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Comparative study of the benthic macroinvertebrate communities of two estuaries on the Southwestern Coast of Ghana

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ABSTRACT

This paper on benthic macroinvertebrates of Kakum and Nyan estuaries is meant as baseline information in the wake of offshore oil drilling, mining and land use due to growing human population on the southwestern coast of Ghana. Ekman grab (0.0225 m^2) was used to sample benthic macroinvertebrates monthly from August 2011 to July 2012. Crustacea (58.96%) and Annelida (35.23%) dominated the 40 species encountered in the Kakum estuary while Annelida (88.15%) alone dominated the 45 species found in the Nyan estuary. The annelids Nereissp., Capitella capitata and Cossura sp. and the dipteran Chironomus sp.were the main pollution tolerant species recorded while the annelids Scoloplos sp. and Amphiglenasp. were the known pollution sensitive ones found. An unknown amphithoid (Amphithoid 'A') andaGammarussp. dominated the Kakum estuary community with mean densities ranging between 67.27 ± 30.94 ind./m^2 to 535.49 ± 275.50 ind./m^2 and 26.91 ± 10.71 ind./m^2 to 398.25 ± 143.90 ind./m^{2}respectively while in the Nyan estuary, Scoloplos sp. and Cossura sp. were dominant in densities (248.91 ± 152.05 ind./m^2 to 270.44 ± 177.39 ind./m^2 and 6.73 ± 3.66 ind./m^2 to 131.85 ± 67.28 ind./m^{2}respectively). Lower species diversity, richness and densities of organisms were found at the mouth of the two estuaries than stations farther from the sea. Benthic macroinvertebrate communities of the two estuaries were highly similar (Sorensen's index, C_s = 0.706). Periodic monitoring is encouraged as a means of checking the possible impacts of human activities on these water bodies.

Keywords: Benthic macroinvertebrates, Annelida, Crustacea, diversity, richness, composition

INTRODUCTION

Though estuaries serve as sources of fisheries, harbours, recreational centres, among others, they are recipients of various domestic and industrial wastes which can cause major changes to the fauna and flora and have a negative impact on the services provided by the estuaries [1]. Periodic monitoring of estuaries has therefore become very necessary in order to assess their ecological health. Benthic macroinvertebrates are known to be the most preferred group of organisms used in such monitoring studies although other indicators of aquatic ecosystem health such as periphytons and fisheshave been documented [2].Several authors have confirmed that benthic macroinvertebrate community composition is closely linked to habitat conditions and many of them may serve as biological indicators of various environmental stresses such as inorganic contaminants [3][4] and organic pollution [5][6]. The commonly used biomonitoring approaches of benthic invertebrates include assessment of biological indices and composition of functional feeding groups among others [2].

Benthic macroinvertebrates are an important component of the food web of aquatic ecosystems [7] therefore changes in the community structure due to pollution can in turn affect trophic relationships in the ecosystem [8]. They are also involved in degradation of organic matter, and metabolism and dispersion of contaminants such as trace metals and oil derivatives [9].Benthic communities also provide a variety of ecosystem services that affect water and sediment quality in estuaries [10]. In relatively shallow areas, filter feeders may effectively remove particles from the water column, which leads to deposition of organic matter from the overlying water at rates greater than what natural sinking and physical mixing would allow. This can result in enhanced water clarity, which may increase the success of submerged aquatic plants. Burrowing forms also help in the aeration of the soil.

Whereas temperate estuaries have been studied extensively to assess their ecological status using benthic macroinvertebrates as indicators of pollution [11][12][13][14], similar studies in tropical estuaries especially in developing countries are few, and recent works in Ghana have concentrated on lagoons [15][16][17]. Recent works of West African estuaries are concentrated on their fish [18][19][20]. Illegal small scale mining and other human activities pose a serious threat to rivers which form estuaries in Ghana and therefore the need for studies in these estuaries focusing on the biomonitoring potential of benthic macroinvertebrates.

This ecological study on the Kakum and Nyan river estuaries constitutes the first comparative study of benthic macroinvertebrate communities along the western coast of Ghana and was designed to support wetland conservation efforts for sustainable coastal livelihoods. It was also meant as a baseline study of benthic organisms in the two estuaries for assessment of future environmental impacts resulting from offshore oil drilling activities and land use due to human population growth in the west coast of Ghana. The paper examines the species composition, density and diversity of the benthic macroinvertebrate communities in the two estuaries.

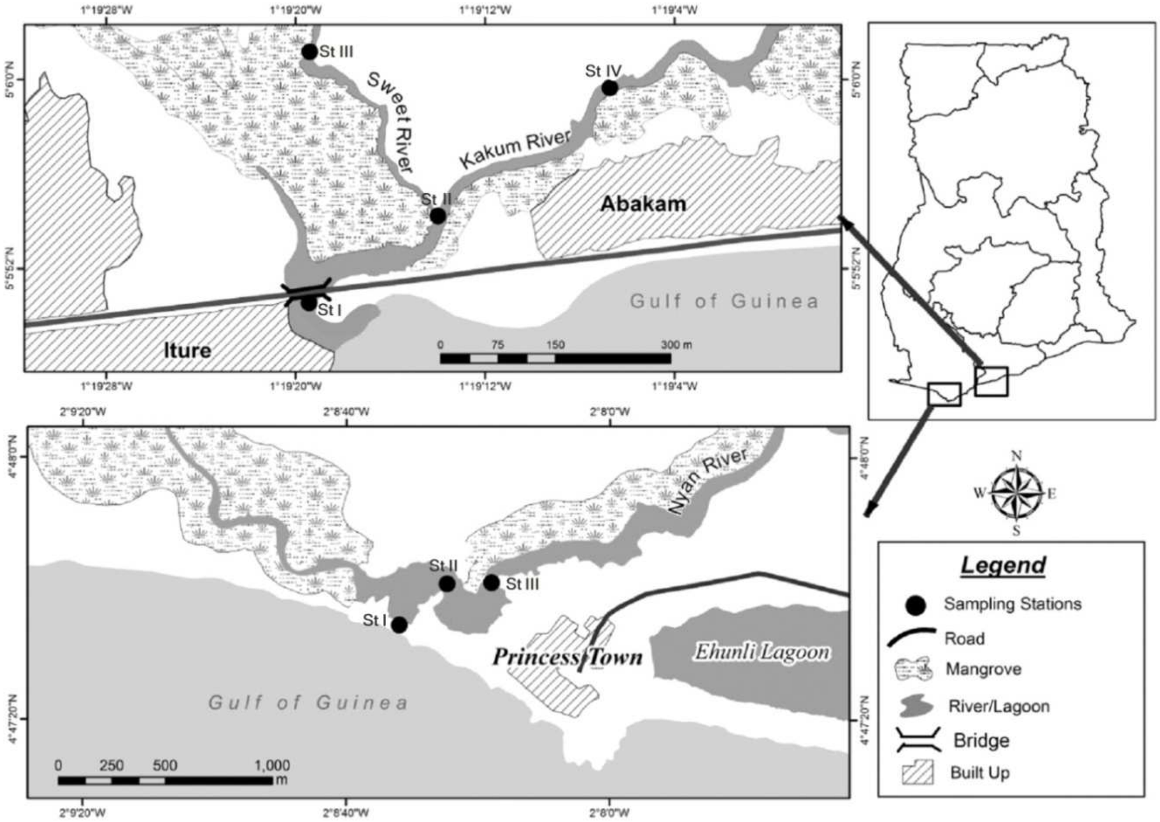

Fig. 1 Map of the study area showing the various stations

MATERIALS AND METHODS

Study areas

The study was conducted in the Kakum and Nyan river estuaries (Fig. 1). The Kakum estuary (5°5' N, 1°19' W), formed by the Kakum and Sweet rivers, is about 5 km west of Cape Coast in the Central region of Ghana. This estuary is located in the dry Equatorial Climatic Zone of Ghana with mean monthly temperatures ranging from 24 °C in August to about 30 °C in March – April. It is fringed by mangrove forests. The two rivers associated with the estuary drain rapidly growing communities in the Cape Coast Metropolis. Sand winning activities occur at the Sweet river arm of the estuary. Four stations were sampled in this estuary. Station I was at the mouth, Station II at the confluence of the two rivers, Station III was located 300 m up the Sweet river arm from the confluence and Station IV also 300 m up the Kakum river.

The Nyan estuary (4º47' N, 2º8' W) is located in Princess Town in the Ahanta West District of the Western region of Ghana. The District falls in the South-Western Equatorial Climatic Zone of Ghana with the highest mean temperature of 34 °C in March and April and lowest mean temperature of 20 °C in August. The estuary is bordered by a mangrove forest and serves as a source of fish and transport route for the local communities living nearby. Small scale mining activities occur in the upper reaches of the Nyan River. Three stations approximately 300 m apart were sampled in the Nyan estuary. Station I was located at the mouth of the estuary and Stations II and III were further upstream.

Sampling
Samples of benthic macroinvertebrates were collected with an Ekman grab (15 cm x 15 cm) from the estuaries at low tide around the middle of every month from August 2011 to July 2012. Three replicate samples were taken at each station. Samples were screened in the field using a set of sieves with mesh sizes of 4.0 mm, 2.0 mm and 0.5 mm. Fauna retained by the sieves were preserved in 10 % formalin for detailed examination in the laboratory. The preserved samples were stained with eosin, sorted and the benthic macroinvertebratesfound were observed under a dissecting microscope and identified to the lowest taxonomic level with the aid of manuals and keys [21][22][23][24]. Counts of the different taxa in the samples were recorded for further analysis. Organisms that were not identified with certainty were given code names.

Density was estimated as the number of individuals in each taxon per grab area and multiplied by a factor of 44.4 to convert to per 1 m^2. Diversity of the communities was calculated using the Shannon-Wiener index (*H*') as $H' = -\sum_{i=1}^{s} P_i(lnP_i)$where $P_i$is the proportion of the i^{th} species and *s* is the number of species in a sample. Richness was determined from Margalef's index (*d*) calculated as$d = \frac{s-1}{\text{In}\, N}$ where *s* is the number of species in a sample and *N* is the number of individuals in the sample. Pielou's index (*J*') which describes the evenness of taxa distribution among the communities was determined by the equation $J' = H'/(\text{In}\, s)$where$s$ is the number of species and *H*' the Shannon-Wiener diversity index. The similarity among the communities at the different stations in the two estuaries was determined by Sorensen's similarity index (C_s) which is calculated as$\text{Cs} = 2j/(a+b)$where *j* is the number of species common to a given pair of communities, and *a* and *b* are the number of species occurring in either community. Data were analysed using Primer 5 and Microsoft Office Excel 2007.

RESULTS

Occurrence
The occurrence of benthic macroinvertebrates at the various stations in the Kakum and Nyan estuaries during the study is shown in Table 1. Out of the 40 taxa found in the Kakum estuary, 25 each were present at Station I and Station III, while 30 taxa and 20 taxa were found at Stations II and IV respectively. In the Nyan estuary, 26 out of a total of 45 taxa were present at Station I, 31 at Station II and 32 at Station III. *Chironomus*sp., in addition to four annelids (*Capitella capitata*, *Nephtys* sp., *Nereis* sp. and an oligochaete known here as Oligochaete 'A'), a ribbon worm (known in this study as *Lineus* sp. 'A') and two crustaceans, *Gammarus* sp. and an amphithoid (Amphithoid 'A') were common to both estuaries. Three annelids (*Eurythoe*sp., *Armandia*sp. and *Amphiglena* sp.),a ribbon worm (*Lineus* sp. 'C') and 6 crustaceans (Amphithoid 'C', Amphithoid 'B', Mantis shrimp, *Clibernarius* sp., *Pandalus* sp. and *Upogebia*sp.) occurred in Kakum estuary only. Ten annelids (*Heteromastus*sp., *Notomastus* sp., *Goniada* sp., *Euclymene*sp., *Eulalia*sp.,*Phyllodoce*sp., *Polydora* sp., an aphroditid, a Paraonid and *Tubifex*sp.), a ribbon worm (*Lineus* sp. 'B'), a crustacean(*Alpheus* sp.),an insect (*Chaoburus* sp.) and 2 molluscs (*Pachymelania aurita* and a Glycymerid clam) were present in the Nyan estuary only.

Percentage composition
Figure 2 shows the composition of the benthic macroinvertebratesin the two estuaries. The benthic macroinvertebratesin the Kakum estuary were dominated by Annelida and Crustacea at all the stations (> 20 %) while the rest of the invertebrate groups had less than 9 % representation each (Fig. 2a). At all the stations in the Nyan estuary, Annelida was dominant with compositions varying between 87.59 – 88.52 % while Phoronida, Anopla, Crustacea, Insecta and Mollusca were less than 6 % of the total number of animals collected at each station (Fig. 2b).

Table 1: Occurrence of benthic macroinvertebrates in the Kakum and Nyan estuaries (+ indicates present, - indicates absent)

		Kakum estuary				Nyan estuary		
Major group	**Organisms**	**St. I**	**St. II**	**St. III**	**St. IV**	**St. I**	**St. II**	**St. III**
Phoronida	Phoronid	-	+	-	+	-	+	+
Anopla	*Lineus* sp. 'A'	+	+	+	+	+	+	+
	Lineus sp. 'B'	-	-	-	-	-	+	+
	Lineus sp. 'C'	+	-	-	-	-	-	-
Annelida	Amphinomid	+	+	+	+	-	+	+
	*Eurythoe*sp.	-	+	+	-	-	-	-
	*Arenicola*sp.	-	+	-	+	-	+	-
	Capitellacapitata	+	+	+	+	+	+	+
	*Heteromastus*sp.	-	-	-	-	+	-	+
	*Notomastus*sp.	-	-	-	-	+	-	-
	*Cirratulus*sp.	-	-	+	-	-	+	+
	*Cossura*sp.	+	+	+	-	+	+	+
	Aphroditid	-	-	-	-	-	+	-
	Eunice sp.	-	+	-	+	+	+	+
	*Lumbriconereis*sp.	+	+	+	-	+	-	+
	*Ophryotrocha*sp.	+	-	-	-	+	+	+
	*Glycera*sp.	-	-	+	-	+	-	+
	*Goniada*sp.	-	-	-	-	+	-	-
	*Rhodine*sp.	-	+	+	+	+	+	+
	*Euclymene*sp.	-	-	-	-	+	+	-
	*Nephtys*sp.	+	+	+	+	+	+	+
	*Nereis*sp.	+	+	+	+	+	+	+
	*Armandia*sp.	-	+	-	-	-	-	-
	*Scoloplos*sp.	+	+	+	+	-	+	+
	Polynoid	-	+	-	-	+	-	-
	*Eulalia*sp.	-	-	-	-	+	+	-
	*Phyllodoce*sp.	-	-	-	-	+	+	-
	Paraonid	-	-	-	-	+	-	+
	*Amphiglena*sp.	+	+	+	+	-	-	-
	*Polydora*sp.	-	-	-	-	+	-	-
	*Spiophanes*sp.	-	-	+	-	-	+	+
	*Exogone*sp.	+	-	+	-	+	-	+
	*Syllis*sp.	-	+	+	-	-	+	+
	Oligochaete 'A'	+	+	+	+	+	+	+
	*Tubifex*sp.	-	-	-	-	-	+	-
	Leech	+	+	+	-	-	+	+
Crustacea	*Alpheus* sp.	-	-	-	-	+	-	+
	Amphithoid 'A'	+	+	+	+	+	+	-
	Amphithoid 'B'	-	+	+	-	-	-	-
	Amphithoid 'C'	+	+	-	-	-	-	-
	*Callinectes*sp.	+	+	-	+	-	+	+
	*Clibernarius*sp.	+	-	-	-	-	-	-
	*Gammarus*sp.	+	+	+	+	+	+	+
	Mantis shrimp	-	+	-	-	-	-	-
	Melitid	+	+	+	+	-	+	+
	Mysis sp.	+	+	+	+	-	+	+
	Unidentified crab stage	-	+	+	+	-	+	+
	*Pandalus*sp.	+	-	-	-	-	-	-
	*Upogebia*sp.	+	+	-	-	-	-	-
Insecta	*Chaoburus*sp.	-	-	-	-	-	+	-
	*Chironomus*sp.	+	+	+	+	+	+	+
	Unidentified insect	-	-	-	+	+	-	-
Mollusca	*Tympanotonusfuscatus*	+	-	-	-	-	-	+
	Pachymelaniaaurita	-	-	-	-	-	-	+
	Glycymerid clam	-	-	-	-	-	-	+

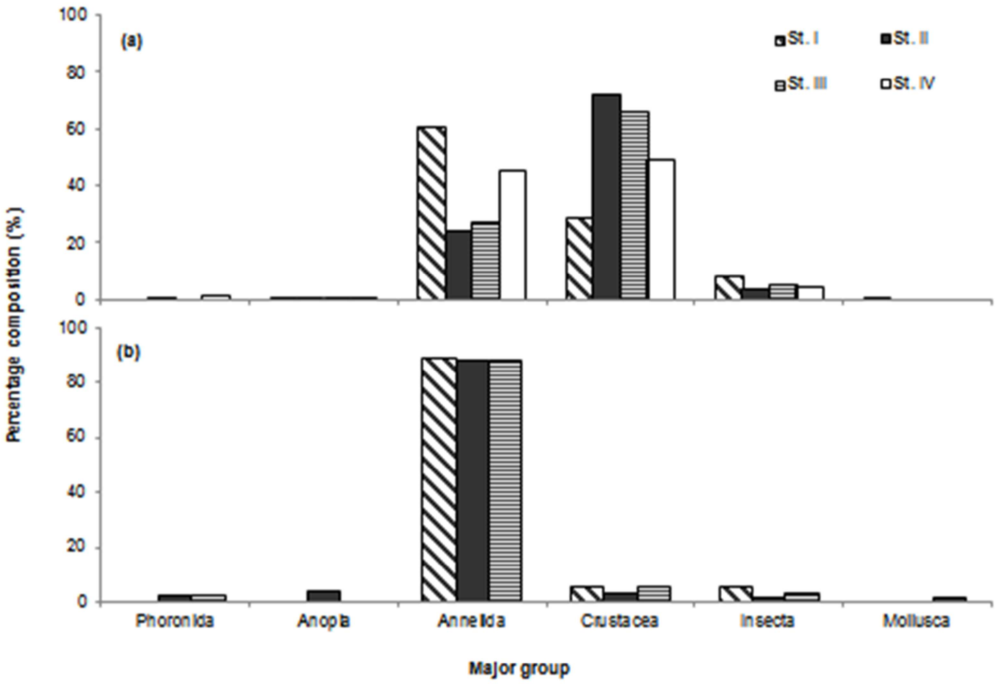

Fig 2 Percentage composition of major groups of benthic macroinvertebrates in the (a) Kakum and (b) Nyan estuaries

From the analysis of the overall composition of major benthic macroinvertebrategroups in the two estuaries, crustaceans and annelids dominated the Kakum estuary comprising 58.96 % and 35.26 % respectively (Fig. 3). The rest of the benthic invertebrate community constituted less than 5 % each. The Nyan estuary on the other hand, was dominated by annelids with a composition of 88.15 % while the other groups constituted between 0.60 – 4.17 %.

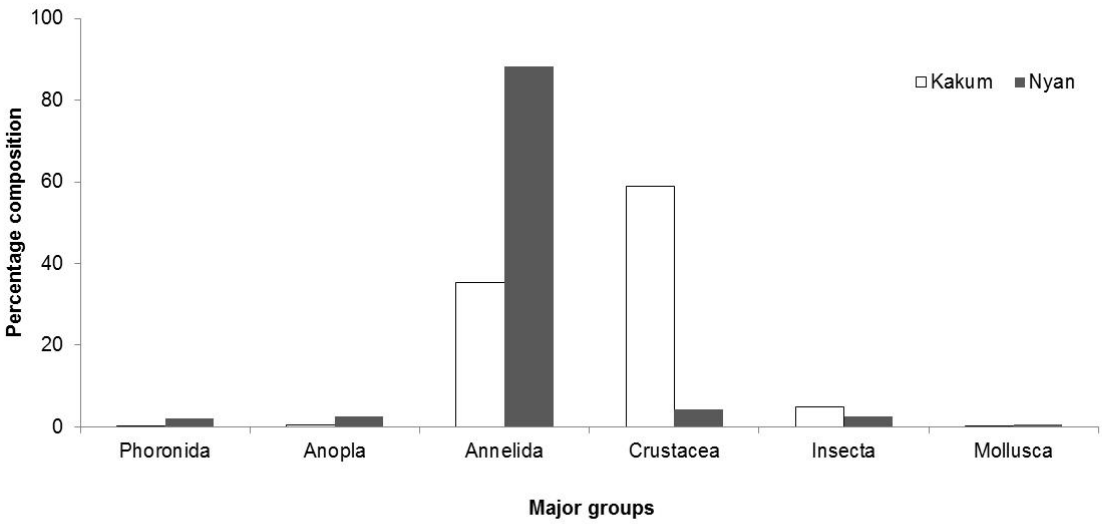

Fig 3 Overall percentage composition of major groups of benthic macroinvertebrates in the Kakum and Nyan estuaries

Density

Table 2 shows the density of benthic macroinvertebrates at the various stations in the Kakum and Nyan estuaries during the study. In the Kakum estuary,*Scoloplos* sp. had the highest density (310.80 ± 255.43 ind./m^2) at Station I. *Chironomus* sp., *Gammarus* sp., a melitid and Amphithoid 'A' had respective mean densities of 49.78 ± 29.89 ind./m^2, 67.27 ± 30.94 ind./m^2, 60.55 ± 54.74 ind./m^2 and 26.91 ± 10.71 ind./m^2.

Table 2: Mean density ± SE (ind./m²) of benthic macroinvertebrates at the various stations in the Kakum estuary

Organisms	Kakum estuary				Nyan estuary		
	St. I	St. II	St. III	St. IV	St. 1	St. II	St.III
Phoronid	-	1.35 ± 1.35	-	10.76 ± 10.76	-	20.18 ± 10.61	16.15 ± 10.83
Lineus sp. 'A'	5.38 ± 3.61	6.73 ± 5.42	4.04 ± 2.08	2.69 ±1.81	1.35 ± 1.35	34.98 ± 19.58	4.04 ± 2.89
Lineus sp. B	-	2.69 ± 2.69	1.35 ± 1.35				
Lineus sp. 'C'	1.35 ± 1.35	-	-	-			
Amphinomid	1.35 ± 1.35	10.76 ± 6.65	1.35 ± 1.35	1.35 ± 1.35	-	6.73 ± 6.73	17.49 ± 14.64
Aphroditid					-	6.73 ± 6.73	-
*Eurythoe*sp.	-	1.35 ± 1.35	1.35 ± 1.35	-			
*Arenicola*sp.	-	2.69 ± 69	-	1.35 ± 1.35	-	2.69 ± 2.69	-
Capitellacapitata	9.42 ± 6.70	21.53 ± 13.29	32.29 ± 17.49	28.25 ± 19.08	45.75 ± 42.82	8.07 ± 5.77	8.07 ± 4.17
*Heteromastus*sp.					2.69 ± 2.69	-	1.35 ± 1.35
*Notomastus*sp.					4.04 ± 4.04	-	-
*Cirratulus*sp.	-	-	2.69 ± 2.69	-	-	8.07 ± 4.62	1.35 ± 1.35
*Cossura*sp.	1.35 ± 1.35	1.35 ± 1.35	1.35 ± 1.35	-	6.73 ± 3.66	60.55 ± 22.44	131.85 ± 67.28
Eunice sp.	-	2.69 ± 2.69	-	1.35 ± 1.35	16.15 ± 11.01	2.69 ± 2.69	2.69 ±2.69
*Lumbriconereis*sp.	1.35 ± 1.35	2.69 ± 1.81	1.35 ± 1.35	-	2.69 ± 2.69	-	8.07 ± 4.17
*Ophrythocha*sp.	4.04 ± 2.89	-	-	-	8.07 ± 5.77	1.35 ± 1.35	2.69 ± 2.69
*Glycera*sp.	-	-	1.35 ± 1.35	-	4.04 ± 2.89	-	2.69 ± 1.81
*Goniada*sp.					2.69 ± 2.69	-	-
*Euclymene*sp.					1.35 ± 1.35	1.35 ± 1.35	-
*Rhodine*sp.	-	12.11 ± 7.14	33.64 ± 15.08	24.22 ± 14.43	8.07 ± 5.42	21.53 ± 11.87	26.91 ± 14.91
*Nephtys*sp.	5.38 ± 3.01	72.65 ± 35.61	100.91 ± 26.46	104.95 ± 22.17	16.15 ± 9.24	45.75 ± 10.46	52.47 ± 18.44
*Nereis*sp.	8.07 ± 4.62	104.95 ± 53.08	39.02 ± 14.15	47.09 ± 12.27	13.45 ± 7.32	82.07 ± 15.50	69.96 ± 23.96
*Armandia*sp.	-	16.15 ± 16.15	-	-			
*Scoloplos*sp.	310.80 ± 255.43	8.07 ± 5.42	4.04 ± 2.89	5.38 ± 3.61	-	270.44 ± 177.39	248.91 ± 152.05
Paraonid					1.35 ± 1.35	-	1.35 ± 1.35
*Eulalia*sp.					4.04 ± 4.04	1.35 ± 1.35	-
*Phyllococe*sp.					6.73 ± 6.73	1.35 ± 1.35	-
Polynoid	-	4.04 ± 4.04	-	-	1.35 ± 1.35	-	1.35 ± 1.35
*Amphiglena*sp.	2.69 ± 1.81	60.55 ± 24.15	6.73 ± 4.62	160.11 ± 135.63			
*Polydora*sp.					1.35 ± 1.35	-	-
*Spiophanes*sp.	-	-	2.69 ± 2.69	-	-	107.64 ± 78.95	14.80 ± 14.80
*Exogone*sp.	1.35 ± 1.35	-	1.35 ± 1.35	-	4.04 ± 2.89	-	4.04 ± 2.89
*Syllis*sp.	-	5.38 ± 3.61	4.04 ± 2.89	-	-	6.73 ± 3.07	10.76 ± 4.93
Oligochaete 'A'	2.69 ± 1.81	40.36 ± 21.59	8.07 ± 4.62	6.73 ± 3.07	5.38 ± 4.13	45.75 ± 18.98	24.22 ±10.80
*Tubifex*sp.					-	115.71 ± 115.71	-
Leech	1.35 ± 1.35	1.35 ± 1.35	2.69 ± 2.69	-	-	2.69 ± 2.69	6.73 ± 6.73
Alpheus sp.					1.35 ± 1.35	-	1.35 ± 1.35
Amphithoid 'A'	26.91 ± 10.71	398.25 ± 143.90	305.42 ± 155.73	129.16 ± 55.16	4.04 ± 4.04	2.69 ± 2.69	-
Amphithoid 'B'	-	14.80 ± 10.37	9.42 ± 9.42	-			
Amphithoid 'C'	1.35 ± 1.35	10.76 ± 8.25	-	-			
*Callinectes*sp.	1.35 ± 1.35	2.69 ± 1.81	-	2.69 ± 1.81	-	10.76 ± 5.31	9.42 ± 5.38
*Clibernarius*sp.	1.35 ± 1.35	-	-	-			
*Gammarus*sp.	67.27 ± 30.94	535.49 ± 275.50	238.15 ± 139.60	244.87 ± 97.47	4.04 ± 2.89	5.38 ± 4.13	16.15 ± 7.59
Mantis shrimp	-	1.35 ± 1.35	-	-			
Melitid	60.55 ± 54.74	53.82 ± 21.61	26.91 ± 15.04	18.84 ± 10.19	-	1.35 ± 1.35	4.04 ± 4.04
Mysis sp.	4.04 ± 2.89	63.24 ± 57.39	2.69 ± 1.81	13.45 ± 7.32	-	2.69 ±2.69	1.35 ± 1.35
*Pandalus*sp.	1.35 ± 1.35	-	-	-			
Unidentified crab stage	-	2.69 ± 2.69	6.73 ± 5.42	1.35 ± 1.35	-	5.38 ± 5.38	5.38 ± 3.01
*Chaoburus*sp.					-	1.35 ± 1.35	-
*Upogebia*sp.	1.35 ± 1.35	1.35 ± 1.35	-	-			
*Chironomus*sp.	49.78 ± 29.89	51.13 ± 19.08	49.78 ± 32.63	34.98 ± 10.03	8.07 ± 3.66	16.15 ± 5.45	20.18 ± 7.54
Unidentified insect	-	-	-	1.35 ± 1.35	1.35 ± 1.35	-	-
Tympanotonusfuscatus	2.69 ± 2.69	-	-	-	-	-	5.38 ± 4.13
Pachymelaniaaurita					-	-	4.04 ± 4.04
Glycymerid clam					-	-	1.35 ± 1.35

The remaining organisms had densities less than 10 ind./m^2. At Station II, *Gammarus* sp. had a density of 535.49 ± 275.50 ind./m^2, followed by Amphithoid 'A' with 398.25 ± 143.90 ind./m^2 and *Nereis* sp. with 104.95 ± 53.08 ind./m^2. Amphinomid, *Capitella capitata*, *Rhodine* sp., *Nephtys* sp., *Amphiglena* sp., *Armandia*sp., Oligochaeta, Amphithoid 'B', Amphithoid 'C', Melitid, *Mysis* sp. and *Chironomus* sp. had mean densities ranging between 10 to 73 ind./m^2 while the rest of the organisms had less than 10 ind./m^2.Amphithoid 'A', *Gammarus* sp. and *Nephtys* sp. had relatively high densities of 305.42 ± 155.73 ind./m^2, 238.15 ± 139.60 ind./m^2 and 100.91 ± 26.46 ind./m^2 respectively at Station III. *Capitella capitata*, *Rhodine* sp., *Nereis* sp., melitidsand *Chironomus*sp. had mean densities between 26 and 50 ind./m^2. The remaining organisms had less than 10 ind./m^2.At Station IV, density values of 244.87 ± 97.47 ind./m^2, 160.11 ± 135.63 ind./m^2, 129.16 ± 55.16 ind/m^{2}and 104.95 ± 22.17 ind./m^{2}were recorded by *Gammarus* sp., *Amphiglena* sp., Amphithoid 'A' and *Nephtys* sp. respectively. Phoronids, *Capitellacapitata*, *Rhodine*sp., *Nereis* sp., melitids, *Mysis* sp. and *Chironomus* sp. had mean densities between 10 and 48 ind./m^2 while the rest of the organisms present were less than 10 ind./m^2.

Most of the organisms in the Nyan estuary were fewer than 10 ind./m^2 at all stations. At Station I, *Nephtys*sp., *Nereis* sp., *Eunice* sp. and *C. capitata* had densities of 16.15 ± 9.24 ind./m^2, 13.45 ± 7.32 ind./m^2, 16.15 ± 11.01 ind./m^2 and 45.75 ± 42.82 ind./m^2 respectively. *Scoloplos*sp. had the highest density (270.44 ± 177.39 ind./m^2) at Station II followed by *Spiophanes* sp. (107.64 ± 78.95 ind./m^2) . Unidentified phoronids, *Lineus* sp. A, *Cossura* sp., *Rhodine* sp., *Nephtys* sp. and *Nereis* sp., had mean densities ranging from 20 to 83 ind./m^2 while the remaining animals had densities below 10 ind./m^2. At Station III, *Scoloplos*sp. had the highest density of 248.91 ± 152.05 ind./m^2, followed by *Cossura* sp. with a value of 131.85 ± 67.28 ind./m^2. Phoronids, amphinomids, *Rhodine*sp., *Nephtys* sp., *Nereis* sp., *Spiophanes* sp., *Syllis*sp., Oligochaete, *Gammarus* sp. and *Chironomus* sp. had mean density values varying from 10 to 70 ind./m^2 while each of the remaining organisms were numbered less than 10 ind./m^2.

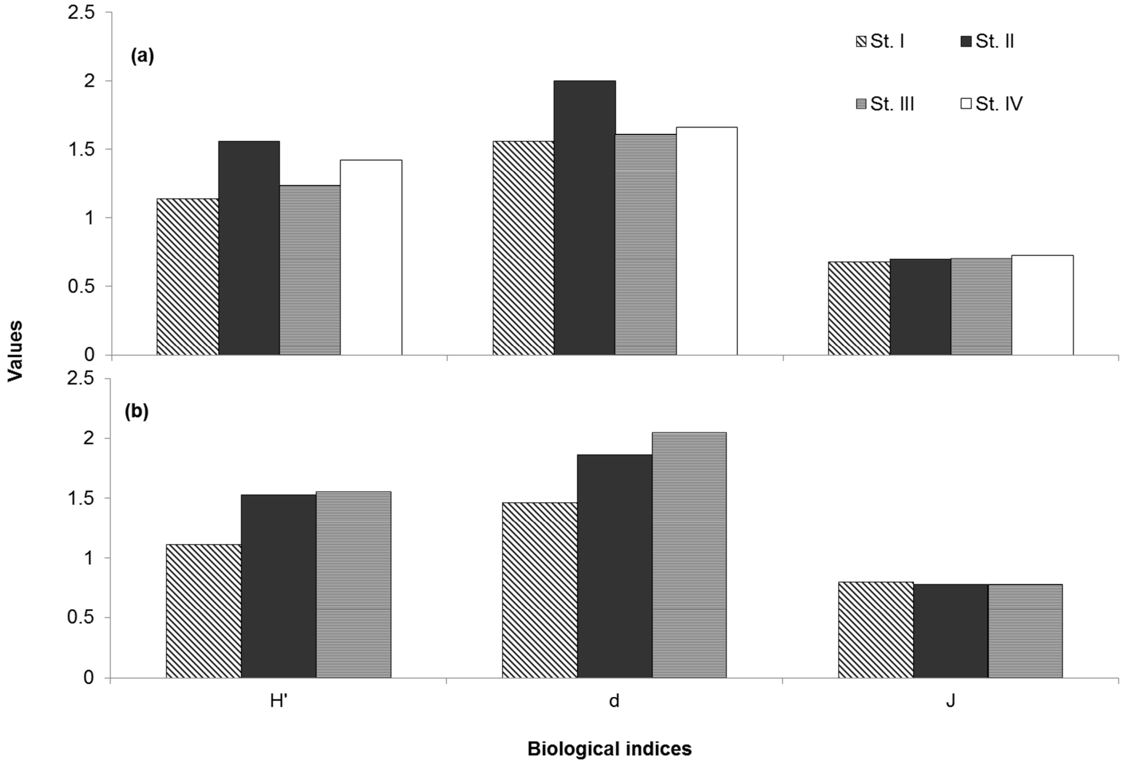

Fig. 4 Biological indices in the (a) Kakum and (b) Nyan estuaries (*H*': Shannon-Weiner diversity index, *d*: Margalef richness index and *J´*: Peliou's evenness index)

Diversity and similarity indices of the benthic macroinvertebrate communities

The biological indices(Shannon-Weiner diversity index (*H´*), Margalef richness index (*d*) and Peliou's evenness index (*J´*) for the benthic macroinvertebrate communities in the two estuaries are shown in Figure 4. Diversity values were within the range of 1.14 – 1.56 in the Kakum estuary and 1.11 – 1.55 in the Nyan estuary. In the Kakum estuary, diversity was highest at the confluence (St. II), followed by Station IV (Kakum river end), Station III (sweet river end) and Station I in that order. Values of diversity at Stations II and III in the Nyan estuary were similar while the mouth (St. I) had the least diversity. Species richness values varied from 1.56 to 2.00 in the Kakum estuary and 1.46 to 2.05 in the Nyan estuary. Richness was highest at the confluence (*d = 2.0*) compared to the other stations (*d*

= 1.56 – 1.66) in the Kakum estuary. Richness increased upstream (*d = 1.46 – 2.05*) in the Nyan estuary. The evenness index (*J′*) was 0.68 – 0.73 in the Kakum estuary and 0.78 – 0.80 in the Nyan estuary.

Table 3 shows Sorensen's similarity indices in the Kakum and Nyan estuaries. The similarity index values in the Kakum estuary ranged from 0.622 to 0.764 suggesting a stronger similarity among the benthic macroinvertebrate communities. Stations II and III were most similar (0.764), followed by Stations II and IV (0.760), and Stations I and IV (0.622). Sorensen's similarity index for the Nyan estuary stations were 0.517 - 0.730 suggesting that the macroinvertebrate communities at the three stations were similar. Stations II and III showed the strongest similarity (0.730) while Stations I and III were the least similar (0.517).

Table 3: Sorensen's similarity indices in the Kakum and Nyan estuaries

	Kakum estuary				Nyan estuary		
	St. I	**St. II**	**St. III**	**St. IV**	**St. I**	**St. II**	**St. III**
St. I							
St. II	0.691				0.526		
St. III	0.68	0.764			0.517	0.73	
St. IV	0.622	0.76	0.667				

The value of similarity index recorded between the benthic macroinvertebratesof the two estuaries was 0.706 suggesting a strong similarity between the two estuaries.

DISCUSSION

Many researcher have found annelids, crustaceans and molluscs as the three most common benthic macroinvertebrates [25][260[27][28]. The two estuaries studied were dominated by annelids and crustaceans.

Some species such as *Notomastus* sp., *Goniada* sp., Polynoid, *Polydora* sp., *Arenicola* sp., *Glycera* sp., *Pandalus* sp., *Clibernarius* sp.,*Mysis* sp., mantid shrimp and *P. aurita*were encountered in low densities. However higher numbers of some of these species have been encountered in estuaries elsewhere [27][29][30][31]. Species such as *C. capitata, Nereis* sp., *Nephtys* sp., *Cossura* sp., *Scoloplos* sp., *Amphiglena* sp.,*Tubifex* sp., *Chironomus* sp., *Gammarus* sp. and an unidentified amphithoid (Amphithoid 'A') dominated in the two estuaries studied.

C. capitata was found to be ubiquitous in both estuaries. Several authors [22][24][32][33] have described this species as tolerant of organic pollution and anoxic conditions. The species has the ability to produce many individuals when organic matter supply is high enough to feed all the population. In non-polluted areas, densities of this species can exceed 250 000 ind./m². Densities of 440 000 ind./m² and 750 000 ind./m² have been recorded in polluted sites [34]. The densities of *C. capitata* recorded in the present study (9.42 - 32.29 ind./m^2 in the Kakum estuary and 8.07 - 45.75 ind./m² in the Nyan estuary) were therefore too low to impute organic pollution of these estuaries.

Nereis sp. occurred at all stations in the two estuaries recording mean densities between 8.07 ind./m^2 and 104.95 ind./m^2 in the Kakum estuary and 13.45 ind./m^2 and 82.07 ind./m^2 in the Nyan estuary. This species is known to be euryhaline[26] which explains its apparent ubiquitous status in the two estuaries. *Nereis* sp. has been reported by some authors as an indicator of organic pollution in aquatic ecosystems [27][33]. The mere presence of this species in the two estuaries cannot however be associated with organic pollution since it was not the sole dominant species, and there were no signs of pollution in both estuaries.

Nephtys sp., like *Nereis* sp. was also ubiquitous in both estuaries. This species is also euryhaline hence its occurrence at all stations in the two estuaries [26]. Densities of *Nephtys*sp.ranged from 5.38 ind/m^2 to 104.95 ind/m^2 in the Kakum estuary and 16.15 ind./m^2 to 52.47 ind./m^2 in the Nyan estuary. To the best of our knowledge, this species has not been associated with pollution in any study.

Cossura sp. was also found in both estuaries. *Cossura*is tolerant of pollution and therefore its presence or absence can be used to predict the health of ecosystems [26]. Densities between 180 ind./m^2 and 210 ind./m^2 of *Cossura* sp. were recorded from a disturbed habitat in the Zuari estuary on the west coast of India [31]. The relatively low densities of this species (1.35 ind./m^2 in the Kakum estuary and 6.73 - 131.85 ind./m^2 in the Nyan estuary) in the current study may therefore not be the result of pollution.

Scoloplos sp. recorded densities of 4.04 – 310.80 ind./m^2 in the Kakum estuary and 248.91 – 270.44 ind./m^2 in the Nyan estuary. *Scoloplos*is a contaminant sensitive species [32]. The densities of *Scoloplos*sp. in the two estuaries compared to other species could be an indication that the estuaries studied are in an ecologically healthy state.

Amphiglena sp. was absent in the Nyan estuary but present at all stations in the Kakum estuary with mean densities between 2.69 and 160.99 ind./m^2. This species is an indicator of non-pollution and may suggest that the Kakum estuary is ecologically healthy [35].

Tubifex sp. (an oligochaete), in addition to an unidentified oligochaete (Oligochaete 'A') were encountered in this study. *Tubifex* sp. was absent in the Kakum estuary and present only at St. II in the Nyan estuary with a density of 115.71 ind./m^2. Oligochaete 'A' had densities of 5.38 to 45.75 ind./m^2 in the Kakum estuary and 2.69 to 40.36 ind./m^2 in the Nyan estuary. Oligochaetes especially *Tubifex* worms can live in severely organically enriched environments [36]. Densities between 100 to 9,000 ind./m^2 for oligochaetes in Muni lagoon which was unpolluted [15]. Density of about 17,000 ind./m^2 in the Domini lagoon was associated to some levels of organic pollution. The comparatively low densities of the oligochaete species in the present study compared to densities in the Muni and Domini lagoons might therefore suggest the absence of organic pollution in the two habitats studied.

Chironomus sp. is generally known to be tolerant of pollution and low dissolved oxygen levels. The density of 266 ind./m^2 in the middle portion of the Amansuri lagoon wasattributed the organic pollution [17]. Densities less than 60 ind./m^2 recorded at all stations in both estuaries are too low to be associated with organic pollution.

*Gammarus*is relatively sensitive to organic pollution and compared to its counterpart, *Asellus*, *Gammarus*may dominate less polluted waters [37]. Using the *Gammarus*: *Asellus*ratio, clean waters have a higher proportion of *Gammarus* while polluted waters have a higher proportion of *Asellus*[38].The densities of *Gammarus*sp. in this study (4.04 ind./m^2 to 16.15 ind./m^2 in the Nyan estuary and 67.27 ind./m^2 to 535.49 ind./m^2 in the Kakum estuary) and the absence of *Asellus* could suggest the two estuaries studied were clean.

A member of the Amphithoidae family designated in this study as Amphithoid 'A' occurred in both estuaries but in higher densities (between 26.91 ind./m^2 and 398.25 ind./m^2) in the Kakum estuary. To the best of our knowledge, species in the Amphithoidae family have not been linked with ecological health of water bodies.

Undisturbed habitats are characterised by high diversity and Shannon-Wiener diversity index values above 3.0 indicate a stable and balanced habitat while values below 1.0 indicate pollution and degradation of habitat structure [39]. It is however important to note that estuaries are generally stressful environments and very few taxa are able to adapt to the environmental stresses and therefore, low diversities may not necessarily indicate pollution and habitat degradation. Mean Shannon-Wiener diversity index values for all stations in both estuaries were between 1.11 and 1.56. The values obtained from the two estuaries show that although they are unpolluted, they are not stable and balanced. Higher diversity (1.86 – 2.75) and richness (3 – 5.95) were recordedat the shelf region off Dhamara estuary [30]. Diversity of 0.00 – 3.72 were recorded in the Negombo estuary [29]. The highly unstable nature of the mouth of both estuaries due to wave action may have accounted for their comparably low species diversity and richness than the other stations.

Values of diversity and richness indices were similar in the two estuaries. Furthermore, the Sorensen's index (> 0.5) suggests that benthic macroinvertebrate communities within and between stations in the two estuaries were very similar which could be due tothe occurrence of similar environmental conditions in the two estuaries [40]. The relatively high values of Pielou's evenness index in both estuaries also suggest that the various taxa were evenly represented.

CONCLUSION

The benthic macroinvertebrate communities of the two estuaries studied were generally similar, with both dominated by annelids and crustaceans. *Scoloplos* sp., *Nephtys* sp., *Nereis* sp., *Amphiglena* sp., *C. capitata*, *Cossura* sp., *Spiophanes* sp., *Tubifex* sp., *Gammarus* sp., and an unidentified crustacean (Amphithoid 'A') were the commonest species encountered.Pollution tolerant species such as *Nereis* sp., *C. capitata*, *Cossura* sp. and *Chironomus* sp.were found in both estuariesbut at low densities. The main pollution sensitive species found were *Scoloplos* sp. and *Amphiglena* sp. There is therefore some biomonitoring potential of the benthic macroinvertebrates in the two estuaries. Estuarine environments are generally stressful and the species diversity and richness values recorded in the two estuaries studied were typical of estuarine environments.Spatial variations in the benthic macroinvertebratecommunities occurred in both estuaries where the lowest diversity, richness and densities were recorded at stations nearer the sea. In general, it could be surmised that the two estuaries were in good ecological health. However, the increased anthropogenic activities associated with the upstream areas of these estuaries and the recent drilling of oil off the west coast of Ghana call for periodic biomonitoring of such water bodies.

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