The percentage contribution of the major macrobenthic invertebrate groups at parts of Gulf of Guinea

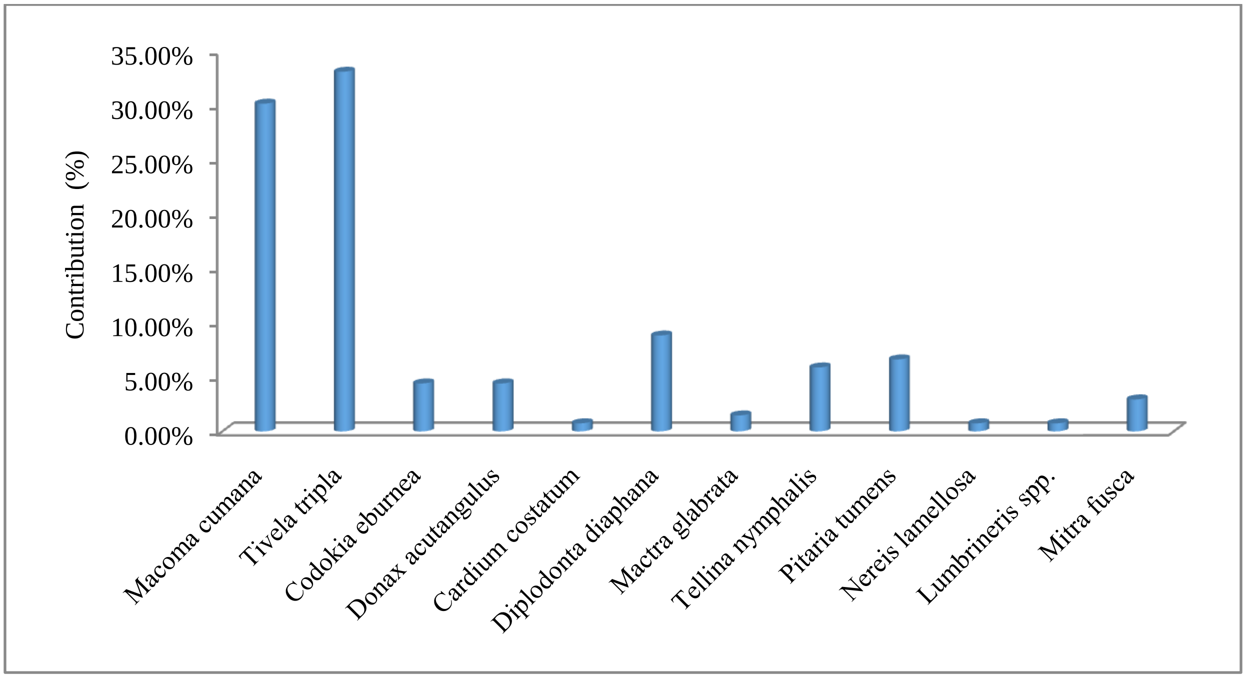

Fig. 12: The percentage contribution of the major macrobenthic invertebrate taxa in parts of the Gulf of Guinea.

Consequently, the low macro-benthic invertebrate community abundance, environmental stress imposed by land based pollutants from a complex mixture of domestic and industrial wastes around the creek. Also, the substrate instability possibly arising from frequent dredging of the creek for marine traffic might have equally contributed to the paucity of macro-benthos at these stations. In addition, high human activity around the sampling stations which released wastes into the river could also be a possible explanation. Elsewhere, relatively less macro-benthic communities at the coast of India was reported to be due to the differences in sampling strategies such as variation in gears, depth and season of sampling as well as differences in sediment properties and other environmental conditions prevailing in the area (Naser, 2011). The dominance of bivalves at the Gulf of Guinea stations, could be attributed to their ability to filter suspended small food particles, that seldom settle out of organic matter deposit, which their subsistence (Yankson and Kendall, 2001).According to Brinkhurst (1970) cited by Yakub and Ugwumba (2009), the bigger the size of a lotic water body the poorer the macro invertebrate richness. However, the present study showed paucity in the species richness and general diversity at the study stations. This could be as a result of pollution, urbanization and human population growth that are increasing along tropical coastlines at an alarming rate.

CONCLUSION

Globally, coastal and marine environments support a diverse array of plankton and macro-benthic communities that play important roles in ecosystem processes and provide several ecological and economic services. However, these assemblages of organism communities composition and diversity may have probably be as a result of inhabit one of the harshest marine environments due to marked anthropogenic effects which could arguably be critical for biodiversity and abundance. In Gulf of Guinea, the abundance of the centric diatoms is an indication of the depth which supports the drifting movement of this group of microalgae. The observation of fish eggs suggested a suitable environment for fish and plankton diversity suggested the possibility of support of organisms in the higher trophic levels.

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