

# Fish as bioindicators of habitat degradation in coastal lagoons of Ghana

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**Abstract.** Eugenia BB, Armah AK, Dankwa HR. 2019. Fish as bioindicators of habitat degradation in coastal lagoons of Ghana. *Bonorowo Wetlands* 9: 9-26. Lagoons' habitat forms an integral part of the marine fishing industry and provides essential spawning and nursery grounds for many fishes. Fish act as biological indicators of water quality and changes by summarizing information regarding their environment. Two lagoons, Laloi and Oyibi, in the Greater Accra and Central Regions of Ghana were studied to determine the ecological status using the Estuarine Fish Community Index (EFCI). Metrics assigned were the species diversity, nursery function, trophic integrity, and species abundance and composition. Water samples were obtained at the riverine, middle, and seaward portions during both high and low tides at each site. Fisherfolks were hired to fish at each of the sites. There are no significant differences between sites as measured by diversity indices. Multivariate analysis showed a considerable similarity between sites regarding species composition. This study identified eighteen species, including both finfish and shellfish. During the study, the two most abundant species were the flathead grey mullet (*Mugil cephalus*) and the black-chinned tilapia (*Sarotherodon melanotheron*). *Mugil cephalus* dominated catches in the Laloi lagoon, whereas *Sarotherodon melanotheron* was dominant in the Oyibi Lagoon. The most predominant species collected for the Laloi lagoon were *S. melanotheron*, *Lutjanus fulgens*, and *Eucinostomus melanopterus*. *Caranx hippos*, *L. fulgens*, and *M. cephalus* constituted a significant part of fishes caught in the Oyibi lagoon. The carangid, *Caranx hippos* contributed primarily to the biomass of fishes collected for both lagoons. In the rainy season, total fish abundance was higher than in the dry season. Chlorophyll-a concentrations and condition factors of *S. melanotheron* were highest at both lagoons. Total organic carbon was high in the Oyibi lagoon; hence, the high numbers of *S. melanotheron* recorded. Tides were an essential factor affecting physicochemical parameters. Oyibi displayed a moderate site rating, suggesting that it was under mild stress with some stress factors identified were garbage dumping, defecation, land-use changes, and increased human pressure. Meanwhile, Laloi Lagoon had a poor site rating, suggesting severe stress. The principal strains identified were overfishing, garbage dumping, mangrove degradation, and increased human settlements along the sides of the lagoon. The multi-metric index described served as an effective method that reflects the status of lagoon fish communities and the overall ecosystem conditions.

**Keywords:** Bioindicator, coastal lagoon, fish

## INTRODUCTION

Lagoons are relatively shallow water that has been partly or wholly sealed off from the sea by forming barriers. The barriers are built up above high tide level by wave action and lie parallel to the shoreline (Kjerfve 1994; Hill 2001). It is a highly productive coastal feature that provides a range of natural services society values. There are over 90 coastal lagoons in Ghana, which cover less than 5 km<sup>2</sup> in the surface area along the 550 km, which forms 7% of the total land area of Ghana (Armah 2005). Lagoons present unique environments and habitats supporting valuable products and services, including fisheries, flood assimilation, regulation and supply of water, and biodiversity protection.

Most tropical lagoons are associated with mangrove swamps. These mangroves serve as a habitat for finishes, migratory birds, and hellfish. They also absorb pollutants from upland sources and coastal, protect the coast against erosion, trap sediments from rivers and accumulate washed silt to increase the ground level, stabilize shorelines and improve water quality (Entsua-Mensah 2002). In Ghana, the majority of mangrove species are *Rhizophora* spp and *Avicennia* spp. These mangrove species are threatened by

salt winning and indiscriminate harvesting as fuelwood for cooking and smoking of fish. Observation has shown that the mangroves, which filter inland water as it flows to the sea and serves as a nursery and habitat for many shells and finfish, are being rapidly destroyed (Entsua-Mensah 1996). Lagoons in Ghana are used in artisanal fisheries and play a significant role in the economy of some coastal inhabitants, particularly during the off-season for marine fishing (Entsua-Mensah et al., 2004).

Environmental conditions underlie the productivity of fisheries (Finney et al. 2002; Wynne & Cote 2007) and fishing on the ecosystem. Fishing activities affect the benthic fauna and habitat, fish community structure, and trophic interaction. Overfishing and reducing fish catches of some fish species have affected the rural fishing economies (Entsua-Mensah 2006). One of the types of over-fishing that occurs in most coastal lagoons is growth overfishing. Growth overfishing is when fish are caught at an average size that is smaller than the per recruit, and recruitment overfishing is when the mature adult population is reduced to a level where it is no longer has the reproductive capacity to replenish itself, thus not enough adults to produce offspring. Overfishing impacts fisheries' livelihoods through income and profit reduction

directly, increasing competition and conflicts over fishing grounds, resources of the fishery, and markets (Entsua-Mensah 2006). Because of increased pressure in fish stock and dwindling stocks, small-scale fishers have started using fine mesh nets, explosives, poisons, putting further pressure on the resource (Bailey 1994; Entsua-Mensah 2006).

Some of the additional pressures in this urbanized coastal area include loss of natural habitat through physical change to the system and discharge of potentially toxic materials into the wetland that can change both aquatic species diversity and the ecosystem due to their toxicity and accumulative behavior (Heath 1987). Degradation of wetlands ultimately caused narrowing of the habitat dimensions, thus, reducing the survival ability of species which cannot adapt (Jude and Pappas 1992). The complexity of fishing gears, excessive fishing pressure, and overexploitation are factors that have an adverse impact on the lagoon ecosystem (Koranteng 1995). Laé (1997) observed that fishing activities could change species composition, size class, structure, and annual fish yields. When fishing activity is high, fish diversity declines and alters the trophic system.

Fish and other species act as biological indicators of water quality and alterations. Fish responds to the cumulative effects of both physical and chemical disturbances to the water in which they live. Bioindicators refer to organisms and their attributes, which could be utilized to assess the environment's health (Peakall, 1992). They can be used to detect changes in the natural environment, monitor for the presence of pollution and its impact on the ecosystem in which the organism living, test substances like drinking water for the existence of contaminants, monitor the progress of environmental cleanup (O' Connor and Ehler 1991; Davis 1993). The most significant reasons for using bioindicators are the direct determination of synergistic and antagonistic effects of multiple pollutants on an organism, the early recognition of pollutants damage to organisms, and toxic dangers to humans. A bioindicator is also relatively low cost compared to technical measuring methods (Zimmermann and Umlauff-Zimmermann 1994). Bioindicators provide the following information for ecosystem management according to Lorenz (2003): a description of ecosystem processes and structures, cause-effect relationships with an ecosystem, and ecosystem condition by comparing the ecosystem with a reference level of proper ecological functioning.

Fish has widely used in the biomonitoring of water pollution because of its unique biological characteristics such as relatively big body size, ease to raise, and long-life cycle (Qunfang et al. 2008). Moreover, fish species are at the top position in the aquatic food chain and might directly affect the health of humans, which makes biomonitoring using fish much more significant. Fish health also reflects the state of pollution very well because of their limited ability to eliminate contaminants (Sucman et al., 2006). Fish serve as an excellent indicator of watershed health because all their life is spent in the water and differ in their tolerance to amount and types of pollution. Fish are easy to collect with the right equipment, easy to identify in the

field, and live for several years. They provide an accurate assessment of environmental health because they have long life spans and therefore can reflect long and short-term water resource quality; they offer a broad spectrum of community tolerances from very sensitive to highly tolerant species. Because they spend their entire life span in water, they integrate the waters' physical, chemical, and biological histories, and they are less affected by natural microhabitat discrepancies than smaller organisms (Holt and Miller 2011).

The objectives of this research are to compare the species diversity, composition, and abundance of the Oyibi and Laloi lagoons of Ghana, determine the similarities and dissimilarities in species composition, ascertain any effects of physicochemical parameters on the distribution of species, to determine the ecological status of the Oyibi and Laloi lagoons.

## MATERIALS AND METHODS

### Study sites

The study sites are taken within the central coast with two rainy seasons, reaching its maximum in May-June, and the minor seasons start in mid-August and end in October. The average rainfall is 735 mm. The typical economic activities in the catchment of the lagoons are salt winning and fishing. The study was conducted in the Laloi (Greater Accra) and Oyibi (Central regions of Ghana) lagoons (Figure 1-2). The sites are situated at Kpone and Nsuekyiri (near Winneba) and were chosen due to their easy accessibility and economic significance.

### Laloi Lagoon

The Laloi lagoon is located within latitude 5.42.30 N and longitude 0.04.35 E, with a total area of 0.695 km<sup>2</sup> (Gordon et al. 1998). It is situated at Prampram and enters the sea at Kpone, which lies in the Tema Export Processing Zone. The lagoon serves an essential economic role in the community by providing fish for domestic purposes and income. The typical economic activity in this area is salt mining and fishing. The lagoon is open all year round, but it is not fished on Tuesdays. Fish landed from the lagoon can only be boiled or smoked. The main fishing gears employed are the dragnets, cast nets, and traps mainly for crabs. Boys mostly use the traps for the blue-swimming legged crab, *Callinectes* sp. The trap is baited and allowed to float in the area. The Gao lagoon feeds the lagoon.

### Oyibi Lagoon

The Oyibi lagoon falls within latitude 5°21'N and longitude 1°36' E with a size of 0.300 km<sup>2</sup> and a mean depth of 0.5 m (Gordon et al. 1998). It is located at the mouth of the Ayensu River and close to Winneba. The lagoon joins the sea at Warabeba, a fishing village with Essuekyir at the northern side of the lagoon and the women mostly fishmongers. There is extensive mangrove cover around the lagoon with mangrove species, including *Rhizophora racemosa* and *Avicennia germinans*. The

primary economic activity at the site is fishing and salt production. The lagoon water is not used to produce salt, but seawater is pumped into pans. The lagoon is open throughout the year but is not fished on Wednesdays. The main fishing gears used in the lagoon are the cast and drag nets.

### Field methods

Each of the sites was visited once a month during the six months. Tide predictions were made by the Ghana Ports and Harbour Authority (GHAPHA). To ascertain any tidal influence on physicochemical parameters, water samples were collected from the seaward, riverine, and middle reaches during low and high tides.

### Sampling

Sampling was performed from January to May 2012.

### Fish sampling methods

Fisherfolks were hired to fish at each location, and the fish samples were also bought from fisherfolks to represent the fish species at each location. The main fishing gear used at the sites was the cast net of mesh size 2.5 cm. Fishing was done during high and low tides. Fish harvested were sorted out according to species and stored in an ice chest before further identification was transported to the laboratory. Fish samples were done from January to May.

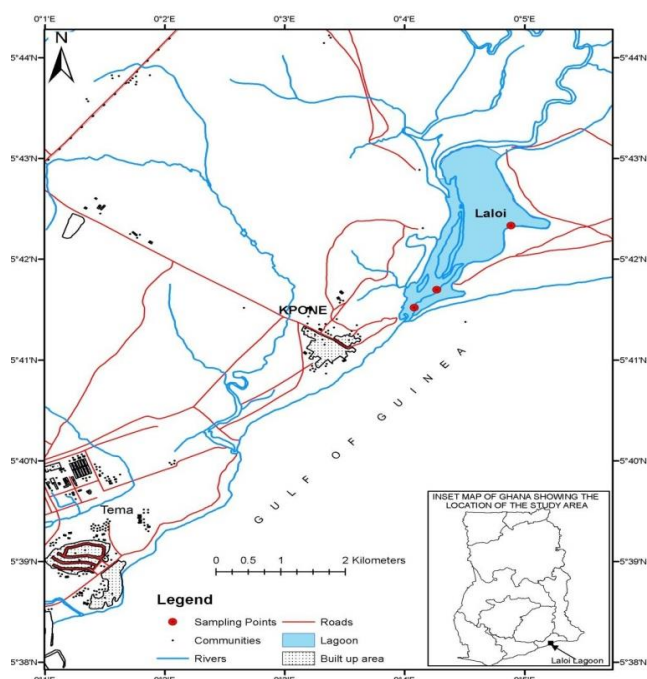
### Water sampling methods

Water samples were acquired from February to May. The physicochemical parameters measured were BOD,

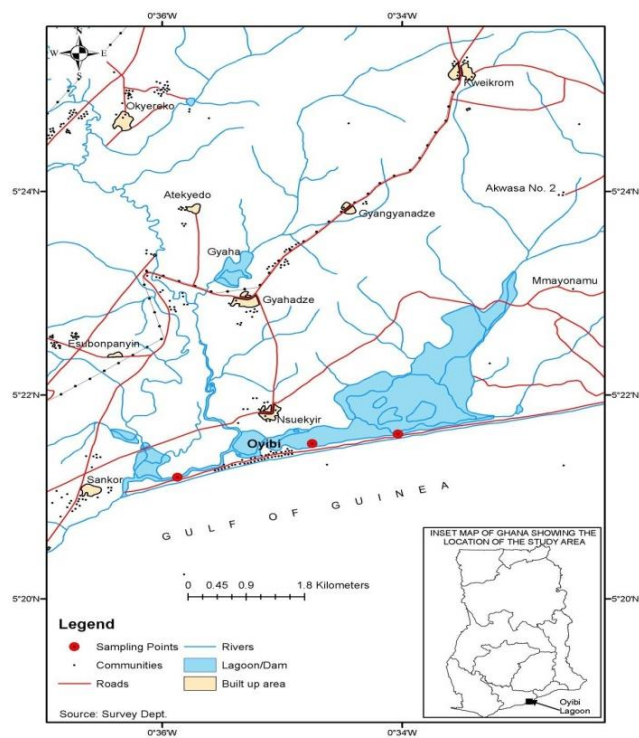
DO, the nutrients (nitrates and phosphates), chlorophyll-a, pH, salinity, temperature, TSS, and TDS. Sub-surface water samples were obtained at three points (lower, middle, and upper reaches) from each site and kept in a 250 mL tight plastic bottle for nutrient analysis. DO was calculated using the Winkler method. Water samples collected were fixed as soon as possible with 2 mL of Winkler 1 (Manganese sulfate) and Winkler 2 (Alkaline iodide-azide reagent) solutions and firmly corked, ensuring no air bubbles were trapped in the bottle. Temperature and pH were calculated in-situ using the YOKOGAWA pH meter model PH 82. Salinity was measured using the ATAGO 2SE refractometer, then analyzed with HACH Spectrophotometer.

### Sediment sampling method

A digger was used for sediment sampling. A cylindrical PVC pipe with open sides was placed vertically in the lagoon and pressed about 2 cm deep. The sediment was then stored in transparent polyethylene bags and transported to the laboratory for analysis. Sediment samples were taken at three locations; middle portions, upper reaches, and the seaward end of both lagoons. Sediment was taken once during the study period at low tide.



**Figure 1.** Map of Laloi lagoon displaying the sampling points, Ghana



**Figure 2.** Map of Oyibi lagoon showing sampling points, Ghana

### Laboratory methods

#### *Length-weight analysis*

The total length (TL) of the dominant fish was calculated from the snout to the extended tip of the caudal fin using a meter rule calibrated in centimeters. The relationship between TL and weight (W) of fish was expressed by formula (Pauly 1983).

$$W = aL^b \dots\dots\dots (1)$$

Where,

W = Weight of fish in (g)

L = Total Length of fish in (cm) a= Constant (intercept)

B = The Length exponent (slope)

The values of constants "a" and "b" were predicted from a linear regression of the length and weight of fish after a logarithmic transformation of equation 1. The correlation ( $r^2$ ), the degree of correlation between the size and weight, was calculated from the linear regression analysis.

The condition factor (CF) of the fish was analyzed by the formula Condition Factor (CF) =  $W / L^3 * 100\%$  (Pauly 1983)

Fish was identified using the identification keys of Schneider (1990), Dankwa et al. (1998), and an online fish identification site FishBase ([www.fishbase.com](http://www.fishbase.com)).

#### **Water analysis**

The water samples were allowed to reach room temperature before laboratory analysis. Nitrates and phosphates content was measured using a direct reading spectrophotometer based on protocols provided in the manual of HATCH 2800 and 2007 and the standard methods for examining water and wastewater (AWWA 1998). The sample blanks utilized deionized water to which reagents were added.

#### *Total suspended solids & total dissolved solids*

A photometric method determined the TSS level. 500 mL of the sample was blended for precisely 2 minutes at high speed, then poured into a 600 mL beaker and stirred. A 10 mL was poured into a sample cell swirled to remove any gas bubbles and suspended residue. TDS was analyzed using the gravimetric method. The sample was filtered, then the filtrate evaporated on a water bath—the waste left after evaporation was dried to a constant weight in an oven at 105°C. The increase in weight over that of the empty dish is the weight of the TD. The weight includes liquids, solids, and materials passed through the filter media that were not volatilized during the drying process (APHA 1998).

#### *Nitrates and phosphates*

Analysis of nitrates was done using the cadmium reduction method. Cadmium metal reduces nitrates to nitrite. The nitrite reacts in an acidic medium with sulphuric acid, creating an intermediate diazonium salt that couples with the acid to form an amber-colored product, the intensity of which depends on the concentration of

nitrates in the sample. Ten mL of each sample was poured into a sample cell, and the contents of one NitraVer 5 nitrate reagent pillow powder were added and stopped. The sample was shaken vigorously to aid in the dissolution of the reagents and inserted into the cell reader.

Phosphates were analyzed using ascorbic acid methods. Phosphates in the sample react with molybdate in an acidic medium to produce a phosphomolybdate complex. Ascorbic acid reduces the complex giving the molybdenum blue color, proportional in intensity to the concentration of phosphates in the sample. Ten mL of each sample was measured into an example, and then PhosVer 3 reagent pillow powder was added, corked, shaken vigorously for 30 seconds, and inserted into the cell holder.

#### *DO and BOD determination.*

Water samples were added with 2 mL of concentrated sulphuric acid ( $H_2SO_4$ ) and shaken until dissolution was complete. A 50 mL solution was titrated with a standard concentration of 0.0125M sodium thiosulphate ( $Na_2S_2O_3 \cdot 5H_2O$ ) solution until a pale-yellow color was obtained. Then, 2mL of the starch indicator was added to the solution, which gave the solution blue color, and titration was continued until the solution became colorless (APHA 1998). The initial DO was measured for BOD calculation and then incubated in the dark at 20°C for five days. After the five days, the DO was measured again. BOD is the difference between the DO consumed by microorganisms during the incubation period and the initial DO.

#### *Chlorophyll a*

Water samples were filtered using filter papers. The filtrate was extracted carefully using 90% acetone. The filtrate and acetone solution was read using the spectrophotometer at wavelengths 630 nm, 647 nm, 664 nm, and 750 nm.

#### *Total organic carbon (TOC)*

TOC was calculated using the wet oxidation method. A 10 mL dichromate solution was mixed to 0.5g of the sediment. 20 mL of concentrated  $H_2SO_4$  was mixed to the sediment, swirled, then allowed to stand for 30 minutes. 200 mL of distilled water, 10mL of orthophosphoric acid, and 2 mL of barium diphenylamine sulphionate indicator were added to the sample. The solution was then titrated with ferrous ammonium sulfate. The percentage of carbon was calculated as follows:

$$\% \text{ Carbon} = (10.0 - (vN)) * 0.3 / W$$

V: volume of ferrous ammonium for titration

N: Normality of Ferrous ammonium

W: Weight of sediment in grams

#### *Health and safety assurance*

The following quality assurance procedures were used:  
(i) Sampling bottles were washed thoroughly and then rinsed with deionized water to remove all traces of soap.  
(ii) Blank samples were prepared using deionized water.

(iii) Water samples were equilibrated to room temperature before analysis. (iv) Personal protective equipment was used to prevent damage from chemicals.

### Data analysis

The environmental parameters and fish communities were described using univariate and multivariate techniques. A multi-metric fish index describes the water bodies' condition, including species diversity and composition, trophic integrity, species abundance, and nursery function following Harrison and Whitfield (2004).

### Metric selection

A metric represents some aspect of biological assemblage structure, function, or another community component that can be measured (USEPA 2000). Community structure and function refers to biological measures such as species dominance, species diversity, faunal abundance and biomass, presence of indicator species, and trophic function or structure (Krebbs 1985; Elliot et al. 2002). The metrics were selected based on work done by Harrison and Whitfield (2004). A total of 10 parameters were chosen from the 14 metrics because of the lack of information on the feeding habits and fisheries of the study sites.

### Species diversity and composition

Species diversity is an attribute of faunal communities used in most biological, environmental health assessments. It tends to be reduced in stressed biotic communities (Odum, 1983). The total number of taxa (metric 1) showed the most straightforward measure of species diversity. The presence of rare or threatened species was selected because their existence imparts additional conservation value to the ecosystem. Because rare species are fragile, they may become endangered or even locally extinct with higher anthropogenic stress (Costello et al., 2002). The presence of exotic or introduced species (metric 3) provides a potential threat to naturally occurring taxa through competitive exclusion and predation. They also serve as a direct measure of human interference.

### Species abundance

The relative abundance of species (metrics 5) in water about a reference from fish community results in a quantitative assessment. Environmental stress generally changes the relative abundance from „diverse“ communities, which consist of many species in relatively low proportions, to “simple” assemblages dominated by a few species (Odum 1983; Fausch et al. 1990). The concept of dominance is linked to this idea; the number of taxa required to make up 90% of the total abundance (metric 6) represents a simple measure of dominance.

### Nursery functions

Lagoons are important nursery sites for marine species and serve as essential habitats for resident taxa (Wallace et al. 1984; Whitefield 1998). The number of estuarine or resident taxa (metrics 7) identified two groups of fishes that are most likely susceptible to lagoon degradation by

characteristics of their strong dependency or association with these environments. The number of estuarine-dependent marine taxa (metric 8) showed how well an estuary fulfills its role as a nursery habitat. Undisturbed water is expected to maintain a relatively balanced fish community consisting of representatives of both groups. An extremely low numerical abundance or unexpected high dominance by one particular group often implies an imbalance or disturbance within a system (Begg 1984a). The relatively high number of both estuarine-dependent marine species (metric 10) and estuarine resident species (metric 9) are complementary measures to quantitatively assess estuarine habitat quality and nursery function for these two major groups.

### Trophic integrity

Lagoons are among the most productive ecosystems on the earth (Odum 1983; McHugh 1985). They provide abundant food resources for filter and deposit-feeding invertebrate prey and various fish species, including detritivorous, zooplanktivorous, herbivorous, benthic invertebrate feeders, and piscivorous taxa, by acting as detritus traps (Whitfield 1998). The condition factor and chlorophyll-a concentration were used to measure trophic integrity for this study.

### Univariate analysis

The community structure was analyzed using abundance and diversity indices, e.g., Shannon-Wiener diversity index ( $H'$ ), Margalef's species richness ( $d$ ), and Pielou's evenness index ( $J$ ) were counted. The Shannon-Wiener diversity index is a combination of richness and evenness species measurement. A minimum value of 0 for this index shows a community with single species. It increases as species' evenness and richness increase (Hamillton 2005).

The Shannon-Wiener diversity index ( $H'$ ) was calculated as

$$H' = -\sum P_i (\log p_i)$$

Where  $p$  = the proportion of the total count coming from the  $i$ th species, the index was calculated using the natural logarithmic base ( $\log_e$ ). The Shannon Diversity Index usually falls between 1.5-3.5 and rarely surpasses 4.5 (Margalef 1972).

Pielou's evenness calculates the relative abundance of species in the community, the number of individuals, biomass, and how it is distributed among the other species (Ludwig and Reynolds 1988).

Species Evenness as Pielou's index ( $J$ ) was calculated as

$$J = H' (\text{observed}) / H'_{\max}$$

Where  $H'$  is the Shannon-Wiener diversity and  $H'_{\max}$  is the maximum possible diversity achievable if all species were equally abundant.

Margalef's richness is an expression of the number of species that constitute the community. Species Richness as Margalef's index (d) was calculated as

$$D = (S-1)/\log N$$

Where  
 S = total number of species  
 N = total number of individuals

These diversity indices were calculated using the PRIMER v.6.0 software package (Plymouth Routine in Marine Ecological Research) (Carr 1996).

Diversity indices compare the statistical associations of organisms and allow populations; they are generally a more reliable indicator of environmental health or stress than are individual indicator species (Cain and Dean 1976). Abundance and distribution graphs were generated using Microsoft Office Excel (v.2010).

#### Multivariate Analysis

##### Bray-Curtis similarity index

Multivariate analysis was done using the PRIMER v.6.0 software package (Plymouth Routine at Marine Ecological Research) (Carr 1996). The similarity matrix for the classification among the Laloi and Oyobi was analyzed as Bray-Curtis's similarity indices (Bray and Curtis 1957). The results were then described in the form of a dendrogram. The Similarity Coefficients are based on the presence or absence of data. They may vary from 0 when the pair of sampling units are entirely different to 1 when sampling units are identical. The Bray-Curtis similarity indices allow all species to contribute to the definition of similarity while retaining some information on the prevalence of a species, ensuring that the widespread species are usually given higher weight than the rare ones.

A 4<sup>th</sup> root transformation was applied to fish data to keep information regarding relative abundance and minimize differences in scale among variables in the standardization of the data on species diversity (Clarke 1993; Anderson and Underwood 1997). The similarity indices of species composition among stations do not consider the double absences usually found in the data. Its calculation is also unaffected by the difference in sample size (Clarke and Green 1988).

##### Metric calculation.

The metrics score assigned 1, 3, or 5. High scores indicate an unpolluted site not suffering from stress, while low scores reflect a polluted site under pressure. The scores are summed to point out sites ratings which are interpreted as follows: 0-15: Critical and no fish, 16-20: the site is very poor, 22-38: the site is rated poor, 40-44: the site is rated moderately stressed, 46-62: the site is rated excellent and 64-68: the site is rated very good.

## RESULTS AND DISCUSSION

### Fish composition and abundance

This study identified 19 species consisting of 17 finfishes and two shellfishes. The finfishes are classified into 14 families and 17 genera, while the shellfish belong

to 2 families and two genera. *Mugil cephalus* was the dominant fish species for the Laloi Lagoon, and *Sarotherodon melanotheron* was majorly found at Laloi. *Callinectes latimanus* and *Penaeus* sp. were the only shellfishes found during the study period from Laloi and Oyibi, respectively. The total number of individuals recorded was 532 (Oyibi), and Laloi was 437. The number of species recorded at Oyibi were 15 fin fishes and two shellfishes. A lower number of species was identified at Laloi, comprising 12 fin-fishes and a shellfish (Table 1). Species encountered at Oyibi was consisted of *S. melanotheron* making up 56% of the total species, followed by *Tilapia guineensis* (4%), *Lutjanus fulgens* (6%), *Mugil cephalus* (7%), and *Caranx hippos* (17%). Species found at Laloi was made up of *M. cephalus* (41%) followed by *S. melanotheron* (20%), *Caranx hippos* (3%), *L. fulgens* (16%), *C. latimanus* (5%), *Eucinostomus melanopterus* (5%), and *T. guineensis* (3%) (Figure 4).

### Metric selection

#### Nurse functions

The number of adventitious marine species found in the Oyibi lagoon was seven species, and six were found in Laloi. The highest number of estuarine resident species recorded was 5 in Oyobi and 3 in Laloi. The number of freshwater species found at both locations was 2 (Figure 3).

#### Trophic Integrity

Chlorophyll-a concentrations were higher at Oyibi than Laloi. For the Oyibi lagoon, the highest chlorophyll-a level was 0.20 mg/L recorded in the riverine end in April at high tide, and the least value recorded was 0.00028 mg/L in May at the middle portion. For the Laloi lagoon, the highest chlorophyll-a level was 0.015 mg/L recorded in the riverine end in March at low tide, and the least value recorded was 0.0010 mg/L in April at the seaward end at low tide (Figure 5).

#### Metric calculation

From the metrics assigned, Laloi scored 34, indicating a poor site rating, suggesting that it was under severe stress, and Oyibi scored 40, stating a moderate site rating, implying that it was under mild stress (Table 2).

### Species diversity

The Shannon Wiener Index ( $H'$ ) calculated for Oyibi shows the highest value of 1.64 and the least value of 0.42 recorded at Oyibi were in April and February, respectively. Laloi recorded the highest amount of 1.51 (May) and the least amount of 1.24 (February). The average for Laloi was  $1.81 \pm 0.53$  (Figure 6).

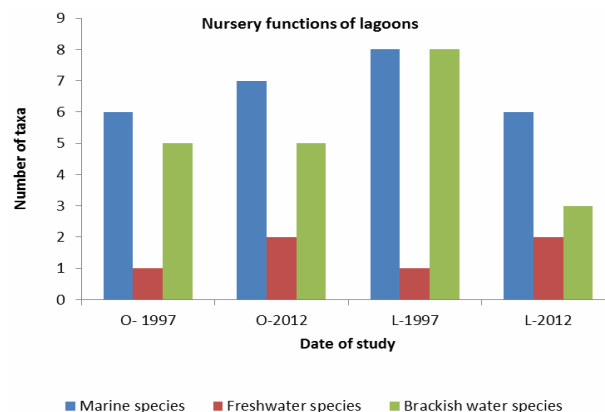
Pielou's species evenness index (J) at Oyibi had the least value of 0.36 in May and the highest amount of 0.71 in April. The average value recorded at Oyibi was  $0.57 \pm 0.13$ . For Laloi, the highest value was recorded in April and the least amount recorded in February. The average recorded for Laloi was  $0.67 \pm 0.10$  (Figure 7).

The Margalef's species richness index (d) recorded for Oyibi had the highest recorded value in March and the least in February. The mean value recorded for Oyibi during the

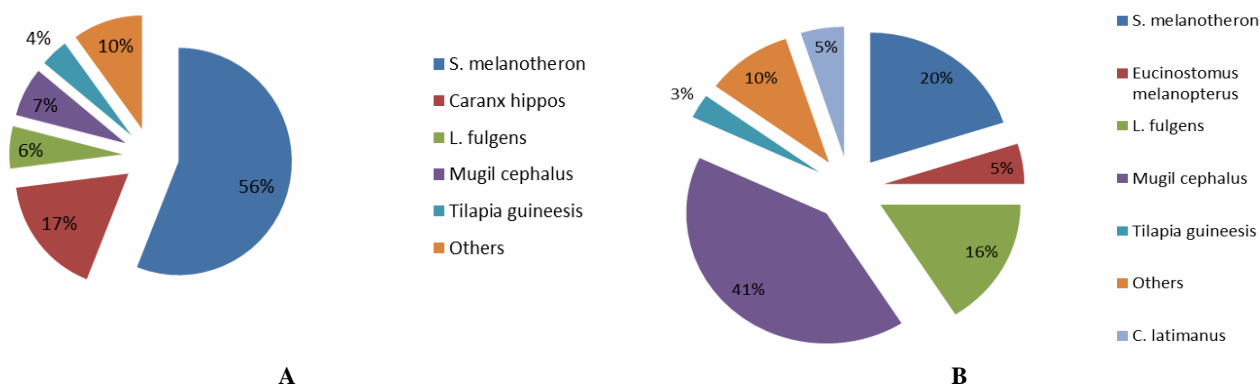
study was  $2.39 \pm 0.63$ . The highest amount of the species richness for Laloi was recorded in February, and the least amount was recorded in April. The mean value recorded for Laloi during the entire study was  $2.30 \pm 0.28$  (Figure 8). The species diversity indices for the analysis are represented in Figure 8.

### Physico-chemical parameters

BOD recorded in the Oyibi lagoon fell between 0.20-2.8 mg/L. DO values recorded in the Oyibi lagoon ranged between 3.3-6.5 mg/L with an average of  $4.7 \pm 0.97$  mg/L for the Oyibi lagoon. DO values were highest at high tide than low tide. BOD observed in the Laloi lagoon ranged between 0.1-4.5 mg/L with an average of  $1.80 \pm 1.04$  mg/L for the entire study. DO values recorded in the Laloi lagoon ranged between 3.0-7.5 mg/L (Figure 10-11).



**Figure 3.** Comparison of the number of taxa of the study locations in 1997 and 2012. Note: O: Oyibi, L: Laloi



**Figure 4. a and b** Relative abundance of species found in the (A) Oyibi and (B) Laloi lagoons, Ghana

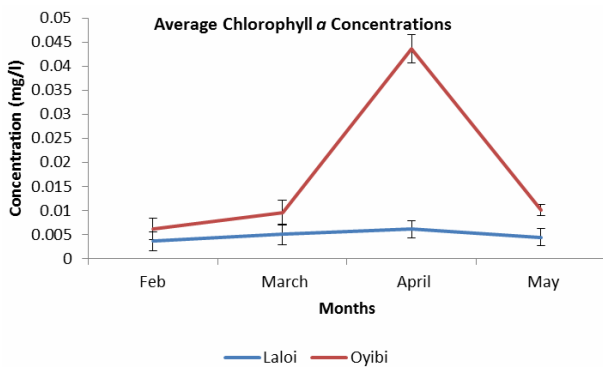
**Table 1.** Fish species identified in the Oyibi and Laloi lagoons, Ghana

Family	Species	Common name	Laloi lagoon	Oyibi lagoon	% Composition	Category
Bothiade	<i>Syacium microrum</i>	Rock sole	+	+	0.9	MA
Carangidae	<i>Caranx hippos</i>	Horse mackerel	+	+	10	MA
Cichlidae	<i>Sarotherodon melanotheron</i>	Black-chinned tilapia	+	+	39	ER
	<i>Tilapia guineensis</i>	Guinean tilapia	+	+	4	FW
	<i>Hemichromis fasciatus</i>	Banded jewelfish	+		0.1	FW
	<i>Oreochromis niloticus</i>	Nile tilapia		+	0.1	FW
	<i>Ethamalosa fimbriata</i>	Bonga shad		+	0.8	MA
Cyprinodontidae	<i>Epiplatys sexfasciatus</i>	Six bar panchax		+	0.3	FW
Eleotridae	<i>Eleotris vittata</i>	Eleotrid	+	+	0.6	ER
Elopeidae	<i>Elops lacerta</i>	Ten pounders		+	0.2	ER
Gerreidae	<i>Eucinostomus melanopterus</i>	Flagfin mojarra	+	+	3	MA
Gobidae	<i>Chonophorus lateristriga</i>	West african freshwater goby		+	0.2	FW
	<i>Lutjanus goreensis</i>	Goreen snapper		+	1	MS
Lutjanidae	<i>Lutjanus fulgens</i>	Golden african snapper	+		11	MS
	<i>Mugil cephalus</i>	Flathead grey mullet	+		22	ER
	<i>Mugil curema</i>	White mullet	+	+	0.7	ER
Penaeidae	<i>Peneaus sp</i>	Shrimp		+	1	FW
Portunidae	<i>Callinectes latimanus</i>	Blue-legged swimming crab	+	+	3	ER
Serranidae	<i>Epinephelus aeneus</i>	Common white grouper	+		0.8	MA
Lethrinidae	<i>Lethrinus atlanticus</i>	Atlantic emperor	+		0.1	MA
Scaridae	<i>Callyodon hoefleri</i>	Parrot wrasse	+		0.5	MA

Note: MA: Marine species, FW: Freshwater species, ER: Estuarine species, X: present

**Table 2.** Estuarine fish community index calculation for the lagoons

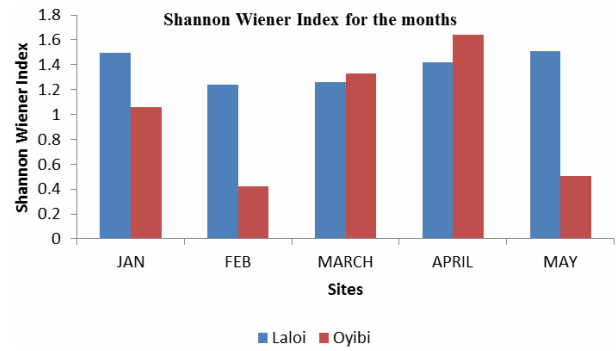
Estuarine Fish Community Index Metric	Score	
	Oyibi	Laloi
<b>Species diversity and composition</b>		
1. Total number of taxa	3	3
2. Species composition	3	3
3. Exotic or introduced species	3	3
4. Rare or threatened species	3	3
<b>Species abundance</b>		
5. Species relative abundance	3	3
6. Number of species that make up 90% of the abundance	3	3
<b>Nursery function</b>		
7. Number of estuarine resident taxa	5	3
8. Number of estuarine-dependent marine taxa	1	1
9. The relative abundance of estuarine resident taxa	5	5
10. The relative abundance of estuarine-dependent marine taxa	5	5
<b>Trophic Integrity</b>		
11. Condition factor	3	1
12. Chlorophyll a	3	1
<b>Total</b>	<b>40</b>	<b>34</b>



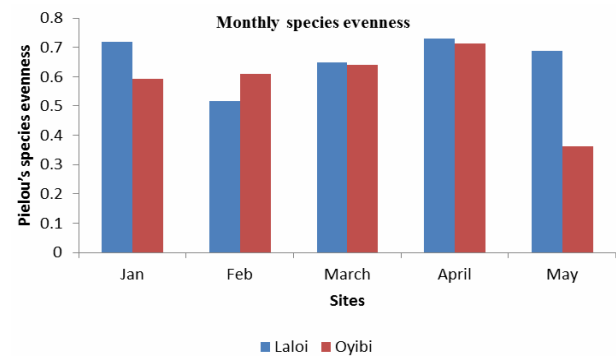
**Figure 5.** Average Chlorophyll an in the Oyibi and Laloi lagoons. (vertical bars =±SD)

TSS recorded for the Oyibi lagoon fell between 10-105 mg/L with an average value of 31.1±21.90 mg/L for the entire study period. The average TSS values recorded for Oyibi lagoon during high tides was 31.1±19.70 mg/L and during low tides was 31.1±24.79 mg/L. TSS recorded for the Laloi lagoon ranged between 5.0-80mg/L with an average value of 19.7±14.81 mg/L for the entire study. The mean for the Laloi lagoon during high and low tide during the study as a whole was 23.3±19.94 mg/L and 16±5.64 mg/L, respectively. The physicochemical parameters measurement is represented in Figures 12.

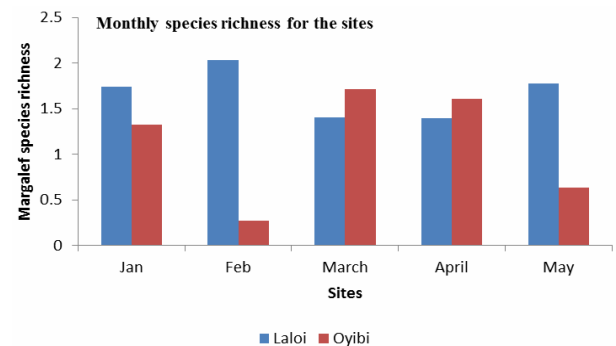
TDS recorded for the Oyibi lagoon fell between 0.15-37.0 mg/L with an average of 11.9±11.74 mg/L for the entire study. The lagoon's mean TDS values were 10.7±10.67 mg/L during high tides, and low tides were 13.1±13.08 mg/L. TDS observed for the Laloi lagoon ranged between 15.0-152.0 mg/L. The average TDS values observed for the Laloi lagoon during high and low tides were 54.7±41.59 mg/L and 38.7±20.72 mg/L, respectively. TDS was highest at Laloi than Oyibi (Figure 13).



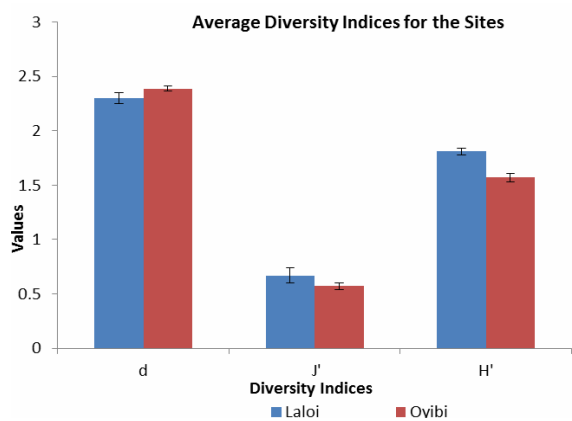
**Figure 6.** Shannon Wiener Index for the Laloi and Oyibi lagoons



**Figure 7.** Pielou's species evenness for the Laloi and Oyibi lagoons



**Figure 8.** Margalef species richness for the Laloi and Oyibi lagoons



**Figure 9.** Average Diversity indices for the Oyibi and Laloi lagoons. (vertical bars =±SD). Note: d: Magarlef's species richness index, J': Pielou's species evenness, H': Shannon Wiener Index

The temperature recorded in the Oyibi lagoon ranged between 22.2°C and 32.4°C with an average of 27.7±0.60°C for the entire study. Temperatures were high at the riverine end than the middle and seaward end at Oyibi. The temperature recorded in the Laloi lagoon ranged between 21.3-33.6°C, with an average of 26.7±3.17°C for the study period. The average temperature at the Laloi lagoon during both high tide and low tides were 27.4±3.36 °C and 26.1±3.03°C, respectively. Average temperatures measured for these lagoon sections were 27.1±3.77°C, 26.8±3.53 °C, and 26.2±2.49 °C, respectively (Figure 14).

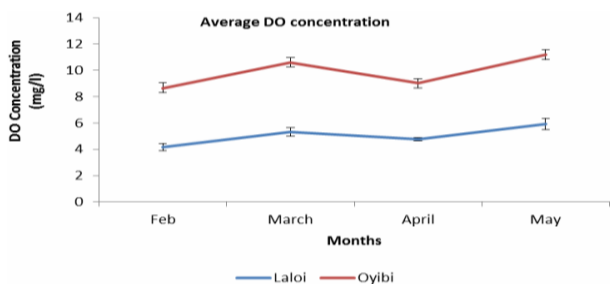
Salinity observed in the Oyibi lagoon ranged between 5‰ and 40‰ with an average of 22.0±7.46‰. The seaward end at Oyibi recorded the least value of 7‰ in March during low tide. The mean salinity values for Oyibi during the high tides was 20.6±6.08‰ and low tides were 23.5±6.08‰. Salinity recorded in the Laloi lagoon ranged from 20.0‰ to 40‰ with an average of 37.0±3.40‰ during the entire study period. The mean salinity values for Laloi during the high and low tides were 37.8±1.47‰ and 36.2±4.54‰, respectively (Figure 15).

The pH recorded in this study ranged between 7.0-9.0 for the Oyibi lagoon, with an average of 7.97±0.40. The average pH values during high and low tides were 8.07±0.39 and 8.02±0.43, respectively. The pH recorded in the Laloi lagoon ranged between 8.0-8.6, with an average of 8.60±0.25. The average pH values for the Laloi lagoon during high tide and low tide were 8.50±0.25 and 8.60±0.26, respectively. Mean pH values recorded for these lagoon sections were 8.60±0.22, 8.6±0.17, and 8.4±0.31, respectively (Figure 16).

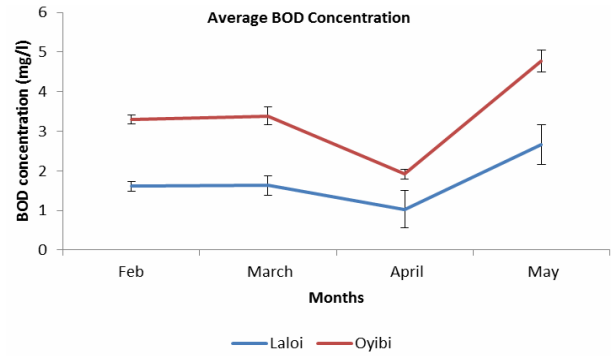
Nitrates levels observed at the Laloi lagoon ranged between 0.30-5.2 mg/L with an average value of 1.77±1.24 mg/L. Nitrate levels observed for the Oyibi lagoon ranged between 0.20-9.9 mg/L with an average value of 3.25±4.59 mg/L. Phosphate levels observed for the Laloi lagoon ranged between 0.07-1.98 mg/L with an average value of 0.61±0.35 mg/L. Phosphate levels observed for the Oyibi lagoon ranged between 0.15-1.12 mg/L with an average value of 0.61±0.24 mg/L. The results for the nutrients are shown in Figures 17-24.

**Length-weight relationship**

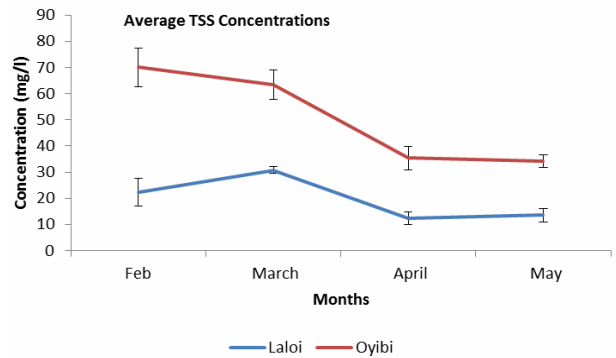
From the length-weight relationship, the condition factor of *Sarotherodon melanotheron* at Oyibi lagoon fell in the range between 1.50 and 2.40, with an average value of 2.07±0.20 for the entire study period. The condition factor observed at Laloi lagoon was measured between 1.40-2.0, with an average value of 1.72±0.12 (Figure 25).



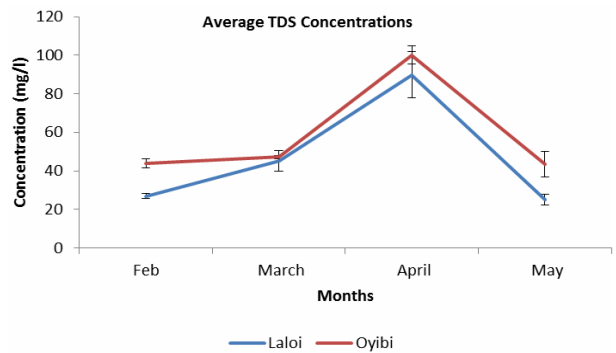
**Figure 10.** Average DO concentrations in the Oyibi and Laloi lagoons. (vertical bars =±SD)



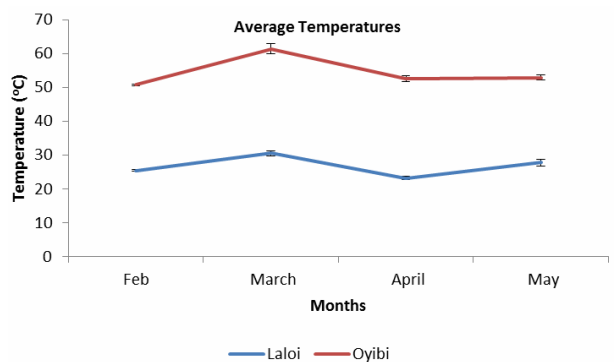
**Figure 11.** Average BOD concentrations in the Oyibi and Laloi lagoons. (vertical bars =±SD)



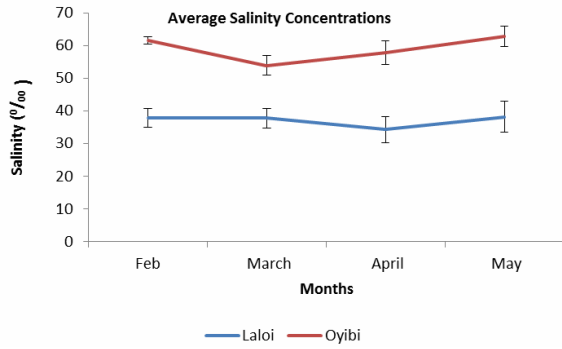
**Figure 12.** Average TSS concentrations in the Oyibi and Laloi lagoons. (vertical bars =±SD)



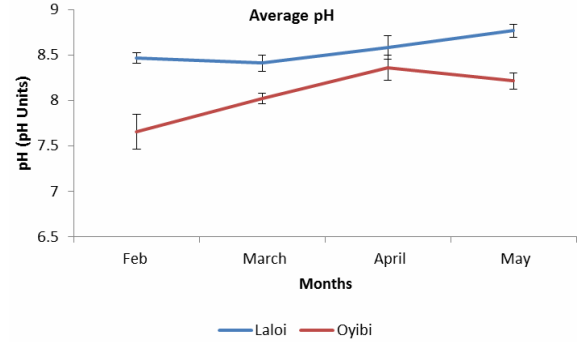
**Figure 13.** Average TDS concentrations in the Oyibi and Laloi lagoons. (vertical bars =±SD)



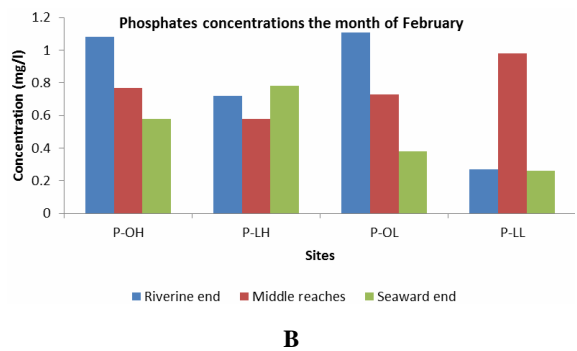
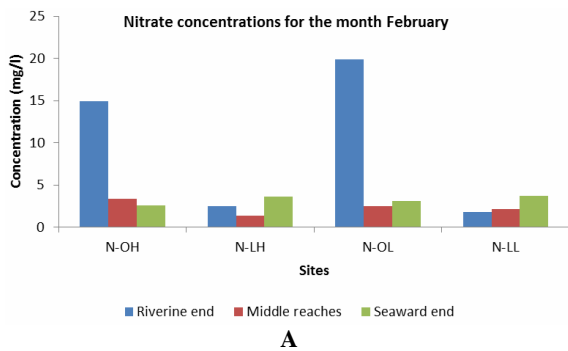
**Figure 14.** Average temperatures in the Oyibi and Laloi lagoons. (Vertical bars =±SD)



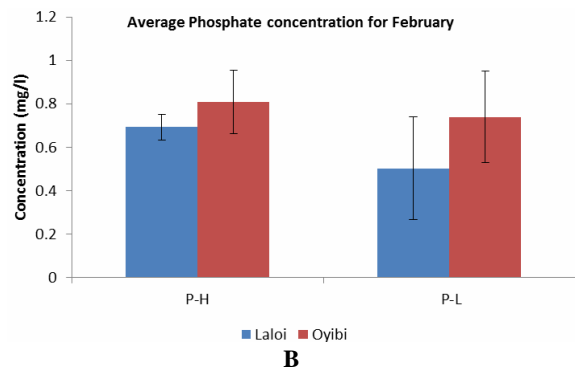
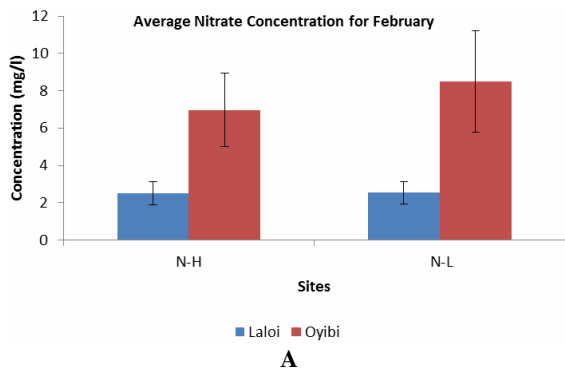
**Figure 15.** Average salinity concentrations in the Oyibi and Laloi lagoons. (Vertical bars =±SD)



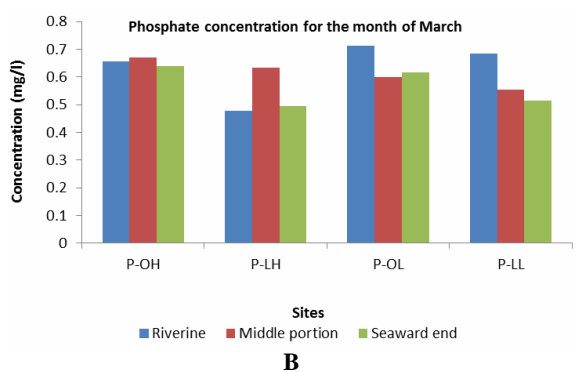
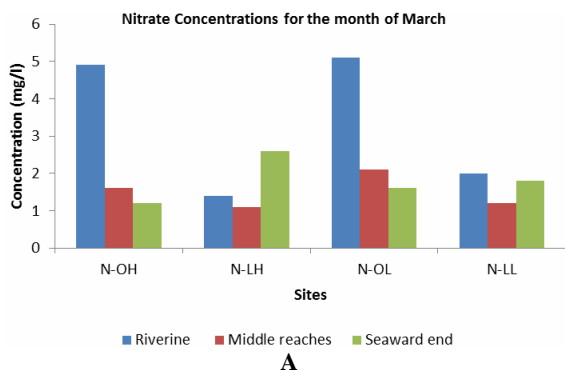
**Figure 16.** Average pH in the Oyibi and Laloi lagoons. (vertical bars =±SD)



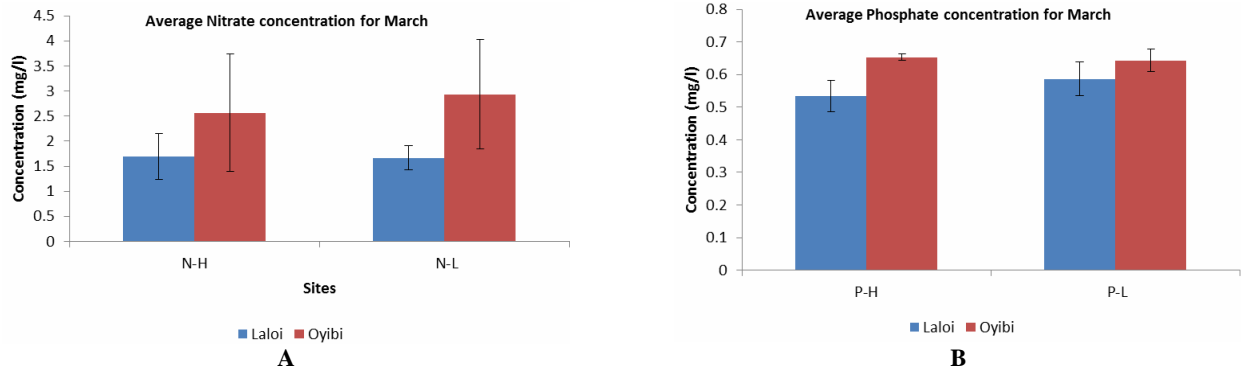
**Figure 17. A-B.** Nitrates and Phosphates concentrations in the Oyibi and Laloi lagoons for February. Note: N: Nitrates. P: Phosphates L: Laloi. O: Oyibi. H: High tide. L: Low tide.



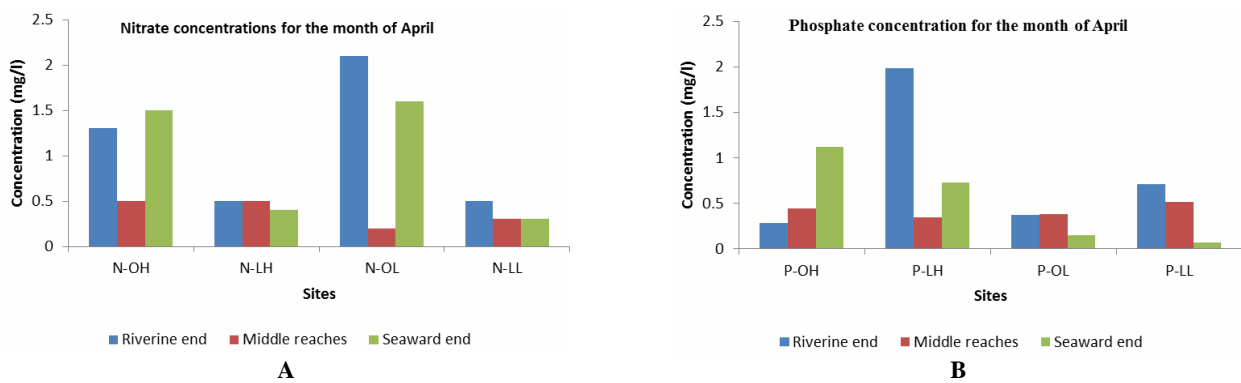
**Figure 18. A-B.** Average Nitrates and Phosphate concentrations in the Oyibi and Laloi lagoons for February. (vertical bars =±SD). Note: Phosphates. N: Nitrates H: High tide. L: Low tide



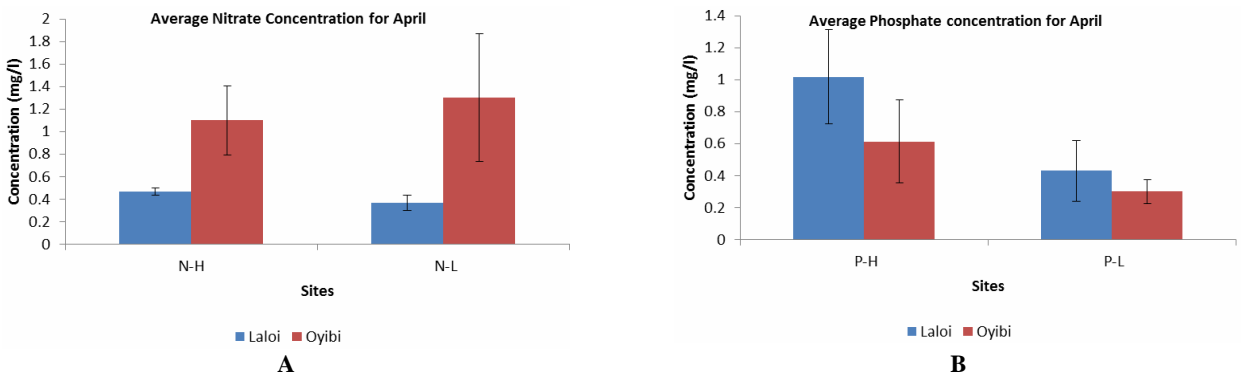
**Figure 19. A-B.** Nitrates and Phosphates concentrations in the Oyibi and Laloi lagoons for March. Note: N: Nitrates. P: Phosphates L: Laloi. O: Oyibi. H: High tide. L: Low tide



**Figure 20. A-B.** Average Nitrates and Phosphate concentrations in the Oyibi and Laloi lagoons for March. (vertical bars =±SD). Note: P: Phosphates. N: Nitrates H: High tide. L: Low tide



**Figure 21. A-B.** Nitrates and Phosphates concentrations in the Oyibi and Laloi lagoons for April. Note: N: Nitrates. P: Phosphates L: Laloi. O: Oyibi. H: High tide. L: Low tide

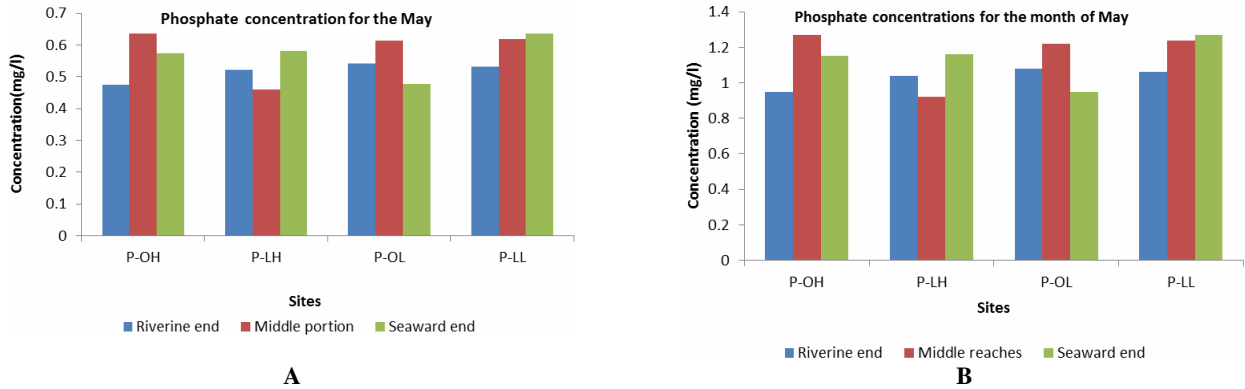


**Figure 22. A-B.** The average concentration of nitrates and phosphate in the Oyibi and Laloi lagoons in April (vertical bars =±SD). Note: P: Phosphates. N: Nitrates H: High tide. L: Low tide

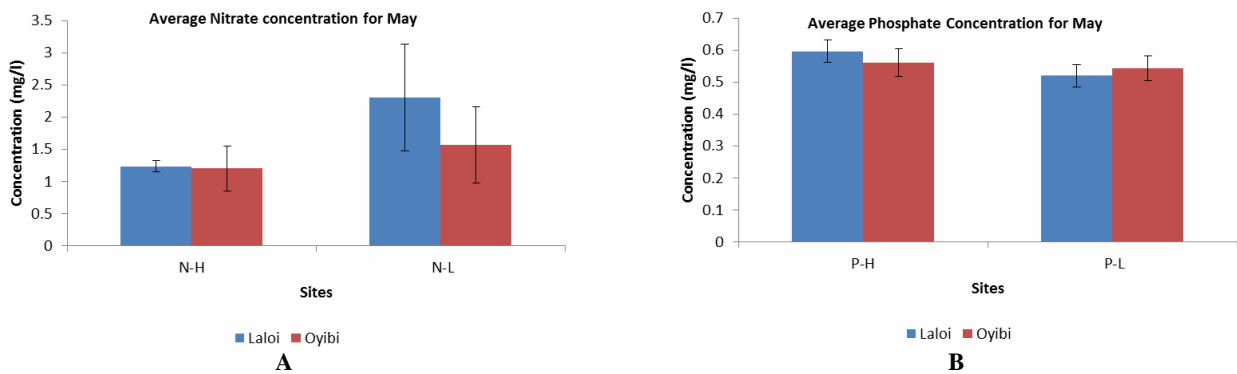
**Similarity analysis**

A Bray-Curtis similarity analysis of species abundance data by applying group averaged linking of Bray-Curtis’s similarities calculated on standardized fourth root transformed data was employed to show similarities in sites sample (Bray & Curtis,1957; Cormack,1971; Everitt,1980). The sites that exhibit species composition and abundance similarities will cluster close together. Figures 26

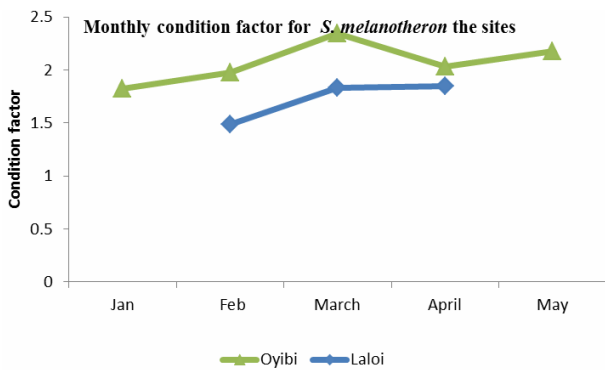
demonstrated the dendrogram for hierarchical clustering of the similarities between months for the locations. Most of the clustering existed between the 35-70 % Bray-Curtis’s similarity scale for the months, while clustering was observed more than 60 % scale for the entire study. The dendrogram shows the similarity in species composition every month and the overall similarity in species composition between the sites.



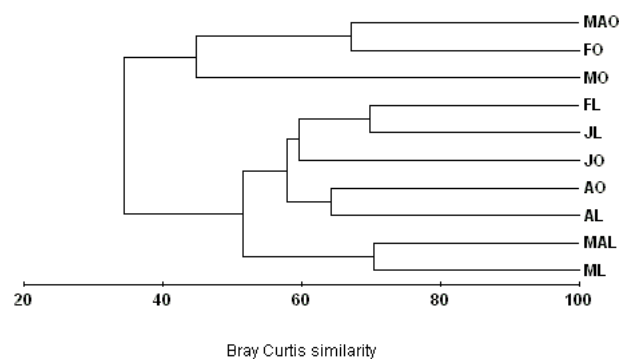
**Figure 23. A-B.** Nitrates and Phosphates concentrations in the Oyibi and Laloi lagoons in May. Note: N: Nitrates. P: Phosphates L: Laloi. O: Oyibi. H: High tide. L: Low tide



**Figure 24. A-B.** Average Nitrates and Phosphate concentrations in the Oyibi and Laloi lagoons in May (vertical bars =±SD). Note: P: Phosphates. N: Nitrates H: High tide. L: Low tide



**Figure 25.** Condition Factor for *S. melanotheron* in the Oyibi and Laloi lagoons for the entire study period

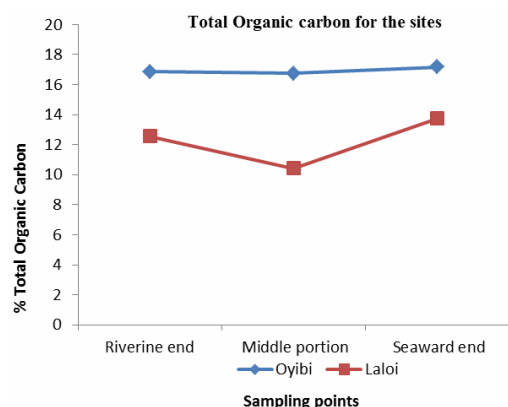


**Figure 26.** Bray-Curtis's similarity between sampling months. Note: J: January; F: February; M: March; A: April; MA: May, O: Oyibi, and L: Laloi

**Total organic carbon**

Total organic carbon recorded for the Oyibi lagoon ranged between 15-20%, with a mean value of 16.92±0.23%. Total organic carbon was higher at Oyibi than at Laloi. The seaward end showed the highest percentage of organic carbon (17.18%), and the least value

of 16.74% was recorded in the middle portion for Oyibi. Total organic carbon observed at Laloi lagoon ranged between 10-13%, with an average value of 12.24±1.68%. For the Laloi lagoon, the highest percentage of organic carbon was 13.73% at the seaward end, and the least value of 10.42% was found in the middle portion (Figure 27).



**Figure 27.** Total Organic carbon for the lagoons during the study period

## Discussion

### *Species composition and abundance*

The total number of species observed consisted of 16 finishes and two shellfishes. *Sarotherodon melanotheron* represents an essential part of lagoon fisheries in Ghana (Eyeson 1983; Blay and Ameyaw 1993; Koranteng 1995) and make up about 80%-90% of all fishes caught in lagoons (Pauly 1975, 1976; Denyoh 1982). The type of species encountered was close to the species that exist in almost all coastal lagoons in Ghana as described by (Dankwa and Entsua-Mensah 1996; Koranteng et al. 1998; Entsua-Mensah 2003). The *Callinectes latimanus* and *Peneus* sp were the only shellfish encountered during the study.

The species encountered can be classified into three categories based on their salinity tolerance; marine stenohaline species, freshwater stenohaline species, and euryhaline species (Pauly 1975; Welcomme 1979; Pauly and Yanez-Arancibia, (1994). The freshwater stenohaline species found were *O. niloticus*, *T. zilli*, and *H. fasciatus*. The euryhaline species found were *S. melanotheron* and *Elops lacerta*. The typical marine stenohaline species encountered were *Mugil cephalus*, *Caranx hippos*, *Lutjanus fulgens*, *Lutjans goreensis*, *Syacium microrum*, and *Epinephelus aeneus*.

An example of the genuinely resident lagoon species found was *S. melanotheron*. *Caranx hippos* and *Ethmalosa fimbriata* were the only marine seasonal migrant species found. The adventitious marine species found were *Syacium microrum*, *Lethrinus atlanticus*, and *Callyodon hoefleri*; some diadromous species found were *Eucinostomus melanopterus* and *Elops lacerta*. The freshwater species found were *Hemichromis fasciatus*, *Oreochromis niloticus*, and *Epiplatys sexfasciatus*.

Oyibi recorded the highest number of species while Laloï had the least amounts of species. Of the 29 shell and finfish species, 15 were recorded at Oyibi and 12 at Laloï. There has been a significant alteration in the number of species as compared to the result of baseline studies (Dankwa et al., 1997). Dankwa et al. (1997) reported the number of species at Oyibi to be 12 and that of Laloï to be 15. There has been an increasing number of species in Oyibi (from 12 to 16) and a reduced number of species at Laloï from 17 to 14. He observed that both closed and

opened lagoons with extensive mangrove cover had high species diversity. These lagoons were Kpani (28 species), Domini (24 species), Oyibi (12 species), Kpeshie (15), and Brenu and Kako (12 species). This result ascertains that mangroves provide feeding and breeding sites for various fish species. The practical implementation of traditional beliefs in management and conservation might contribute to the high mangrove forest at Oyibi. By comparing the size composition of *S. melanotheron* and *T. fuscatius* in Djange and Sakumo lagoons, a group clearly showed that traditional beliefs and associated taboos could be valuable tools for conservation if they are adhered to (Ntiamoah-Baidu 1991).

The difference in species abundance and composition in both lagoons can be due to the variation of physicochemical parameters such as pH, salinity, temperature, environmental characteristics of the habitats, the size of local human populations, effort, the type of fishing gear, and the associated fishing pressure. *S. melanotheron* was confined more to the upper reaches of the Oyibi lagoon and in Laloï the upper and middle reaches. The marine, primarily stenohaline, lived in the lower ranges when the tides came in.

The tolerance and preference against salinity can influence the abundance and distribution of fish species. In 1978, Yanez-Arancibia, working in Mexican estuarine lagoons, reported significant declines in fish species diversity, densities, and biomass when the salinities rose above 34‰ or declined below 15‰. Wallace (1975) said that species diversity and abundance in the estuarine lake St. Lucia in South Africa declined during hypersaline periods. Thiel et al. (1995) also observed that decreased salinity upstream would be followed by decreased species diversity. Salinity recorded between the two lagoons showed no significant difference and had no impact on the fisheries of the range ~ 34.5‰ and 35.5‰ (Anang 1979). The higher salinity towards the eastern coast of Ghana is due to variation in rainfall patterns (Entsua-Mensah 2003). At the seaward end of the Oyibi lagoon, salinity was lowest due to dilution from the Ayensu River.

The pH recorded in this study was optimal for the growth and survival of most aquatic species (Addy et al., 2004). The highest DO at the seaward end is due to mixing and turbulence by the sea. The TDS values fell in the range which could not be harmful to fisheries (below the background values of 50.0-1000 mg/L. The TSS values were above the background levels of 0.5-10.0 mg/L, affecting primary production by attenuating light penetration. The decrease in light penetration through the water column could restrict the rate at which periphyton, emergent, and submerged macrophytes can assimilate the energy through photosynthesis, directly impacting primary consumers (Bilotta and Brazier 2008).

Land use practices around these lagoons may contribute to the increased nutrient concentrations. The primary land-use methods along these lagoons are salt mining, farming, harvesting of mangroves for firewood, and housing construction. The high concentration of nitrates and phosphates in the two lagoons indicates increased human activities in the catchment region and the increased loading

from the rivers into the lagoon. High concentration of nitrate at the riverine end of Oyibi lagoon might be caused by agricultural activities as well as other domestic activities and has been described as mildly eutrophic using the Carlson's TSI scale of 56) and the seaward being moderately clear with a TSI score of 42 (Ansa-Asare et al. 2007). It can also be associated with their proximity to population centers and their historical importance as sources of protein and as an area for disposal of human waste (Kennish 2002).

Human population density alone has also been reported to account for a significant variation in riverine transport of nitrogen and phosphorus (Howarth 1988; Caraco 1995) from a wide variety of large watersheds. The high concentration of phosphates can be due to industrial and domestic effluents entering the lagoon from the surrounding area. This may not favor the development of fishes in the lagoons because, at a certain threshold of phosphates, phytoplankton diversity is known to decline; thus, affecting primary productivity (Biney 1990).

Biological oxygen demand (BOD) has been employed to measure the number of organic materials in aquatic solutions with maximum values due to high organic matter. Lagoon with BOD concentration below 4 mg/L is considered unpolluted, and those over 12 mg/L as grossly polluted (Biney 1982). The high BOD concentrations measured at the riverine sections of Oyobi and Laloi lagoons can be attached to the increased human activities at these sections. The smallest value of BOD recorded in April in the Laloi lagoon was due to the decrease in temperatures. Low temperatures tend to retard the reproduction rate of organisms that break down organic matter. For the whole study period, high levels of BOD were recorded at Laloi than Oyibi. The high concentration of BOD in the Laloi lagoon might be caused by the location of the Laloi, which is in an urban area, and hence increase human pressure on its resources. The poor water quality is a strong indication of pollution.

There is a positive relationship between primary productivity and fish production (Boyd 1990). Chlorophyll-*a* concentrations indicate the trophic status, maximum photosynthetic rate, and water quality. Here, the seaward end of both lagoons recorded the least concentrations of chlorophyll-*a*. This result can be attached to the tides or influx of seawater. Tidal mixing reduces the residence time of algae in the photic zone and makes up fine sediment to resuspend, reducing the amount of light available for photosynthesis (Brando et al., 2012). Flushing dilutes nutrients and moves them away from plants, making them less available (Monbet 1992). It can be said that higher chlorophyll-*a* concentration increases species abundance and biomass. Therefore, the increased number of species and biomass from the Oyibi lagoon can be attributed to high chlorophyll-*a* concentrations recorded in the lagoon.

#### *Metric selection*

The number of resident species in Laloi reduced from eight to three species. This phenomenon supports the assumption that environmental stress caused by pollution decreases the number of species (Harrison and Whitfield

2004). The decline in brackish water species in Laloi might be due to the increased environmental stress. This supports the hypothesis that the relative abundance of species decreases in disturbed systems (Harrison and Whitfield 2004). In the Oyibi lagoon, the number of estuarine-dependent marine taxa identified showed a vast improvement over time, while Laloi decreased. The assumption is that disturbed systems have simple communities dominated by a few taxa. Meanwhile, more natural systems have a more diverse population, with many species dominating was not supported by the study. These phenomena suggest that the Laloi lagoon recorded more taxa, making up 90% of the total abundance than the Oyibi lagoon. The minimum information on the total number of individual species in the reference study on these lagoon fisheries became a significant setback to the metric selection. The total for Oyibi is 40, and Laloi is 34. From the metric evaluation and other biological data such as condition factor and length-weight relationship, Oyibi was observed to be moderately stressed, and Laloi was poorly stressed.

Deposition of organic matter to the sediment by mangroves and high nutrient concentrations contribute to the high chlorophyll-*a* concentration at Oyibi. The growth of planktonic algae in a water body is related to the presence of nutrients, in particular nitrates and phosphates (Brando et al. 2006). This result was supported by the high nitrates and phosphates concentrations recorded in the Oyibi lagoon. Excessive water column productivity, expressed by high chlorophyll concentrations, can supply large amounts of quickly organic decomposition matter to the sediments, as observed by Duarte (1995). Elevated chlorophyll levels indicate high numbers of phytoplankton and free-floating macroalgae and can translate into changes in animal and plant species diversity (Duarte 1995; Nielson and Jernakoff 1996).

#### *Species diversity*

Species diversity is an indicator of the well-being of ecological systems (Magurran 1988). The differences in species diversity can be attached to abiotic and biotic factors. The variety of nutrient levels can also be an influencing factor. Increased salts such as phosphates and nitrates are important in supporting phytoplankton growth, which is the basis in the primary food chain and greatly enhances fish production.

The high species richness in Laloi can be attached to the number of fishers that exploit different niches. There were five fishers at Laloi, while for Oyibi, on average, there were three fishers. Fishing contributes to the reduced abundance of species that spend all or part of their life cycle in estuaries (Lotze et al. 2006).

The diversity of fish species within a region is partly a function of the number of available niches and area size (Wootton 1990). Here, Oyibi had the highest species richness, which might be related to the presence of extensive mangrove forest that supports microhabitats for species (Connor et al. 1997). The size of the catchment area has been identified as a significant factor governing both fish species diversity and abundance in South African

water (Marais 1988). Biotic factors such as cannibalism, density-dependent predator mortality, intraguild predation, grazer-resistance of algae, and predator-dependent functional responses tend to increase bottom-up effects hence affecting species diversity in aquatic systems (McCauly et al. 1988; Gatto 1991; Ginzburg and Akçakaya 1992; McCann et al. 1998 and Hart 2002).

#### *Length-weight relationship*

The Length-weight relationship provides information that the fishes were isometric in their growth, meaning that the length increases in equal proportions with body weight and with a regression coefficient of „1“ indicates isometric growth (Gayando and Pauly 1997). The condition factor of *S. melanotheron* compares favorably with that from Sakumo, Muni, and Densu of values (2.61-2.77) as seen by Koranteng (1995) and Fosu lagoon of value 2.65 as observed by Blay and Asabere-Ameyaw (1993).

January (Oyibi) and April (Laloi) showed the highest value for the co-efficient growth. The highest value recorded in January can be attached to the upwelling season in the coastal waters (January-February). The mixture of surface and bottom waters raises nutrient salts such as phosphates and nitrates, increasing primary productivity. The highest value observed in April (Laloi) can be attached to the rainfall that occurred on sampling. Rain affects fisheries by making nutrients available and influencing salinity regimes. Koranteng's (1995) research on the Sakumo II lagoon showed that rainfall affects conditions, factors, and species diversity. In his study, he showed that the number of species decreased from 59 in March to 26 in June, resulting in a decrease in species diversity, while the condition factor increased from 3.12 in March to 3.72 in June during the onset of the rains.

Condition factor provides information when used to compare two populations living in specific feeding, climate, density. Other condition also serves important information, such as when determining the period of gonad maturation and when following up the degree of feeding activity of a species to verify whether it is making good use of its feed source (Weatherley 1972). The condition factor of *S. melanotheron* improved during the study, which can be attributed to seasonal variability of the environment and food availability or habitat suitability (Mommensen 1998; Henderson 2005; Nieto-Navarro et al. 2010). The high nutrient concentration at Oyibi boosting primary productivity may be one accounting for the high condition factor of the fishes. Biological factors such as nutrition and reproduction cause discrepancies in the condition factor. Higher values may imply the accumulation of fat and gonadal development (Le Cren 1951), while the lowest values suggest the transfer of resources to the gonads during the reproductive period (Vazzoler 1996).

#### *Similarity analysis*

There was no variation in species within the months of sampling, as seen via the Bray-Curtis similarity analysis, though there was a significant similarity between the sites. These results suggest that lagoons experience great

environmental variation in temperature, salinity, dissolved oxygen, and turbidity due to the influx of fresh and marine waters. Fish species that live in lagoons must cope with these rapid and extensive environmental changes. If fishes in water consistently respond to the environment, then the communities occupying similar types of estuaries in a particular region would be expected to reflect the similarity (Whitfield 1999).

#### *Total organic carbon*

The small numbers of *Sarotherodon melanotheron* found in the Laloi lagoon can be attached to the low organic matter content in the sediment of the lagoon. This reason also confers with fisher folks at the site revealed that this species was missing in catches for the past three years compared to previous years. *S. melanotheron* are bottom feeders in the food pyramids, and low organic matter content indicates less food for the species. The stomachs of adult *S. melanotheron* contain a fine fraction of bottom mud, comprising pennate diatoms, inorganic granules of 50-100  $\mu$  diameter, and organic detritus (Pauly 1976). Meanwhile, the high organic matter levels in the sediment at Oyibi can be attributed to the extensive mangrove cover. Because organic carbon is an organic pollutant, the high total organic carbon in these lagoons can be attributed to domestic wastes, human excreta, and mangrove forests' litter. The degradation of these wastes in the water column releases organic carbon that accumulates in the sediments. The high total organic matter measured at the seaward end can be attributed to the tidal influx that induces flow and transport of sediments (Blondeaux and Vittori 2005). Sediment transport and deposition may be strongly affected by tide-induced residual currents (Byun and Wang 2003). Ocean water deposits sediments and leaves them behind when the tide goes out during high tide (SlideShare Inc. 2009).

In conclusion, Oyibi, the lagoon with extensive mangrove cover, exhibited the highest species diversity than in the lagoon without mangroves (Laloi). The size of the lagoon was also found to be a possible factor that affects the abundance and distribution of species. During the study, the two most abundant species were the flathead grey mullet (*Mugil cephalus*) and the black-chinned tilapia (*Sarotherodon melanotheron*). In the Laloi lagoon, *Mugil cephalus* dominated catches while *Sarotherodon melanotheron* dominated catches in the Oyibi lagoon. *Lutjanus fulgens*, *S. melanotheron*, and *Eucinostomus melanopterus* were the most abundant species collected for the Laloi lagoon. *L. fulgens*, *Caranx hippos*, and *M. cephalus* constituted a major part of fishes caught in the Oyibi lagoon. The *Caranx hippos* contributed much of the biomass of fishes collected from both lagoons. The total fish number was most significant in the rainy season. Oyibi demonstrated a moderate site rating from the metrics assigned, suggesting that it was under mild stress, probably caused by garbage dumping, defecation, land-use changes, and increased human pressure. Laloi lagoon showed a poor site rating, suggesting that it was under severe stress, probably due to overfishing, mangrove degradation, defecation, garbage dumping, mangrove harvesting, and

increased human settlements along the banks of the lagoon. The multi-metric index assigned reflects the status of lagoon fish communities and the overall ecosystem conditions. Oyibi lagoon with extensive mangrove cover had high Chlorophyll-*a* level and top condition factor of fish species. Anthropogenic activities and tidal influx are possible factors affecting nutrient value in coastal lagoons. The tidal regime was an important factor that influences physiochemical parameters in coastal lagoons. Total organic carbon in sediments was an essential factor in determining the abundance of *S. melanotheron*.

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