Websites:
http://www.sciencepub.net
http://www.sciencepub.net/report

Emails:
editor@sciencepub.net
reportopinion@gmail.com

Report and Opinion

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Towards Conservation of Coastal Wetlands: An Assessment of the Ecological Health Status of a Neglected Lagoon in Ghana

Margaret Fafa Awushie Akwetey[a,b*], Sika Abrokwah[b], Richard Adade[b], Gertrude Lucky Aku Dali[c], Ivy Serwaa Gyimah Akuoko[b]

a. Department of Fisheries and Aquatic Sciences - African Union Centre of Excellence in Marine Fisheries and Coastal Management, University of Cape Coast, Ghana
b. Centre for Coastal Management - Africa Centre of Excellence in Coastal Resilience (ACECoR), University of Cape Coast, Ghana
c. Department of Environmental Science, School of Biological Sciences, College of Agricultural and Natural Sciences, University of Cape Coast, Ghana

***Corresponding author**: Margaret Fafa Awushie Akwetey, Email address: mfakwetey@ucc.edu.gh; Postal address: Department of Fisheries and Aquatic Sciences, School of Biological Sciences, University of Cape Coast, Ghana

Abstract: Coastal wetlands are important ecosystems that support biological communities and human populations. Anthropogenic activities have over the years affected these coastal wetlands globally leading to a loss of about 50% of these areas. There have therefore been calls to conserve these wetlands in order to sustain future generations. However, data to support conservation efforts on most of these ecosystems is lacking. The ecological health status of an aquatic system is one indicator that can form the basis of conservation or restoration actions. In Ghana, the Brenu Lagoon in the Central Region has been neglected in terms of ecological health research over the years. This study therefore aimed at assessing the ecological health of the Brenu lagoon using benthic macroinvertebrates. The study showed that the lagoon is hypersaline and moderately polluted with a dominance of two stress-tolerant species – *Capitella Capitata* and *Ampithoe sp*. The current state of pollution of the lagoon may be associated with waste disposal and agricultural activities within the catchment of the lagoon. Further studies are required to establish the linkage between these activities and the state of the lagoon on the basis of which remedial actions can be taken.

[Margaret Fafa Awushie Akwetey, Sika Abrokwah, Richard Adade, Gertrude Lucky Aku Dali, Ivy Serwaa Gyimah Akuoko. **Towards Conservation of Coastal Wetlands: An Assessment of the Ecological Health Status of a Neglected Lagoon in Ghana**. *Rep Opinion* 2021;13(11):9-20]. ISSN 1553-9873 (print); ISSN 2375-7205 (online). http://www.sciencepub.net/report. 3.doi:10.7537/marsroj131121.03.

Keywords: Benthic, Conservation, Ecological, Health, Macroinvertebrates

Introduction

Conservation of coastal wetlands has become a topical issue globally as these ecosystems continue to experience pressure from natural events and anthropogenic activities. Coastal wetlands are fragile ecosystems but play important roles ecologically supporting aquatic and terrestrial life. They are a source of rich natural resources that are often exploited by humans for livelihood and economic development. The exploitation of these resources is often done unsustainably and has resulted in the loss of about 50 % of coastal wetlands worldwide, loss of species of ecological importance and degradation of water quality (Davidson 2014, Lotze et al. 2006). Apart from resource exploitation, wetlands are often treated as wastelands receiving waste from nearby communities and industries. Recognizing the services that coastal wetlands provide, it is important that these ecosystems are protected and conserved. It is now also recognised that biodiversity conservation plays an important role in ensuring sustainable development rather than working against it as it was previously thought to (Niesenbaum 2019). Consistent with this, the Sustainable Development Goal 14 (SDG) target 5 of the 2030 Agenda for Sustainable Development aims to “by 2020, conserve at least 10 percent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.” However, globally biodiversity conservation is plagued with data insufficiency (Christie et al. 2020). Due to limited resources, biodiversity research is limited both geographically and taxonomically (Christie et al. 2020, Donaldson et al. 2017) and this includes coastal ecosystems such as wetlands. To adequately protect these ecosystems, there is the need to fill the knowledge gaps to inform policy direction and conservation initiatives. This has become particularly critical in developing countries where these coastal ecosystems have become an important source of income and livelihood for many in the face of rapid urbanisation, industrialisation and economic growth in areas.

Ghana, a developing country in West Africa, has a 550 km coastline rich with different types of wetland ecosystems made up of ninety-eight (98) lagoons and ten (10) estuaries (Yankson & Obodai 1998). Five (5) of these wetland ecosystems have been designated as Ramsar sites, namely the Keta, Densu, Songor, Muni-Pomadze and Sakumo lagoons (Willoughby et al. 2001) however, the rest remain unprotected. Of the unprotected, some including the Benya, Narkwa and Fosu Lagoon in the Central region, the Korle, Chemu and Kpeshie lagoon in the Greater Accra Region and Butuah lagoon in the Western region, have been studied over the years in terms of water quality, species diversity and anthropogenic pressures among others (Armah et al. 2012, Mensah & Enu-Kwesi 2019, Odjer-Bio et al. 2015). These studies have shown various degrees of degradation within these systems, which has informed some restorative plans and/or actions taken in some of these lagoons over the years (Doamekpor et al 2018, Karikari et al. 2009, United Nations Industrial Development Organization 2019). However, several other lagoons have attracted little attention in terms of research and conservation. With data deficiency on these lagoons, it is impossible to define the extent of loss and degradation these systems have encountered over the years. It is also impossible to determine the potential for the conservation or restoration of these systems.

Brenu lagoon in the Brenu Akyinim community in the Central Region is one of such lagoons that has been poorly studied over the years. A search through literature shows a study on periwinkles (*Tympanotonus fuscata)* by Aggrey-Fynn (2010) to determine their size distribution, another by Zuh et al. (2019) on black-chinned tilapia *Sarotherodon melanotheron* to compare size differences with those found in an open lagoon (Narkwa) and Essumang et al. (2007) to determine levels of heavy metals in the both the *Tympanotonus fuscata* and *Sarotherodon melanotheron*. Also, Aheto (2004) conducted a study on economic valuation of the Brenu mangrove ecosystem. However, to date, there has not been any health status assessment of the Brenu Lagoon. The health status of an aquatic ecosystem determines the ecosystem services it provides to surrounding biological and human communities. An understanding of this health status, therefore, provides the basis for efforts towards protecting the ecosystem (Costanza et al. 1997).

Benthic macroinvertebrates are the most commonly used bioindicators of water quality (Bonada et al. 2006) and are a cost-effective way of assessing the ecological health of an aquatic ecosystem. They are greatly influenced by the physical and chemical conditions of the water body. The ecological condition of an aquatic ecosystem is reflected in the benthic community structure (Heino et al. 2003). As compared to chemical assessment methods that show only short-term changes in an aquatic ecosystem, benthic macroinvertebrates provide a better understanding of the changes or fluctuations that have occurred within that ecosystem over a period of time (Nkwoji et al. 2020). Apart from their usefulness as bioindicators, benthic macroinvertebrates play an important role within the ecosystem, providing food for other invertebrates and vertebrates and feeding on organic matter that is deposited within the water column, ensuring an adequate balance of organic matter within the ecosystem (Moulton et al. 2010).

The aim of this paper, therefore, is to determine the health status of the Brenu lagoon using benthic macroinvertebrates as an indicator. The results of this study are expected to inform policy towards protecting the resource and also provide relevant stakeholders such as the Non-governmental Organisations (NGO's) with baseline information to initiate actions towards restoration and/or conservation of the lagoon.

Materials and Methods:

Study Area:

The study was carried out at the Brenu Lagoon (5° 4' 7.8" N; 1° 25' 53.3" W) located in Brenu Akyenim in the Central Region of Ghana, as shown in Fig. 1. The lagoon covers an area of 0.82 km^2 and is bordered by two communities – Brenu Akyenim and Ampenyi-Ayensudo. Five small streams, Obuahu, Asosi, Burabin, Esuaku and Asenche feed into the lagoon, however, most of them dry out during the dry season (Essumang et al. 2007). The lagoon experiences hypersaline conditions during the dry season since the main source of dilution is from rainfall (Yankson 1982). It is closed to the sea by a sandbar which is opened annually by residents of the community to prevent flooding during the rainy season. The sandbar is also removed during the celebration of an annual festival 'Bakatue' to link the lagoon to the sea to allow entry of marine fishes into the lagoon (Aggrey-Fynn 2010). The bottom of the water body is mostly soft mud, with some areas interspersed by sandy and rocky substratum. Fishes in the Brenu lagoon mostly include the tilapia, *Sarotherodon melanotheron* and other species such as mullets and shrimps (Aheto 2004). Inhabitants from the neighbouring communities of Brenu Akyenim and Ampenyi-Ayensudo harvest resources from the lagoon for their livelihood, most especially in the dry season, when less farm activities takes place (Zuh et al. 2019). Fishing in the lagoon is mainly done using simple fishing gears chiefly cast nets and hooks, however, fishing is prohibited on Wednesdays (Aheto 2004). There is an indication of over-exploitation of the mollusc *Tympanotonus fuscata* is (Aggrey-Fynn 2010). The lagoon is also bordered by strands of mangroves, predominantly *Avicennia* sp. and small patches of marsh (Zuh et al. 2019). Evidence of mangrove harvesting in the past can be seen along the perimeter of the lagoon, which might have resulted in only patches of the mangrove *Avicennia* sp. remaining. Also, discharge of domestic sewage, dumping of refuse and agricultural run-offs into lagoon and the adjoining mangroves are major anthropogenic threats the lagoon (Aheto 2004).

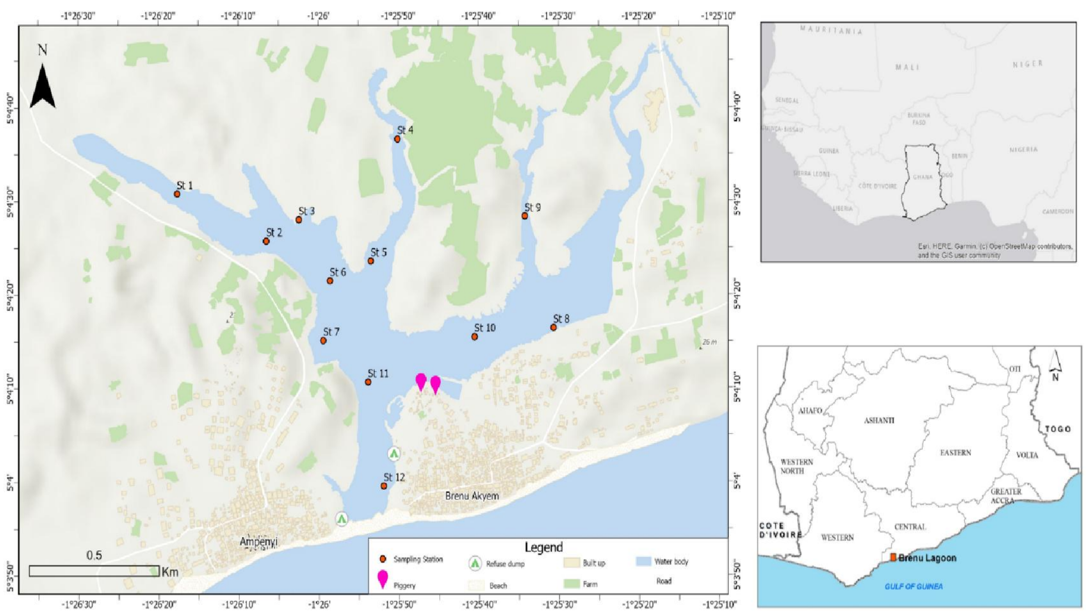

Fig. 1 Study area map

Sampling method:

Sampling was done in September 2020 (minor wet season) from twelve stations were demarcated across the lagoon. Physico-chemical parameters such as temperature (℃), salinity (ppt), pH, DO (mg/l), conductivity (µS/cm) and TDS (mg/l) were measured using a multi-parametric meter (Eutech PCD 650). Measurements were done in three replicates at all stations. Mean particles sizes (MPS) was determined following Yankson (2000). Organic matter content was determined using the weight loss on ignition method by burning sediments in a furnace at 550 °C for 4 hours to burn off the organic matter.

Benthic macroinvertebrates samples were collected from twelve stations as the environmental parameters, using a 0.0225 m^2 Ekman grab. The samples were screened through a set of sieves (2 mm, 1 mm and 0.5 mm) with the larger meshed sizes stacked above, the smaller ones, preserved in formalin and stained with eosin to aid sorting. Organisms collected were identified to the lowest possible taxonomic level using a dissecting microscope with the aid of some identification keys (Macan 1959, Day 1967, Edmunds 1978, Yankson & Kendall 2001, Gerber & Gabriel 2002, Al-yamani et al. 2012). Mean and standard errors were calculated. Analysis of variance (ANOVA) and subsequently Tukey's posthoc test was run to determine spatial variations in environmental parameters. With the benthic macroinvertebrates, frequency of occurrence (F index) described by Guille (1970) was determined as $F = pa/P \times 100$ where pa represents the number of samples a particular species occurred throughout the study period and P is the total number of samples collected throughout the study period. Using this formula, species were classified as constant (F ≥ 50 %), common (10 % < F < 49 %) and rare (F < 10 %). Species composition was computed $\frac{\text{Total number of a particular species}}{\text{Total number of all species}} \times 100$ while density was standardised to the number of individuals of each species per square meter. Species richness were computed by counting the number of species while species diversity was computed using Shannon Wiener index (H') in PRIMER v6 package based on the formula $H' = -\sum_{i=1}^{s} \mathrm{p_i} \ \mathrm{In}\ \mathrm{p_i}$ where s = number of species recorded, and pi = proportions of the i^{th} species. Data on macroinvertebrates were fourth root transformed to stabilise and normalise the variance prior to determination of species diversity. The similarity in benthic community structure among the stations were determined based on Bray-Curtis similarity index in PRIMER v6 package. Station classification was achieved using a complete linkage dendrogram and non-metric multidimensional scaling. SIMPROF test was used to determined similarity in benthic community structure among stations. The biotic index, BENTIX was used in the ecological classification of the various stations in the lagoon (Simboura & Zenetos 2002).

Results:

Variations in environmental factors in the Brenu Lagoon are shown in Table 1. Spatial variations were only observed in temperature and salinity ($p < 0.05$). Mean temperature ranged from 30.10 ℃ – 32.33 ℃, with St 9 and St 1 being significantly higher and lower respectively than most of the other stations. Salinity was generally high within the lagoon, with mean values ranging between 39.68 ppt to 42.14 ppt. Salinity at St 1 was significantly higher than most of the other stations. pH, DO and conductivity showed no significant variations spatially. Mean pH within this water body ranged from 8.67 – 9.37, with St 1 recording a comparatively lower value than the other stations. DO ranged between 5.93 mg/l – 6.70 mg/l with relatively low values in stations 11 and 12. Regarding conductivity, values ranged from 27.14 – 33.29 µS/cm, with relatively lower values at stations 1, 8 and 11.

Table 1: Spatial variations in environmental parameters within the Brenu Lagoon

Stations	Temperature (℃)	pH	DO (mg/l)	Salinity (ppt)	Conductivity (μScm^{-1})
St1	30.10 ± 0.25^{f}	8.67 ± 0.58	6.12 ± 0.05	42.14 ± 1.08^{a}	29.64 ± 3.55
St2	$30.63 \pm 0.03^{e,f}$	9.33 ± 0.03	6.06 ± 0.11	$41.60 \pm 0.04^{a,b,c}$	33.29 ± 0.02
St3	$30.93 \pm 0.13^{d,e,f}$	9.35 ± 0.01	6.22 ± 0.13	$41.83 \pm 0.01^{a,b}$	31.30 ± 1.00
St4	$30.77 \pm 0.07^{d,e,f}$	9.37 ± 0.00	6.43 ± 0.15	$40.71 \pm 0.02^{a,b,c,d}$	32.56 ± 0.03
St5	$31.40 \pm 0.06^{b,c,e,f}$	9.30 ± 0.00	6.70 ± 0.04	$40.04 \pm 0.01^{c,d}$	32.27 ± 0.01
St6	$31.50 \pm 0.00^{a,b,c,d,e}$	9.31 ± 0.01	6.53 ± 0.20	$40.65 \pm 0.01^{a,b,c,d}$	32.61 ± 0.01
St7	$32.07 \pm 0.03^{a,b}$	9.28 ± 0.01	6.48 ± 0.19	$40.37 \pm 0.26^{b,c,d}$	32.48 ± 0.00
St8	$31.97 \pm 0.12^{a,b,c}$	8.94 ± 0.34	6.10 ± 0.11	$40.10 \pm 0.26^{c,d}$	27.19 ± 4.92
St9	32.33 ± 0.27^{a}	9.34 ± 0.00	6.66 ± 0.03	$40.58 \pm 0.03^{a,b,c,d}$	32.54 ± 0.03
St10	$32.27 \pm 0.33^{a,b}$	9.13 ± 0.04	6.31 ± 0.13	$40.06 \pm 0.02^{c,d}$	30.53 ± 1.60

Fourteen (14) species comprising of 7 polychaetes, 2 crustaceans, 2 insects and 1 species each of Nemertea, Oligochaeta and Mollusca were encountered (Table 2). *Capitella capitata*, *Ampithoe* sp., *Pristina* sp., *Chironomus* sp., *Tympanotonus fuscatus* and *Lineus* sp. had F-index ≥ 50 % representing constant species. *Eunice* sp. and *Glycera* sp. were rare (F-index < 10 %) while the rest of the species were common (i.e. 10 % < F < 49 %). *Ampithoe* sp. had the highest density of 770.95 $ind.m^{-2}$, followed by *C. capitata* with a density of $ind.m^{-2}$. *Lineus* sp., *Pristina* sp., *Gammarus* sp., *Chironomus* sp., *T. fuscatus* and *Eurythoe* sp. had densities between 100 – 265 $ind.m^{-2}$ while the rest of the species had densities less than 100 $ind.m^{-2}$.

Table 2: Percentage frequency of occurrence and density of macroinvertebrate species in the Brenu Lagoon

Major group	Species	F-index	Density (ind.m^{-2})
Nemertea	*Lineus* sp.	50.00	261.47
Crustacea	*Ampithoe* sp.	91.67	770.95
Crustacea	*Gammarus* sp.	16.67	236.80
Insecta	*Hydropsyche* sp.	33.33	92.50
Insecta	*Chironomus* sp.	75.00	171.02
Polychaeta	*Eurythoe* sp.	41.67	106.56
Polychaeta	*Rhodine* sp.	25.00	19.73
Polychaeta	*Capitella capitata*	100.00	693.13
Polychaeta	*Eunice* sp.	8.33	14.80
Polychaeta	*Glycera* sp.	8.33	44.40
Polychaeta	*Nereis* sp.	25.00	34.53
Polychaeta	*Phyllochaetopterus sp.*	41.67	53.28
Oligochaeta	*Pristina* sp.	91.67	238.15
Mollusca	*Tympanotonus fuscatus*	66.67	155.4

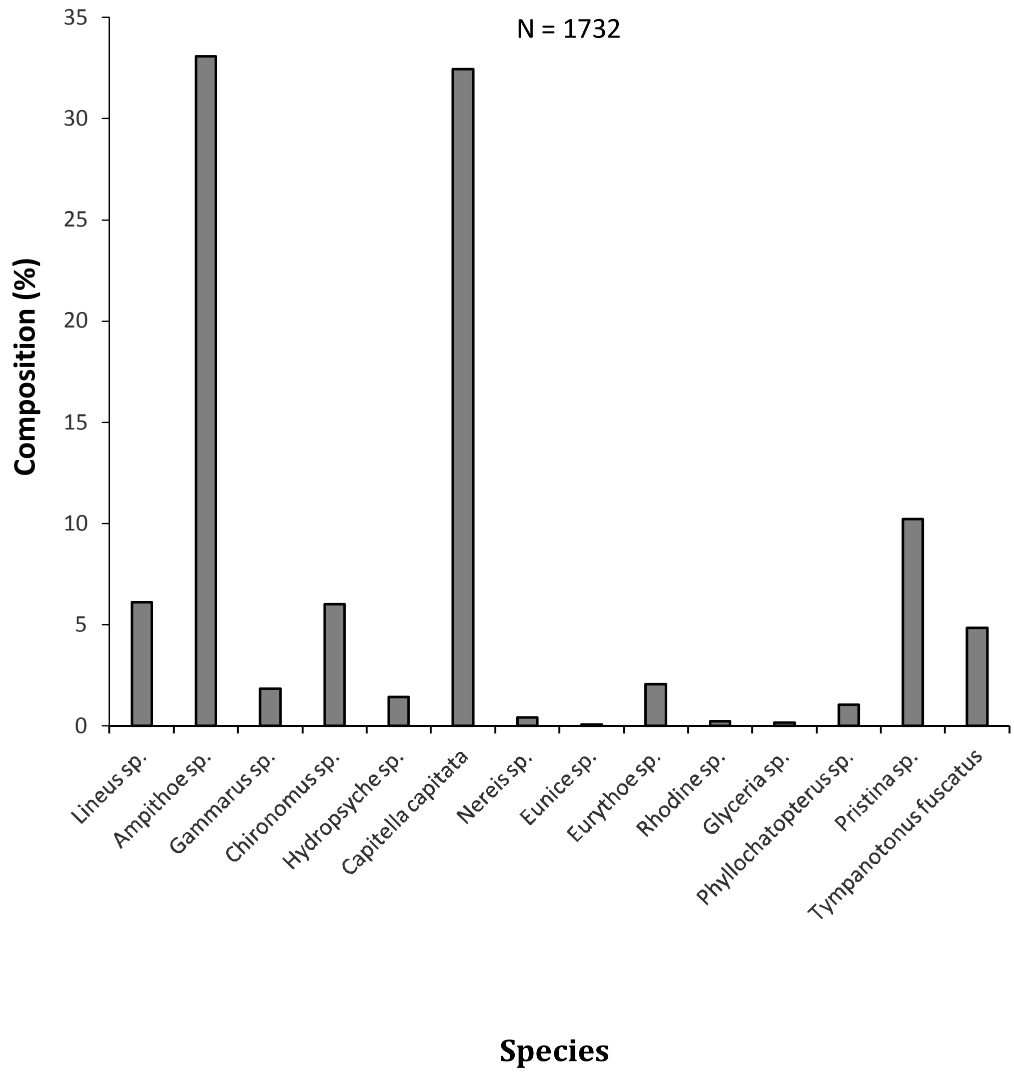

Fig. 2: Overall percentage composition of macroinvertebrate species in the Brenu Lagoon

A total of 1732 individual specimens of benthic macroinvertebrates were encountered of which *Ampithoe* sp. accounted for 33.08 % and *Capitella capitata* constituted 32.45 % (Figure 2). This was followed by *Pristina* sp. (10.22 %), *Lineus* sp. (6.12 %) and *Chironomus* sp. (6.00 %). This rest of the species had < 5 % composition.

Spatial distribution of benthic macroinvertebrates in the lagoon is shown in Table 3. Generally, *Ampithoe* sp. and *Capitella capitata* dominated at all stations in the Brenu Lagoon. *Chironomus* sp., *Pristina* sp. and *Tympanotonus fuscatus* also showed prominence in a number of stations. *Eunice* sp., for instance, occurred only at St 11 with a composition of 0.74 %. Similarly, *Glycera* sp. was present at St 2, recording only 1.52 %. *Gammarus* sp. was found at only Stations 1 and 2 recording 3.80 % and 13.13 % respectively. There was general patchiness in species distribution in the lagoon.

Table 3: Percentage composition of macroinvertebrate species at the various stations in the Brenu Lagoon (Dominant species are in bold)

Major group	Species	St 1	St 2	St 3	St 4	St 5	St 6	St 7	St 8	St 9	St 10	St 11	St 12
Nemertea	*Lineus* sp.			3.73			26.77		18.40	1.96		10.37	1.18
Crustacea	***Ampithoe* sp.**		**35.35**	**38.51**	**69.05**	**12.63**	**1.52**	**53.00**	**42.94**	**16.67**	**80.17**	**44.44**	**40.00**
Crustacea	*Gammarus* sp.	3.80	13.13										
Insecta	*Chironomus* sp.	25.32		8.07	0.79	1.05	1.01		0.61	34.31	1.72	5.93	
Insecta	*Hydropsyche* sp.	0.63				8.95	2.53						2.35
Polychaeta	***Capitella capitata***	**55.06**	**42.93**	**40.99**	**26.98**	**24.74**	**23.23**	**35.00**	**23.31**	**44.12**	**15.52**	**30.37**	**23.53**
Polychaeta	*Nereis* sp.	0.63				1.58			1.84				
Polychaeta	*Eunice* sp.											0.74	
Polychaeta	*Eurythoe* sp.	8.23				8.42	2.02	1.00					2.35
Polychaeta	*Rhodine* sp.		1.01		0.79	0.53							
Polychaeta	*Glycera* sp.		1.52										
Polychaeta	*Phyllochaetopterus* sp.		2.02	1.86				2.00	1.23			5.19	
Oligochaeta	*Pristina* sp.	5.06		4.97	0.79	42.11	15.15	8.00	4.91	2.94	2.59	1.48	30.59
Mollusca	*Tympanotonus fuscatus*	1.27	4.04	1.86	1.59		27.78	1.00	6.75			1.48	

Species diversity and richness were lower in Stations 4, 7, 9, 10 and 11, with the rest of the stations having comparable richness and diversity (Figure 3). Stations 1, 5, 6, 8, and 11 each had eight (8) species, representing the highest number per station, while the lowest species richness of 4 was reported at Station 10, followed by five (5) species at Station 9. Correspondingly, species diversity was lowest at stations 10 and 9 with values of 1.31 and 1.56, respectively. Species diversity for the entire lagoon was 2.54 while species richness was 14.

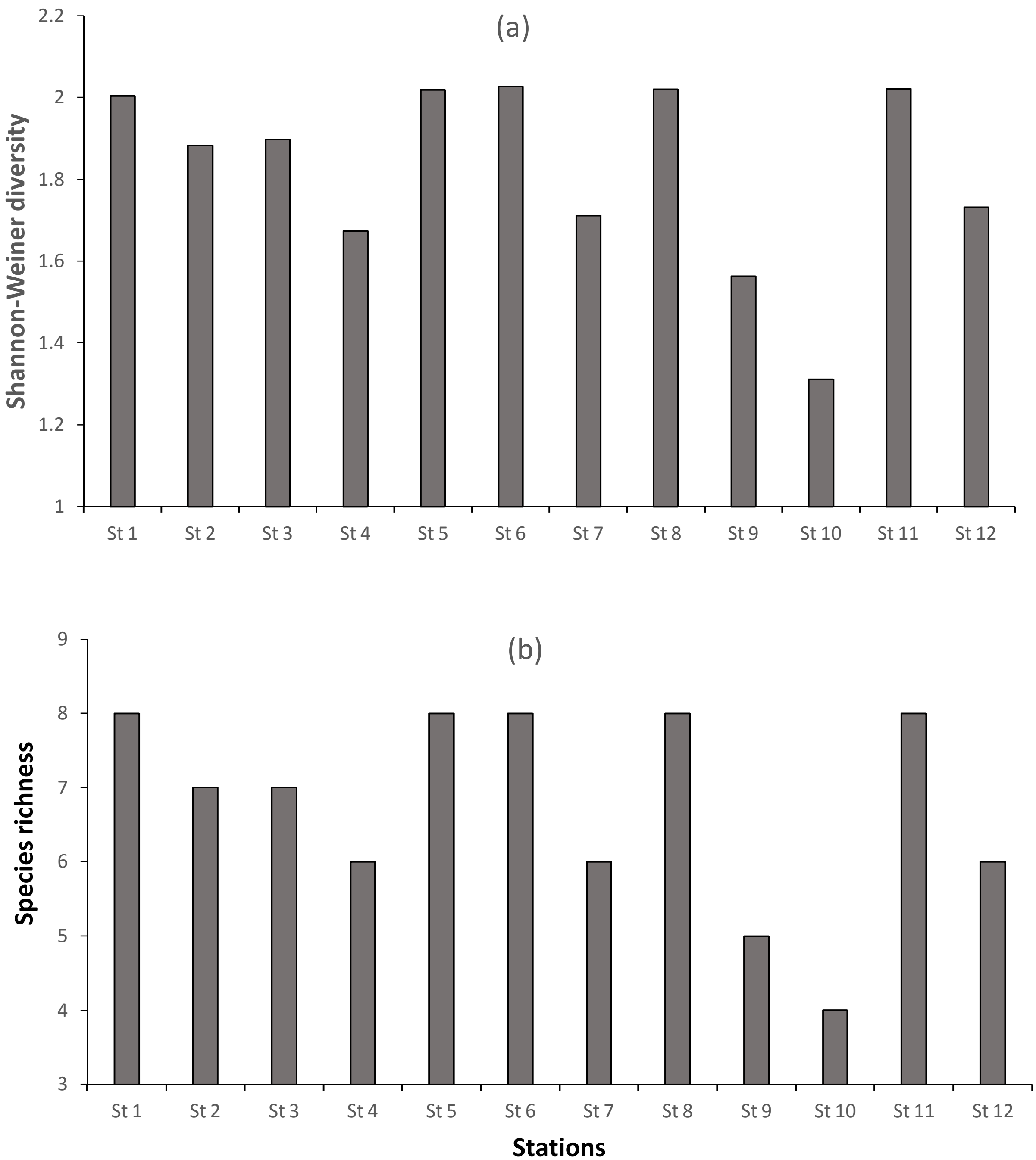

Fig. 3: Species diversity and richness at the various stations in the Brenu Lagoon

Figure 4 is a dendrogram showing Bray-Curtis similarity of stations based on benthic macroinvertebrates data. All stations were similar at 37.82 %. SIMPROF test indicates the similarity in benthic community structure among stations was significant ($p < 0.05$).

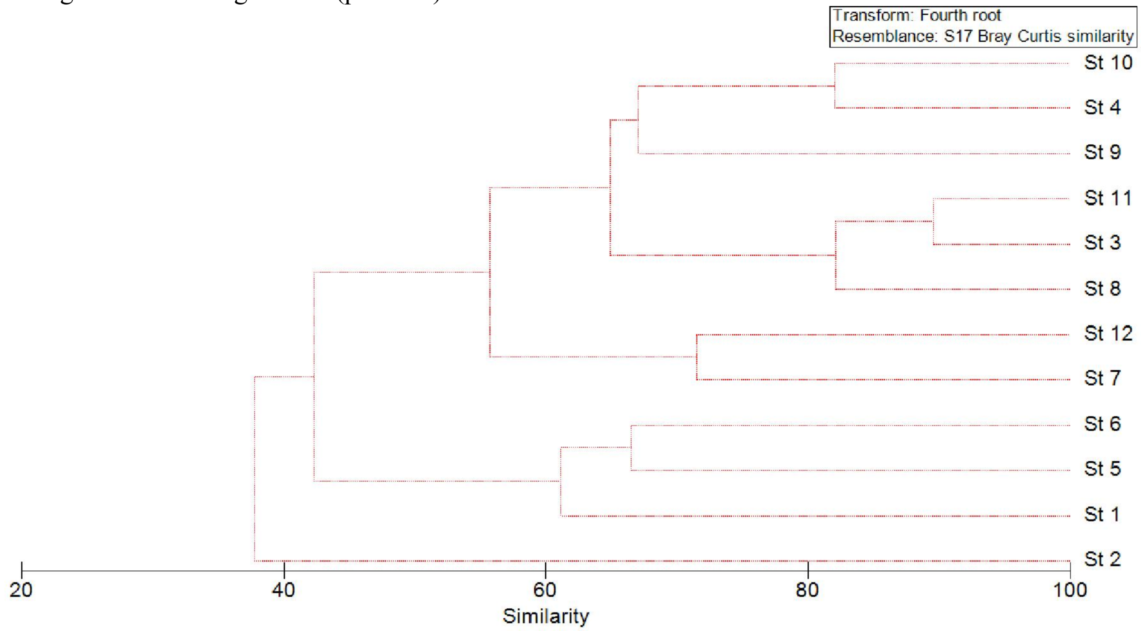

Figure 4: Complete linkage of Bray-Curtis similarity of benthic macroinvertebrates among stations in the Brenu Lagoon (red lines indicate significant evidence of structure, p < 0.05 by SIMPROF test)

Figure 5 shows nmMDS ordination plot indicating similarity of macroinvertebrate species composition and abundance among stations. At a similarity of 40%, two main groups were formed; St 2 on one hand, and the rest of the stations on the other. Within the bigger group, further similarities were seen among the stations. At 60% similarity, stations 1, 5 and 6 formed one group, station 7 and 12 formed another while at the same time, station 7 was similar to stations 3, 4, 7, 8, 9, 10 and 11. At 80 %, stations 4 and 10 were similar, and stations 3, 8 and 11 were similar. The rest of the stations showed no similarity to one another at 80 %.

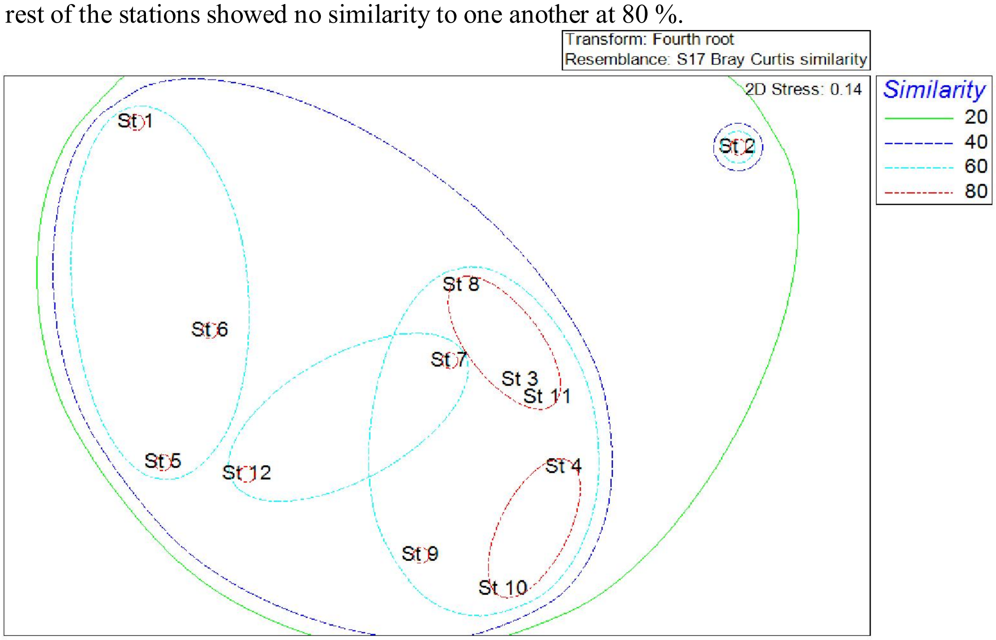

Figure 5: Non-metric Multidimentional scaling (nmMDS) of stations based on benthic macroinvertebrates abundance and composition in the Brenu Lagoon

Table 4 shows BENTIX scores and classifications for the various stations in the lagoon. St 6 was of good quality while the rest of the stations were between moderate and poor status. Stations 3, 4, 7, 9, 10 and 12 were of poor quality. The Brenu Lagoon, in totality, was of moderate quality.

Table 4: BENTIX scores and respective classifications for the various stations in the Brenu Lagoon

Stations	GS (sensitive)	GT (tolerant)	No. Species	No. Specimens	Sum GS	Sum GT	Bentix	EQR	Classification
St 1	13.92%	86.08%	8	158	22	136	2.56	0.43	Moderate
St 2	20.71%	79.29%	7	198	41	157	2.83	0.47	Moderate
St 3	7.45%	92.55%	7	161	12	149	2.30	0.38	Poor
St 4	1.59%	98.41%	6	126	2	124	2.06	0.34	Poor
St 5	17.37%	82.63%	8	190	33	157	2.69	0.45	Moderate
St 6	59.09%	40.91%	8	198	117	81	4.36	0.73	Good
St 7	4.00%	96.00%	6	100	4	96	2.16	0.36	Poor
St 8	26.38%	73.62%	8	163	43	120	3.06	0.51	Moderate
St 9	1.96%	98.04%	5	102	2	100	2.08	0.35	Poor
St 10	0.00%	100.00%	4	116	0	116	2.00	0.33	Poor
St 11	17.78%	82.22%	8	135	24	111	2.71	0.45	Moderate
St 12	5.88%	94.12%	6	85	5	80	2.24	0.37	Poor
ALL	17.61%	82.39%	14	1732	305	1427	2.70	0.45	Moderate

Discussion

Healthy and undisturbed environments are characterized by high species richness and diversity (Turkmen & Kazanci 2010). Species diversity values above 3.0 indicate that the structure of the habitat is stable and balanced; the values under 1.0 indicate that there are pollution and degradation of habitat structure. This implies that diversity indices ranging between 1.31 to 2.0 reported at the various stations sampled is an indication of a not so stable environment. This may be due to hypersaline conditions encountered in this lagoon with minimum salinity of about 40. Salinity values recorded in this lagoon are comparable to values recorded by Dzakpasu (2019) in the hypersaline Muni Lagoon. Salinity as high as 59.50 ppt has been recorded in this lagoon in a previous study (Aggrey-Fynn 2010). The hypersaline nature of this lagoon is an indication of stress for many benthic organisms. This is similar to the situation at the Muni Lagoon, a hypersaline lagoon of up to 165ppt salinity during the dry season, where Gordon (2000) found no benthos during the dry season even though all other environmental parameters within that lagoon were well within acceptable limits (Gordon et al. 2000). Interestingly, the overall species diversity of the Brenu lagoon indicated a moderately balanced and stable structure. The species diversity encountered in this lagoon is higher than Fosu (Armah et al. 2012) and Sakumo (Dzakpasu 2019).

At all sampling stations however, there was a dominance of stress-tolerant species *Ampithoe* sp. and *Capitella capitata* indicative of some degree of stress within the entire lagoon system. Nevertheless, there were variations among the stations where 6 stations showed a higher degree of stress than others (Table 4) even though salinity remained quite stable at all the stations sampled. This pattern observed is indicative of other possible stressors or pollutants creating an unfavourable environment for sensitive species. However, temperature, DO, pH and Conductivity levels measured were conducive for many benthic macroinvertebrate species. Temperature values recorded in this study are similar to other coastal water bodies in the subregion (Davies et al. 2008, Dzakpasu 2019, Ewa et al. 2011, Nirmal Kumar et al. 2010). Aggrey-Fynn (2010) recorded temperature values of 26.15 – 32.90 ℃ in this lagoon. pH within the Brenu Lagoon is alkaline. Alkaline conditions were reported in other closed lagoons such as the Fosu and Muni (Dzakpasu 2019). DO values in this lagoon are within ranges conducive to the survival of many aquatic organisms. Fluctuations among stations were minimal compared to 2.18 – 9.45 mg/l reported by Aggrey-Fynn (2010). According to Scannell and Jacobs (2001), conductivity values lower than 1500 mg/l are good for the growth and survival of aquatic organisms implying conditions within this lagoon (< 35 mg/l) are healthy. Likewise, conductivity values less than 200 µS/cm are indicative of healthy or clean environments (Horne & Goldman 1994).

On the basis of the pattern observed, it is important to explore other potential stressors or pollutant sources to provide a better understanding of the dynamics of the Brenu Lagoon. As mentioned earlier, two major communities border the lagoon – Brenu Akyenim and Ampenyi-Ayensudo. Agriculture is a source of livelihood for the residents in both communities and these agricultural lands are in close proximity to the lagoon (Fig 1). Possible runoffs from these lands during rain events potentially drain organic fertilizers, pesticides and other agrochemicals into the lagoon. Again, pockets of waste dumps have been created along the perimeter of the lagoon. These wastes along with their leachates are also discharged into the lagoon, particularly during heavy rain events. Also, several abandoned salt pans can also be found around the lagoon which may contribute to high salinity in the sediments depending on the length of time since abandonment, flooding regime and the drainage of the lagoon (Bouzillé et al. 2001). Consistent with this, the stations that recorded poor BENTIX scores were located closer to areas of human activity as shown in Fig.1 and several studies have found that these types of anthropogenic activities impact benthic macroinvertebrate community structure (Armah et al. 2012, Devi et al. 2013, Gichana et al. 2015).

Conclusion and Recommendations:
The Brenu Lagoon is moderately polluted and the most obvious stressor from this study is the hypersaline conditions within this ecosystem. However, the variations in the level of pollution within the stations sampled despite the stability of salinity levels measured indicate the presence of other potential stressors which may be impacting the benthic community structure. Human activities, including waste disposal and agriculture by residents of the communities bordering the lagoon, are potential sources of pollutants that may leak into the water body and impact the stability of the ecosystem. Despite the current status of the lagoon, there are still opportunities to improve or restore the health of the lagoon if the stressors are identified. There is, therefore, the need for further research to establish the linkage between these identified anthropogenic activities and the current state of the lagoon. There is the need to investigate pollutants that may be present in the water body, identify the sources of these pollutants and determine the impact of these pollutants on macrofauna within the water body since the community relies on these as a source of protein and livelihood.

Declarations
Funding: Not Applicable
Conflicts of interest/Competing interests: No conflicts/competing interest
Ethics approval: Ethics approval was not required for this study
Consent to participate: Not Applicable
Consent for publication: Not Applicable
Availability of data and material (data transparency): All data produced from this study are provided in this manuscript
Code availability (software application or custom code): Yes

Author's contributions: MFAA and SA were involved in the conceptualization and research design, data collection, analyses and interpretation, writing, review and editing of the manuscript. RA, GLAD and ISGA were involved in data collection, writing and editing of the manuscript. All authors read and approved the final manuscript.

Running head: The state of Brenu Lagoon, Ghana

References
1. Aggrey-Fynn J (2010) Length-Weight Relationship and Distribution of *Tympanotonus Fuscata* (Mollusca: Potamididae) in Brenu Lagoon, Ghana. *Journal of the Ghana Science Association*. https://doi.org/10.4314/jgsa.v12i2.62796
2. Aheto DW (2004) *Community involvement in mangrove ecosystem utilization: The case study of Kuve and Brenu, Ghana*. MSc. Thesis (University of Bremen).
3. Al-yamani FY, Skryabin V, Boltachova N, Revkov N, Makarov M, Grintsov V, Kolesnikova E (2012) *Illustrated Atlas on the Zoobenthos of of Kuwait*. Kuwait: Kuwait Institute of Scientific Research. https://doi.org/10.1093/plankt/fbs079
4. Armah FA, Ason B, Luginaah I, Essandoh PK (2012) Characterization of macro-benthic fauna for ecological health status of the Fosu and Benya lagoons in coastal Ghana. *Journal of Ecology and Field Biology*, *35*(4), 279–289. https://doi.org/10.5141/JEFB.2012.033
5. Armah FA, Luginaah I, Essandoh PK, Afrifa EK (2012) Ecological Health Status of the Fosu Lagoon, Southern Ghana I: Biotic Assessment. *Journal of Ecosystem & Ecography*, *02*(03), 110–119. https://doi.org/10.4172/2157-7625.1000110
6. Bonada N, Prat N, Resh VH, Statzner B (2006) Developments in aquatic insect biomonitoring: A comparative analysis of recent approaches. *Annual Review Entomology*, *51*, 495–523. https://doi.org/10.1146/annurev.ento.51.110104.151124
7. Bouzillé JB, Kernéis E, Bonis A, Touzard B (2001) Vegetation and ecological gradients in

abandoned salt pans in western France. *Journal of Vegetation Science*, *12*(2), 269–278. https://doi.org/10.2307/3236611
8. Christie AP, Amano T, Martin PA, Petrovan SO, Shackelford GE, Simmons BI., … Sutherland WJ (2020) Poor availability of context-specific evidence hampers decision-making in conservation. *Biological Conservation*, *248*(July), 108666. https://doi.org/10.1016/j.biocon.2020.108666
9. Costanza R, d'Arge R, de Groot R, Farberll S, Grassot M, Hannon B, … van den Belt M (1997) The value of the world's ecosystem services and natural capital, *387*(May), 253–260.
10. Davidson NC (2014) How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research*, *65*(10), 934–941. https://doi.org/10.1071/MF14173
11. Davies OA, Ugwumba AAA, Abolude DS (2008) Physico-chemistry quality of Trans-Amadi (Woji) creek Port Harcourt, Niger Delta, Nigeria. *Journal of Fisheries International*, *3*(3), 91–97.
12. Day JH (1967) *A monograph on the polychaete of Southern Africa, Part I (Errantia) and Part II (Sedentaria)*. London: Trustees of the British Museum, Natural History.
13. Devi TSR, Shah DN (2013) Evaluation of benthic macroinvertebrate assemblage for disturbance zonation in urban rivers using multivariate analysis: Implications for river management. *Journal of Earth System Science*, *122*(4), 1125–1139. https://doi.org/10.1007/s12040-013-0317-8
14. Doamekpor LK, Abusa Y, Ketemepi HK, Klake RK (2018) Assessment of heavy metals in water and sediments of Sakumo II, Chemu and Kpeshie Lagoons - Ghana. *West African Journal of Applied Ecology*, *26*(2), 56–71. https://doi.org/10.4314/wajae.v26i2
15. Donaldson MR, Burnett NJ, Braun DC, Suski CD, Hinch SG, Cooke SJ, Kerr JT (2017) Taxonomic bias and international biodiversity conservation research. *Facets*, *1*(1), 105–113. https://doi.org/10.1139/facets-2016-0011
16. Dzakpasu MFA (2019) *Ecological assessment of some caostal lagoons and estuaries in Ghana: Abiotic and biotic approaches*. University of Ghana. Retrieved from http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI
17. Dzakpasu MFA, Yankson K (2015) Hydrographic characteristics of two estuaries on the south western coast of Ghana. *New York Science Journal*, *8*(4), 60–69. https://doi.org/10.1017/CBO9781107415324.004
18. Edmunds J (1978) *Sea shells and other molluscs found on West African coast and estuaries*. Accra: Arakan Press Ltd.
19. Ewa EE, Iwara AI, Adeyemi JA, Eja EI, Ajake AO, Otu CA (2011) Impact of industrial activites on water quality of Omoku Creek. *Sacha Journal of Environmental Studies*, *1*(2), 8–16.
20. Gerber A, Gabriel MJM (2002) *Aquatic invertebrates of South African rivers field guide* (1st ed.). Pretoria, South Africa: Institute of Water Quality Studies.
21. Gichana Z, Njiru M, Raburu PO, Masese FO (2015) Effects of human activities on benthic macroinvertebrate community composition and water quality in the upper catchment of the Mara River Basin, Kenya. *Lakes and Reservoirs: Research and Management*, *20*(2), 128–137. https://doi.org/10.1111/lre.12094
22. Gordon C (2000) Hypersaline lagoons as conservation habitats: Macro-invertebrates at Muni Lagoon, Ghana. *Biodiversity and Conservation*, *9*(4), 465–478. https://doi.org/10.1023/A:1008906503227
23. Gordon C, Ntiamoa-Baidu Y, Ryan JM. (2000) The Muni-Pomadze Ramsar site. *Biodiversity and Conservation*, *9*(4), 447–464. https://doi.org/10.1023/A:1008954302319
24. Heino J, Muotka T, Paavola R (2003) Determinants of macroinvertebrate diversity in headwater streams : regional and local influences, 425–434.
25. Horne AJ, Goldman, CR (1994) *Limnology* (2nd ed.). New York: McGraw-Hill, Inc.
26. Karikari A, Asante K, Biney C (2009) Water quality characteristics at the estuary of Korle Lagoon in Ghana. *West African Journal of Applied Ecology*, *10*(1). https://doi.org/10.4314/wajae.v10i1.45700
27. Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, … Bay M (2006) and Coastal Seas. *Science*, *312*(June), 1806–1809.
28. Macan TT (1959) *A guide to freshwater invertebrate animals*. London: Longman.
29. Mensah J, Enu-Kwesi F (2019) Implications

of environmental sanitation management for sustainable livelihoods in the catchment area of Benya Lagoon in Ghana. *Journal of Integrative Environmental Sciences*, *16*(1), 23–43. https://doi.org/10.1080/1943815X.2018.1554591

30. Moulton TP, Magalhães-Fraga SAP, Brito EF, Barbosa FA (2010) Macroconsumers are more important than specialist macroinvertebrate shredders in leaf processing in urban forest streams of Rio de Janeiro, Brazil. *Hydrobiologia*, *638*, 55–66. https://doi.org/10.1007/s10750-009-0009-1
31. Niesenbaum RA (2019) The integration of conservation, biodiversity, and sustainability. *Sustainability (Switzerland)*, *11*(17). https://doi.org/10.3390/su11174676
32. Nirmal Kumar JI, George B, Kumar RN, Sajish PR, Viyol S (2010) Assessment of spatial and temporal fluctuations in water quality of a tropical permanent estuarine system - Tapi, West Coast India. *Applied Ecology and Environmental Research*, *7*(3), 267–276. https://doi.org/10.15666/aeer/0703_267276
33. Nkwoji JA, Ugbana SI, Ina-salwany MY (2020) Impacts of land-based pollutants on water chemistry and benthic macroinvertebrates community in a coastal lagoon , Lagos , Nigeria. *Scientific African*, *7*, e00220. https://doi.org/10.1016/j.sciaf.2019.e00220
34. Odjer-Bio NT, Belford EJD, Ansong M (2015) What is happening to our Lagoons? The example of Butuah Lagoon in Ghana. *International Journal of Energy and Environmental Engineering*, *6*(2), 183–193. https://doi.org/10.1007/s40095-015-0165-1
35. Scannell PW, Jacobs LL (2001) Effects of Total Dissolved Solids On Aquatic Organisms, 7.
36. Simboura N, Zenetos A (2002) Benthic indicators to use in ecological quality classification of Mediterranean soft bottom marine ecosystems, including a new Biotic Index. *Mediterranean Marine Science*, *3*(2), 77–111. https://doi.org/10.12681/mms.249
37. Turkmen G, Kazanc N (2010) Applications of various diversity indices to benthic macroinvertebrate assemblages in streams of a natural park in Turkey. *Review of Hydrobiology*, *3*(2), 111–125.
38. United Nations Industrial Development Organization (2019) *Health and pollution action plan (HPAP); Republic of Ghana*.
39. Willoughby N, Grimble R, Ellenbroek W, Danso E, Amatekpor J (2001) The wise use of wetlands: Identifying development options for Ghana's coastal Ramsar sites. *Hydrobiologia*, *458*, 221–234. https://doi.org/10.1023/A:1013158329107
40. Yankson K (2000) Aspects of conchological features of *Anadara senilis* in relation to the nature of substratum. *Journal of Ghana Science Association*, *2*, 123–128.
41. Yankson K, Kendall M (2001) *A student's guide to the fauna of seashores in West Africa*. Newcastle: Darwin Initiative.

9/2/2021