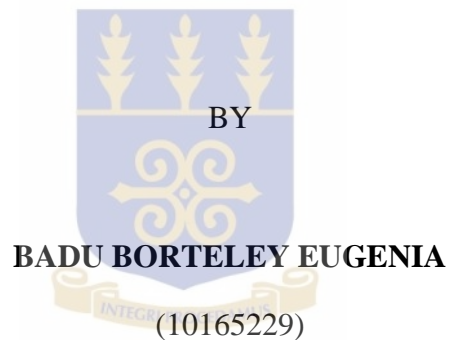


UNIVERSITY OF GHANA, LEGON

INSTITUTE FOR ENVIRONMENT AND SANITATION STUDIES

**FISH AS BIOINDICATORS OF HABITAT DEGRADATION IN COASTAL
LAGOONS**



A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE AWARD OF A
MASTER OF PHILOSOPHY (M.PHIL) DEGREE IN ENVIRONMENTAL SCIENCE.

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DECLARATION

This thesis is the result of a research work undertaken by Eugenia Borteley Badu in the Institute of Environment and Sanitation Studies, University of Ghana, Legon under the supervision of Mr. A. K. Armah and Dr. H. R. Dankwa. This work has not been submitted for any degree anywhere.

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DEDICATION

I dedicate this work to all who believed in me and gave me the needed support.



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This is the doing of the lord and it is wonderful in the sight. I thank the almighty God for His strength and Grace throughout the entire study.

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ABSTRACT

Lagoons and their wetlands are some of the most biologically and ecologically important ecosystems. The lagoon habitat also forms an integral part of the marine fishing industry and provides important spawning and nursery grounds for many fishes. Aquatic communities including fish and other species act as biological indicators of water quality and alterations by summarizing information about their environment. Two lagoons, Lalo and Oyibi in the Greater Accra and Central Regions of Ghana were studied from January to May to determine the ecological status using the Estuarine Fish Community Index (EFCI). Metrics assigned were the species diversity, trophic integrity, nursery function and species abundance and composition. At each site, water samples were taken at the riverine, middle and seaward portions during both high and low tides. Fisher folks were hired to fish at each of the sites. Uni-variate analyses (diversity) indices showed no significant differences between sites. Multi-variate analysis (Bray-Curtis similarity) showed a significant similarity between sites in relation to species composition. Eighteen species including both finfish and shellfish were identified. The flat head grey mullet (*Mugil cephalus*) and the black-chinned tilapia (*Sarotherodon melanotheron*) were the two most abundant species during the study. *Mugil cephalus* dominated catches in the Lalo lagoon and *Sarotherodon melanotheron* dominated catches in the Oyibi Lagoon. *S. melanotheron*, *Lutjanus fulgens* and *Eucinostomus melanopterus* were the most abundant species collected for the Lalo lagoon. *Caranx hippos*, *L. fulgens*, and *M. cephalus* constituted a major part of fishes caught in the Oyibi lagoon. The carangid, *Caranx hippos* contributed much of the biomass of fishes collected for both lagoons. Total fish

abundance was greatest in the rainy season than the dry season. Chlorophyll *a* concentrations and condition factor of *S. melanotheron* were highest at Oyibi Lagoon than Laloi Lagoon. Total organic carbon was observed to be high in the Oyibi lagoon hence the high numbers of *S. melanotheron* recorded. Tides were important factor affecting physico-chemical parameters. From the metrics assigned, Oyibi had a moderate site rating, suggesting that it was under moderate stress. The main stress factors identified were garbage dumping, defecation, land use changes and increased human pressure. Laloi Lagoon had a poor site rating, suggesting that it was under severe stress. The main stresses identified were overfishing, mangrove degradation, garbage dumping and increased human settlements along the sides of the lagoon. The multi-metric index described is an effective method that reflects the status of lagoon fish communities and the overall ecosystem conditions.

CHAPTER ONE

INTRODUCTION

1.1 Background

Lagoons are highly productive coastal features that provide a range of natural services that society values. A lagoon can be defined as an area of relatively shallow water that has been partly or wholly sealed off from the sea by the formation of spits or barriers built up above high tide level by wave action and lie parallel to the shoreline (Kjerfve 1994; Hill, 2001). Over 13% of coastlines in the world consist of shallow marine waters lying behind barrier pits or islands (Bird, 1982). In Ghana, there are over 90 coastal lagoons which cover less than 5 km² in surface area along the 550 km stretch of the coastline which forms 7% of the total land area of Ghana (Armah, 2005). Coastal lagoons are formed and maintained through sediment transport processes. Sediment carried by rivers, waves, currents, wind, and tides accumulates in river and tidal deltas, on marshes and flats where submerged aquatic vegetation slows currents, and on washover fans. The process of sedimentation can eventually fill in lagoons (Nichols and Boon, 1994). Lagoon barriers are constantly eroded by waves and wind, requiring continuous sediment deposition to maintain them (Bird, 1994). Coastal lagoons are modified by erosion and deposition (Lampsey, 2011).

Boughey (1957) classified the coastal lagoons of Ghana into 'open' and 'closed' lagoons. The open lagoon, often referred to as an estuary has sufficient volume of water at all

seasons to maintain a permanent outflow from its mouth into the sea and they mostly occur in western part of the coastline where rainfall is heavy (mean of about 1250 mm per annum) and the lagoons are fed continuously by rivers (Ansa-Asare *et al.*, 2007). The closed lagoons are fed by seasonal rivers and streams. They usually lie behind a sand barrier, which separates them from the sea and are normally opened for one or two seasons of the year during the rainy season (May- September) and mostly occur on the eastern coastal region where the rainfall is low (Ansa-Asare *et al.*, 2007).

Lagoons and their wetlands are some of the most biologically and ecologically important ecosystems. Wetlands present unique environments and habitats providing valuable products and services, which include the support of fisheries, flood assimilation, regulation and supply of water and protection of biodiversity. Wetlands also provide important roosting, nesting and feeding sites for many species of birds, especially migratory ones (Armah, 1993). The coastal wetland habitat also forms an integral part of the marine fishing industry and provides important spawning and nursery grounds for many fishes.

Associated with most tropical lagoons are mangrove swamps. In Ghana, the commonest mangrove species are *Rhizophora* spp and *Avicennia* spp. These mangroves serve as habitat for migratory birds, shellfish and fin fishes, they also absorb pollutants from coastal and upland sources, trap sediments from rivers and accumulate washed silt to raise the ground level, protect the coast against erosion, stabilize shorelines and improve water

quality (Entsua-Mensah, 2002). These mangroves are threatened by salt winning and indiscriminate harvesting as fuel wood for cooking and smoking of fish. Observations have shown that the mangroves, which filter inland water as it flows to the sea and serve as nursery and habitat for many shell and finfish are being rapidly destroyed (Entsua-Mensah, 1996). Lagoons in Ghana have a great influence in the socio-economic well being and health of communities that live close to and beyond. They are used in artisanal fisheries and play an important role in the economy of some coastal inhabitants, especially during the off-season for marine fishing ((Entsua-Mensah *et al.*, 2004)).

Environmental conditions underlie fisheries productivity (Finney *et al.*, 2002; Wynne & Cote, 2007) as well as fishing on the ecosystem. Fishing affects the benthic fauna and habitat, fish community structure and trophic interaction. Loss of habitat directly and indirectly through fishing and other processes, poses a major threat to the continual existence of many species (Roberts & Hawkins, 1999; Rodwell *et al.*, 2003). The fish community structure depends on both biotic and abiotic factors. Among the abiotic factors are: salinity, oxygen, pH, conductivity, total dissolved solids, phosphates, nitrates and silicates. Salinity is the most important in lagoons. Wide fluctuations in salinity may occur annually, seasonally or with the tide and may vary from the lower reaches nearest the sea to the riverine upper reaches. Temperature changes in lagoons are most noticeable in temperate and polar latitudes and often affect fish population densities (Whitfield, 1990). Temperature variations in the tropics are minimal. The annual shifts from wet and dry periods strongly influence the rate at which essential nutrients such as (nitrogen,

phosphorus and silica) enter the system from the surrounding watershed (Constanza *et al.*, 1993).

Overfishing and reduction of fish catches of certain fish species have affected the rural fishing economies (Entsua-Mensah, 2006). The types of over-fishing that occurs in most coastal lagoons are growth overfishing and recruitment overfishing. Growth overfishing is when fish are harvested at an average size that is smaller than the per recruit and recruitment overfishing is when the mature adult (spawner) population is depleted to a level where it no longer has the reproductive capacity to replenish itself thus not enough adults to produce offspring. Overfishing directly impacts on fisheries livelihoods through income and profit reduction, increasing competition and conflicts over fishing grounds, fishery resources and markets (Entsua-Mensah, 2006). Due to increased pressure in fish stock and dwindling stocks, small-scale fishers have begun using fine mesh nets, poisons and explosives putting further pressure on the resource (Bailey, 1994; Entsua-Mensah, 2006).

Additional pressures in this urbanized coastal area which includes loss of natural habitat through physical alteration to the system, discharge of potentially toxic materials into the wetland can change both aquatic species diversity and ecosystem due to their toxicity and accumulative behaviour (Heath, 1987). Degradation of wetlands ultimately results in narrow habitat dimensions, which reduce the survival ability of species, which cannot adapt (Jude and Pappas, 1992). The complexity of fishing gears (which are able to exploit

different niches), excessive fishing pressure and over exploitation, are some of the factors which have a negative impact on the lagoon ecosystem (Koranteng, 1995). A comparative study conducted by Laé (1997) on the effect of high and low fishing activities in Lake Togo, Togo and Ebrie lagoon, Ivory Coast respectively. He observed that fishing activities can change species composition, size class, structure and annual fish yields. Where fishing activity is high, fish diversity declines and alters the trophic structure.

Aquatic communities including fish and other species act as biological indicators of water quality and alterations. They respond to the cumulative effects of both physical and chemical disturbances to the water in which they live. Biomonitoring is defined as the use of organisms *in situ* to identify and quantify toxicants in the environment. It takes advantage of the ability of pollution sensitive organisms to respond to pollution of their environment (Chaphekar, 1991). Biomonitoring as defined by Ramakrishnan, (2003) as the use of biological response to assess changes in the environment, generally changes due to anthropogenic cause. Biological monitoring is a valuable assessment tool in water quality monitoring programs (Kennish, 1992) and it is used for detecting aquatic life impairments and assessing their relative severity, evaluating the effectiveness of control measures and in the planning and management of water resources (Ramakrishnan, 2003).

Bioindicators refers more specifically to organisms and their attributes which could be used to assess the health of the environment (Peakall,1992). It also refers to organisms or

organism associations which respond to pollutant load with changes in vital functions, or which accumulate pollutant. They are used to detect changes in the natural environment, monitor for the presence of pollution and its effect on the ecosystem in which the organisms lives, monitor the progress of environmental cleanup and test substances like drinking water, for the presence of contaminants (O'Connor & Ehler, 1991; Davis, 1993). The most important reasons for using bioindicators are the direct determination of synergistic and antagonistic effects of multiple pollutants on an organisms, the early recognition of pollutants damage to organisms as well as toxic dangers to humans and relatively low cost compared to technical measuring methods (Zimmermann & Umlauff-Zimmermann, 1994). Bioindicators can provide the following information for ecosystem management according to Lorenz, (2003): a description of ecosystem processes and structures, ecosystem condition by comparing the ecosystem with a reference level of good ecological functioning and cause-effect relationships with an ecosystem.

According to Burger & Gochfeld (1999), a bioindicator should exhibit changes in response to a stressor (sensitivity), have low natural variability, have measurable changes (preferably monotonically in response), exhibit persistent changes that are most likely attributable to the stressor (specificity), encompass variations in scale and complexity, and embody biologically important changes. A useful indicator is one that responds to stressors that are of concern, because then it can serve as an early warning of potential adverse effect. However, the responses should not be so sensitive that it falsely indicates trivial or biologically unimportant variations (Nkwoji *et al.*, 2010).

Fish has attracted much attention in the biomonitoring of water pollution due to its special biological characters such as relatively big body size, long life cycle and easy to raise (Qunfang *et al.*, 2008). More importantly, fish species are at the top position in the aquatic food chain and may directly affect the health of humans, which makes it much of significance for biomonitoring using fish. They also reflect the state of pollution very well because of their limited ability to eliminate contaminants (Sucman *et al.*, 2006). Fish are excellent indicators of watershed health because they:

- Live in water all their life and differ in their tolerance to amount and types of pollution.
- They are easy to collect with the right equipment, live for several years and easy to identify in the field.

They provide accurate assessment environmental health because:

- They have long life spans and hence can reflect both long and short term water resource quality.
- They present a broad spectrum of community tolerances from very sensitive to highly tolerant species.

Since they spend most of their life span in water, they integrate the chemical, physical and biological histories of the waters and they are less affected by natural microhabitat differences than smaller organisms (Holt and Miller, 2011).

Hence the objective of this study is to assess habitat degradation in coastal lagoons using fish as bioindicators.

1.2 Problem Statement and Justification

Lagoons are rich in nutrient salt and elementary productivity force resource, hence they have become an area for developing sea transport, reclamation, aquaculture and tourism (Zhuang,1992). Therefore they are more human activities in coastal areas than inland areas. Coastal and inland waters usually act as receptors for environmental pollutants which eventually flow into the sea (Akoto *et al.*, 2008). Their setting within the coastal landscape leaves them especially vulnerable to profound physical, ecological, and associated societal disturbance from global climate change and anthropogenic influences (Anthony *et al.*, 2009). Lagoons have been found to be extremely vulnerable to build up of contaminants from terrestrial freshwater and marine environment (Ansa-Asare *et al.*, 2007). In recent times, people are suffering from socio-economic and environmental hardship due to destruction and mismanagement of natural resources (Lambert, 2003). The destruction of wetlands has resulted in increased floods, poverty, scarcity of food and lack of good drinking water.

There is a growing evidence of lagoons in Ghana deteriorating at an alarming rate. This situation is attributed mainly to increased human population, urbanization, land use changes, overgrazing and global climate change. The direct consequence is reduction in fish landings, fish diversity and loss of aesthetic values of these lagoons such as the Korle and Chemu lagoons. There is therefore a need for prudent measures for the protection and sustainable management of the resource of the lagoons.

Specifically the study aims to:

- Compare the species diversity, composition and abundance of the Laloï and Oyibi lagoons
- Determine the similarities and dissimilarities in species composition
- Ascertain any effects of physico-chemical parameters on distribution of species
- To determine the ecological status of the Oyibi and Laloï lagoons.

CHAPTER TWO

LITERATURE REVIEW

2.1 COASTAL LAGOONS

Coastal lagoons are typically found along low-lying coastlines that have a tidal range of < 4 m (Martin and Dominguez , 1994). Lagoons constitute 13% of coastal regions globally, range in area from < 0.01 km² to > 10,000 km², and are typically < 5 m deep (Phleger, 1969; Bird 1994; Kjerfve 1994) and are often impacted by both natural and anthropogenic influences (Mee, 1978; Sikora and Kjerfve, 1985). In Ghana, there are over 90 coastal lagoons (FOE, 1994) along the 565 km stretch of the coastline (Wellens-Mensah *et al.*, 2002) with five designated RAMSAR sites; Densu Delta; Songor; Keta Complex; Muni-Pomadze and Sakumo II lagoons. Wetlands constitute about 10 percent of Ghana's total land area. The three main types of wetlands are: marine/coastal wetlands; inland wetlands; and human-made wetlands. Wetlands in Ghana are very productive and their resources have been traditionally used by local populations as a source of the basic necessities of life, ranging from building materials, hunting and fishing areas, to sources of water for humans and livestock (FAO, 2005).

2.2 TYPES OF LAGOONS

Kjerfve (1986) sub-divided coastal lagoons into three geomorphic types according to water exchange with the coastal ocean. They are choked, restricted and leaky lagoons.

Choked lagoons are lagoons which usually consist of a series of connected elliptical cells, connected by a single long narrow entrance channel, along coasts with high wave energy and significant littoral drift. These lagoons are characterised by long flushing time, dominant wind forcing and intermittent stratification due to intense solar radiation or run-off events and are associated with river deltas. These lagoons become permanently or temporary hypersaline in arid or semi-arid regions of the world (Copeland, 1967; More & Slinn, 1984).

The other type of lagoon is restricted lagoon which consists of a large and wide water body usually oriented shore-parallel and exhibit two or more entrance channels or inlets. Hence, they have a well defined tidal circulation and are influenced by wind, are mostly vertically well mixed and exhibit salinities from brackish water to oceanic salinities. Wind patterns in restricted lagoons can also cause surface currents to develop, thus helping to transport large volumes of water downwind (Hill, 2001).

Leaky lagoons are elongated and oriented shore-parallel with many ocean channels entrance where tidal currents are very small. It is characterised by numerous wide tidal passes, unimpaired water exchange with the ocean in waves and tides. Salinity is close to that of the coastal ocean. The lagoons under study can be described as leaky, since there is unimpaired exchange of water with the ocean.

2.3 ECOLOGICAL SIGNIFICANCE

Lagoons and its associated wetlands support a range of natural services that are highly valued by society (Gönenç and Wolflin, 2005) and diverse fish and fisheries. They are highly productive ecosystems and contribute to the overall productivity of coastal waters by supporting a variety of habitats, including salt marshes, seagrasses, and mangroves. They also provide essential habitat for many fish and shellfish species (Anthony *et al.*, 2009) and important as nursery grounds for a variety of marine fishes and shrimps (Day and Yañez-Arancibia, 1985; De Wit, 2003). Pauly (1975) categorised the fish in Ghanaian lagoons as follows:

- a) Fresh water fishes which swim into the lagoon through permanent or temporary rivers: *Tillapia zillii*, *Clarias anguillaris*, *Heterobranchus bidorsalis*, *Hemichromis fasciatus*, *Hemichromis bimaculatus*.
- b) Those that spend most of their lifetime in the lagoon: *Sarotherodon melanotheron*, *Porogobius schlegeli*, *Gobioides ansorgii*,
- c) Those that have their juvenile forms washed into the lagoon from the sea after the rainy season: *Ethmalosa fimbrita*, *Syacium microrum*, *Mugil cephalus*, *Liza falcippinis*, *Elops lacerta*.
- d) Marine species which make short incursions into the lagoon: *Lutjanus fulgens*, *Caranx hippos*, *Epinepheus aenus*, *Pegusa lascaris*, *Pseudotolithus senegalensis*.

Fishes in coastal lagoons can be put in ecological guilds and classified according to Elliot and Dewailly (1995) and Entsua-Mensah (1998) as follows;

Truly lagoon resident species and spends entire life in lagoon (ER), Marine adventitious visitors that appear irregularly in the lagoon but have no apparent lagoonal requirements (MA), Diadromous (Catadromous and Anadromous migrant species) that use the lagoon to pass between salt and freshwater for spawning and feeding (CA), Marine juvenile migrant species which use the lagoon primarily as nursery ground, usually spawning and spending much of their adult life at sea but often returning seasonally to the lagoon (MJ), Freshwater adventitious species which occasionally enter brackish water from freshwater but have no apparent requirements (FW) and Marine seasonal migrant species which have regular seasonal visits to the lagoon usually as adults (MS).

The highly diverse and productive communities of lagoons also provide some economic benefits such as the harvesting of fish and shellfish for food and income and shell picking for the ceramic and building industries. In Ghana, lagoon fishing is carried out by four main groups of people (Willoughby and Entsua-Mensah, 1998). These include:

Fishers, (male) who are commercial fishermen some of them operate solely within the lagoons, others are primarily marine fishermen, but fish in the lagoon when the weather is too bad for fishing, or when there are prohibited marine fishing days;

Fishers, (male) with small quantities of gear (e.g. cast nets and traps) who are operating barely on subsistence level;

Fishers, (female and children) who use small scale gear or gleaning techniques to supplement the family diet, usually fish for shellfish rather than catching fish for sale;

Recreational fishers, (mainly male) who are paid in employment elsewhere, but use spare time to fish for pleasure and the family table.

Lagoons serve as sanctuaries in certain areas for endangered species such as crocodiles and hippopotami (Day and Yañez-Arancibia, 1985) and economically important in their use for aquaculture facilities (Day and Yañez-Arancibia, 1985). They are used in the production of salts, through the process of crystallization of saline waters which is a common practice in the Songor and Keta lagoons in Ghana. Other values associated with coastal lagoons include inspirational activities such as landscape paintings as well as settings for films, literature, songs and other artistic expressions. Religious beliefs are another benefit derived from lagoons. In Ghana, most coastal lagoons are believed to be female gods and there are days set aside where there are no activities in these lagoons (non -fishing days). For instance, there are no fishing activities in the Muni lagoon on Wednesdays and a traditional rite is performed before any research activities are carried out in lagoons.

2.4 PHYSICAL CHARACTERISTICS OF LAGOONS

Depending on local climatic conditions, lagoons exhibit salinities which range from completely fresh to hypersaline (More & Slinn, 1984; Kjerfve, 1986; Kjerfve & Magell, 1989; Merino *et al.*, 1990; Knoppers *et al.*, 1991). The size of coastal lagoons varies substantially with surface areas ranging up to 10,200 km² as in the case of Lajoa dos patus in Brazil (Kjerfve, 1994). The water depth is typical 1-3 m, and almost always less than 5 m with the exception of inlet channels and isolated relic holes or channels.

The quality and quantity of water in a lagoon is influenced by the rate at which the lagoon loses or gains water from evaporation, precipitation, groundwater input, surface runoff, and exchange with the ocean (Allen *et al.*, 1981). Lagoon–ocean exchange is driven by tides and wave action (Zimmerman, 1981) and is often the largest component of lagoon water balance (Smith, 1994). Heat is also lost and gained through exchange with the atmosphere, sediment, and ocean (Smith, 1994). The flushing rate, i.e., the rate at which water enters, circulates through, and exits the lagoon, is a fundamental physical property and controls the retention time of waterborne constituents. Lagoons tend to have low flushing rates because of restricted exchange with the ocean, contributing to high primary productivity and potentially high pollutant concentrations (Spaulding, 1994). Determinants of the flushing rate include the size and shape of the lagoon, the level of connectivity with the ocean, tidal range, and freshwater flow (Phleger, 1981), because of

their relatively low flushing rates, coastal lagoons are favorable habitats for primary producers (phytoplankton and aquatic plants).

Sources of nutrients in lagoons include surface and groundwater flows and through exchange with the ocean. Nutrients availability often limits primary productivity, hence coastal lagoons foster high rates of primary production, thereby supporting high rates of secondary production compared to other aquatic ecosystems (Nixon, 1982; 1995). However, if primary production exceeds the demands of consumers, eutrophication occurs (Valiela *et al.*, 1992). Eutrophication is characterized by excessive phytoplankton and macroalgal blooms and subsequent hypoxia, reduced light penetration (McGlathery, 2001; Anderson *et al.*, 2002), stress and die-offs of marine organisms, loss of seagrass beds, changes in food web interactions and community structure, and loss of biodiversity (National Research Council, 2000).

2.5 BIOINDICATORS

Ecosystems are influenced by both biotic and abiotic stress factors such as fluctuations in climate, varying radiation and food supply, predator-prey relationships, parasites, diseases, and competition within and between species (Markert *et al.*, 2003). These stressors lead to physiological or morphological changes, decrease species diversity and alteration in community structure and composition. According to Markert *et al.*, (2003), a bioindicator is an organisms or part of an organism or a community of organisms that

contains information on the quality of the environment or part of the environment while a biomonitor is an organism or part of an organism or a community of organisms that contains information on the quantitative aspects of the quality of the environment. Bioindication helps to define environmental quality or assess environmental hazards and risks (Fränzle, 2003) and provide information on the occurrence of ecological processes (Lorenz, 2003).

According to Lorenz (2003) bioindicators can provide the following information for ecosystem management:

- A description of ecosystem processes and structures.
- The ecosystem condition by comparing the ecosystem with a reference level of good ecological functioning.
- Cause- effect relationships within an ecosystem.

2.5.1 Characteristics of bioindicators

Table 2.1 Characteristics of bioindicators

CHARACTERISTICS	DESCRIPTION/COMMENTS
Good indicator ability	Provide measurable response (sensitive to the disturbance or stress but does not experience mortality or accumulate pollutants directly from their environment).
	Response reflects the whole populations/community/ecosystem response.
	Respond in proportion to degree of contamination or degradation.
Abundant and common	Adequate local population density (rare species are not optimal)
	Common, including distribution within area of question.
	Relatively stable despite moderate climatic and environmental variability.
Well-studied	Ecology and life history well documented

<i>Table 2.1 cont'd</i>	
	Taxonomically well documented and stable
	Easy and cheap to survey
Economically/commercially important	Species already being harvested for other purposes
	Public interest in or awareness of the species.

Source: Holt & Miller, 2011

2.6 FISH AS BIOLOGICAL INDICATORS

2.6.1 History and development

Fish have been and remain a major part of any aquatic study designed to evaluate water quality (Simon, 1999) and fish community characteristics have been used to measure relative ecosystem health. Fish as a bioindicator, mainly developed from the US, where fish have been one of the most studied groups of aquatic organisms since 18th century (Jha,2006). Earlier work done on bioindication include the use of fish zonation patterns for river classification (Fritsch, 1872; Thienemann,1912; 1925). Other works include studies on the changes in fish distribution as a result of pollution plumes and sewerage outfalls (Brinley, 1942; Katz & Gaufin,1953; and Karr *et al.*, 1985a) .

2.6.1. 1 Advantages of fish as bioindicators

There are several reasons why fish are widely used and accepted to describe natural conditions as well as the alterations of aquatic systems. The advantages mentioned here are the compilations of the advantages listed by many scientists working in this field (Karr, 1981; Fausch *et al.*, 1984; Leonard & Orthe 1986; Hughes & Noss ,1992; Paller *et al.*,1996; Simon, 1999; Yoder & Smith, 1999; Hughes & Oberdorff, 1999; Chovanec *et al.*, 2003; Fränzel, 2003; Lorenz, 2003)

- Most fish species have long life spans (2-10+) years and can reflect both long-term and current water resource quality. Due to their longevity and their size of their bodies and organs a great variety of analytical procedures can be carried out.
- Fish are relatively easy to identify. Thus most fish samples can be sorted and identified on site.
- Life history information is extensive for most fish species and information about conditions of fish community can easily be understood by the general public.
- Fish represent a broad spectrum of community tolerances from very sensitive to highly tolerant and respond to chemical, physical and biological degradation in characteristic response patterns.
- Fish have larger ranges and are less affected by natural microhabitat differences than smaller organisms. Thus making fish extremely useful for assessing regional and macrohabitat differences

- Fish are present, even in the smallest streams and in all but the most polluted waters. They continually inhabit the receiving water and integrate the chemical, physical and biological histories of the waters.
- Fish communities generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivore, planktivores, piscivores) and include foods of both aquatic and terrestrial origin. Their position at the top of the aquatic web in relation to diatoms and invertebrates also helps to provide an integrative view of the watershed environment.
- As migratory organisms, they are suitable indicators of habitat connectivity or fragmentation.
- A long tradition of ecological, physiological and ecotoxicology research on fish has led to an advanced knowledge of the ecological, physiological requirements of a large number of fish species. The effectiveness of bioindication approaches depends on sound knowledge of the indicator's ecological demands and physiology.
- They have both economic and aesthetic values and thus help raise awareness of the value of conserving aquatic systems.

2.6.1.2 Disadvantages of fish as bioindicators

- Fishery caused alteration, such as species transfer, stocking and overfishing make it more difficult to discuss other man-induced degradations of aquatic ecosystems.
- The mobility of many species makes it difficult to identify not only the exact source of pollution, but also the time and duration of exposure.

2.7 FISH STRESS AND HEALTH

Fishes are important indicators of environmental and ecological change and can reveal the magnitude of changes in aquatic environment over time. Stress is the cumulative and quantifiable effect of a factor or combination of factors operating on an individual, population, community or ecosystem that renders it less fit for survival (Whitfield & Elliott, 2002). This stress can take the form of environmental and ecological impacts. Guastella (1994) found that the catch rate of anglers in Durban Bay declined between 1976 and 1991, and attributed this decrease to factors such as loss of habitat, poor water quality, disturbance by harbour traffic and possible over-exploitation of fish stocks. A study conducted by Hamerlynck and Hostens (1994) in the Oosterschelde Estuary in Europe observed that the number of anadromous fishes decreased with the construction of a storm-surge barrier at the mouth of the estuary.

Fish health is also influenced by any adverse effects following the accumulation of heavy metals and other toxins from polluted environment. A study conducted by Blaber *et al.*, (1984) on fish as indicators of estuarine environment abuse observed that the juvenile Mugilidae from Mdloti Estuary had average dieldrin levels of 49 mg/ kg at a time when this pesticide was a banned substance in South Africa. Fish samples collected from the Kosi estuarine system in 1976 all had DDT in both the muscle and liver, with the flathead mullet *Mugil cephalus* L. having DDT concentrations of 400 mg/kg in the muscle and 860 mg/kg in the liver (Butler *et al.*, 1983).

2.8 FISH AS INDICATORS OF ENVIRONMENT AND ECOLOGICAL CHANGE

Gess and Hiller (1995) studied fish as indicators of changes in aquatic environment over time using fossil research in Grahamstown area as South Africa. This research provided the evidence of a fish assemblage that occupied an estuarine lagoon c. 360 million years ago. Palaeozoic fishes found in these deposits are represented by both juveniles and adults (Anderson *et al.*, 1994). According to Karr and Dudley (1981), physical and chemical attributes of water are unsuccessful as surrogates for measuring biotic integrity. Oberdorff and Hughes (1992) used fish assemblage based index of biotic integrity (IBI) to assess water quality in the Seine River catchment. They found that comparisons between the IBI and an independent water quality Index (based on water chemistry) indicated that the former was a more sensitive and robust measure of water body quality.

Hocutt (1981) suggested that the structure and functional diverse fish communities provide evidence of water quality in that they incorporate all the local environmental perturbations into the stability of the communities. He concluded that fish communities present a viable option for assessing human-related impacts on freshwater ecosystems. Elliot and Dewailly (1995) attempted to determine the usual estuarine fish community for European estuaries based on both a taxonomic and functional approach, illustrating that such comparisons are possible.

Fish communities have often been used to illustrate changes in the condition of estuarine environments (Whitfield, 1997), particularly as they relate to organic and inorganic pollution of these systems (Elliot and Hemingway, 2002). This is well represented in a study conducted in the United Kingdom in the Clyde and Thames estuaries. By 1845, fish population in the upper estuary appeared to have been eliminated altogether and severely damaged in the lower estuary (Gordon, 1845). According to the 1872 Rivers Pollution Commission the demise of the fishes in the Clyde by 1850 was attributed to a long history of increasing organic and industrial pollution. The return of fish species and changes in their abundance at several localities in the estuary coincided with reductions in organic pollution and increasing DO levels during the 1970s (Wharfe *et al.*, 1984). Further positive changes in the fish populations during the late 1970s and early 1980s were documented by Henderson and Hamilton (1986) and related to continuing improvements in water quality and recovery of the invertebrate benthos.

In the Thames estuary, there was the collapse of the smelt *Osmerus eperanus* (L.) fishery in the tidal Thames due to 'the state of the water' in that portion of the estuary. Similarly, salmon were also in the process of being eliminated from the Thames estuary in the early 1800s (Yarrell, 1836). The decline and demise of the fisheries was linked to increasing pollution levels in the Thames and overfishing. According to Wheeler (1979), the turn of the twentieth century saw improvements to the Thames following attempts to treat London's sewage and resulted in the return of some species of fish to the London region of the Thames Estuary. Other studies in the U.K. have used changes in species abundance to document the recovery of estuarine systems, e.g. Potter *et al.*, (2001) documented an increase between the 1970s and 1990s in the annual fish catches from the intake screens of the Oldbury Power Station in the Seven Estuary. These authors suggested that the marked increase in species abundance such as sand goby *Pomatoschistus minutus*, *Merlangius merlangus*, bass *Dicentrarchus labrax*, thin-lipped grey mullet *Liza ramada*, herring, sprat and Norway pout *Trisopterus esmarkii* reflects the great improvement that occurred in the water quality of the Seven Estuary between these decades (Little & Smith, 1994).

Other aquatic organisms that can be used as bioindicators include plankton, algae, insect, mollusk, bird, plant and benthos. Pearson and Rosenberg (1978) identified the cosmopolitan endobenthic polychaete *Capitella capitata* (Fabricus) as an indicator for organically polluted and disturbed marine environments.

2.9 CONDITION FACTOR OF FISHES (CF)

Condition factor compares the well-being of a fish and it is based on hypothesis that heavier fish of a given length are in better condition (Bagenal & Tesch, 1978; Baginal, 1978). The length-weight relationship is very important for proper exploitation and management of the population of fish species (Anene, 2005). CF is important for stabilizing the taxonomic characters of the species (Pervin & Mortuza, 2008).

The L-W relationship of fish is an important fishery management tool (Abowei *et al.*, 2009), and an important factor in stock assessment models (Morato *et al.*, 2001; Stergiou and Moutopoulos, 2001) by converting growth in-length equations to growth in-weight, estimate biomass from length frequency distributions (Petraakis & Stergiou, 1995; Dulčić & Krajević, 1996) and compare life history and morphological aspects of populations inhabiting different regions (Stergiou and Moutopoulos, 2001). Its importance is pronounced in estimating the average weight at a given length group (Beyer, 1987) and in assessing the relative well being of a fish population (Bolger and Connoly, 1989). CF has been used as an index for monitoring growth rates, age and feeding intensity in fish (Fagade, 1979; Oni *et al.*, 1983), condition factor decreases with increase in length (Bakare, 1970; Fagade 1979) also influences the reproductive cycle in fish (Welcome, 1979).

It is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live (Anene, 2005). Other indicators that could offer information on the general health condition of fish include Hepatosomatic index (HSI) which is defined as the ratio of liver weight to body weight and Gonado-Somatic Index (GSI) is the ratio of gonad weight to body weight used to estimate reproductive condition.

2.10 FACTORS AFFECTING FISHERIES IN COASTAL LAGOONS

Due to their generally shallow nature and small size, environmental factors have a marked bearing on the flora and fauna inhabiting lagoons (Colombo, 1977). They are systems that are easily disturbed both by natural processes and by pollution from adjacent urban and industrial development. As a result they are affected by an array of physical, chemical and biological factors.

2.10.1 Environmental factors

Environmental gradients are important in structuring communities by allowing some species to survive (Badu, 2007). Climate change is only one of many sources of disturbance to lagoon ecosystems, and these disturbances occur concurrently at multiple temporal and spatial scales (Anthony *et al.*, 2009). Climate change stressors can manifest

slowly over decades and on regional and continental spatial scales, local, site-specific stressors can occur rapidly and cause significant impacts to lagoons. The effects of environmental degradation on biotic assemblages include a decline in generally intolerant or sensitive species, increase in tolerant or insensitive species, decline in abundance of the total number of individuals, percentage decline of old growth individuals, the number of size and age class declines, reproduction of generally sensitive species decrease, increase diseases or anomalies.

2.10.1.1 Sea level

Accelerated sea level increase is a threat to low-lying, shallow-gradient coastal ecosystems (Anthony *et al.*, 2009). This greatly influence barrier lagoons or open lagoon systems. Most barrier- lagoon systems respond naturally to sea level increase by migrating landward along undeveloped shorelines with gentle slopes (Hayes, 2005); the retreating shore face profile can remain essentially unchanged as the shoreline retreats landward and upward in response to moderate seal level increases (Bruun, 1962). However, with accelerated sea level increase, landward retreat of barriers may not be rapid enough to prevent inundation (Zhang *et al.*, 2004). As lagoons are inundated by seawater, salinity will increase, possibly altering the species composition (Bird, 1993; Mackenzie *et al.*, 2007), this can be attributed to retreat of lagoon barriers landward increasing the vulnerability of the barriers' to breaching and the lagoons' flushing rates (Zimmerman, 1981) and the shortening of the length of existing inlets (Bird, 1994).

Another impact of increased sea level on coastal lagoon is the reduction of light penetration to submerged aquatic vegetation, this reduces the photosynthetic potential of primary producers and changing the nutrient dynamics such that lagoons may be more susceptible to eutrophication (Lloret *et al.*, 2008). Physico-chemical studies conducted on estuaries (Biney, 1985) and lagoons (Biney, 1986; 1990) in Ghana also showed that the quality of these waters is affected by the transfer of solutes from the ocean and the influx of freshwater.

2.10.1.2 Temperature

Fish is affected by the temperature of the surrounding water which intends influences the body temperature, growth rate, food consumption, feed conversion and other functions (Houlihan *et al.*, 1993; Britz *et al.*, 1997; Azevedo *et al.*, 1998) because they are cold-blooded animals. Water temperature is a driving force in the fish life because it has a more predictable and seasonal effect (Kausar & Salim, 2006). Growth and livability in fish are optimum within a defined temperature range (Gadowaski & Caddell, 1991). Each fish species has an ideal temperature within which it grows quickly.

In warmer environments fish have a longer growing season and faster growth rate but tend to have a shorter life span than in cool water. High water temperature increases the metabolic rates, resulting in increased food demand. Although, fish can generally function in a wide range of temperature, but they do have an optimum range, as well as lower and upper lethal temperature for various activities (Beschta *et al.*, 1987). Freshwater fish have

an optimum growing temperature in the range of 25-30°C (Anonymous, 1983) at which they grow quickly. An increased in temperature increases the activity of digestive enzymes, which may accelerate the digestion of the nutrients, thus resulting in better growth (Shcherbina & Kazlaaskene, 1971). A study conducted by Kausar and Salim, (2006) on the effect of water temperature on the growth performance and feed conversion ratio of *Labeo rohita* observed that the best Feed Conversion Ratio was recorded in the fish kept at 24-26°C temperature range, followed by those maintained at 22-24 °C and 20-22 °C. Thus FCR increased with increasing temperature.

Changes in air temperature strongly influence the water temperature of slow-moving, shallow water bodies such as coastal lagoons (Turner, 2003). Air temperatures increase quickly over land than over oceans, hence coastal temperatures are also likely to increase more rapidly (Harley *et al.*, 2006). Water temperature influences DO concentrations, as well as the physiology of lagoon organisms, species' ranges, and patterns of migration (Woodward, 1987; Turner, 2003). Increase in air temperature of lagoons, makes them susceptible to colonization by invasive species that thrive in warmer waters (Stachowiz *et al.*, 2002). As lagoon temperatures increases, DO concentrations are likely to decrease (Bopp *et al.*, 2002; Joos *et al.*, 2003). In restricted lagoons with low flushing rates and high nutrient inputs, temperature increases will increase the hypoxic events (D'Avanzo & Kremer, 1994). Chronic hypoxia leads to changes in benthic community structure characterised by a persistent shift in species composition (Anthony *et al.*, 2009).

Fish migration is linked to water temperature. Rising water temperature may cue fish to migrate to a new location or to begin their spawning season. As temperature drops, juvenile marine fish and shrimp move from their nursery grounds in the estuaries out into the ocean, or into rivers. Diatoms grow well at temperatures of 15°C- 25 °C, green algae at 25-35 °C, and blue-green algae at 30-40 °C. Warm water also makes some substances, such as cyanides, phenol, xylene and zinc more toxic for aquatic animals. Tropical fishes survives best in a range of 21 °C -32 °C but may not survive in a temperature below 15°C.

2.10.2 PHYSICOCHEMICAL PARAMETERS

2.10.2.1 Ammonia, Nitrites and Nitrates

Nitrogen occurs in natural waters as nitrate (NO_3), Nitrite (NO_2), Ammonia (NH_3) and organically bound nitrogen. Ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-) are the most common ionic (reactive) forms of dissolved inorganic nitrogen in aquatic ecosystem (Camargo & Alonso, 2007) and play the most important in the biogeochemical processes in aquatic medium. The main sources of these ions are either natural or anthropogenic. Naturally, they occur through atmospheric deposition, surface and groundwater runoff, dissolution of nitrogen containing geological deposits, N_2 fixation by cyanobacteria and biological degradation of organic matter.

Anthropogenic sources are derived from both point and non-point sources. Non-point sources include agricultural run-off, cultivation of N_2 fixing crop species, emissions from reduced and Oxidized N compounds and runoff from burned forests and grasslands. As aquatic plants and animals die, bacteria break down organically bound nitrogen in these organisms to ammonia. Point sources include municipal and industrial sewage effluents, greywater from livestock farming and aquaculture operations and runoff and infiltration from waste disposal sites. NH_4-N play an important role as key plant nutrients as it is most favourable form of plant N for assimilation (Wetzel,2001).

NO_3-N is an important plant nutrients and an indicator of the trophic status of lagoons. Increased amount causes increase algal biomass content of the lagoons with adverse ecological effects such as hypoanorexia.

2.10.2.2 Phosphate

In aqueous solution, phosphorus exists as orthophosphate, polyphosphate or organic phosphate. The orthophosphates, $H_2PO_4^-$, H_3PO_4 , HPO_4^{2-} are available for biological metabolisms without further breakdown. PO_4 is an important plant nutrient and usually a limiting factor in lagoons, excess of which causes eutrophication due to extensive algal bloom. Sources of phosphorus include human and animal wastes (i.e., sewage), industrial wastes, soil erosion, and fertilizers.

2.10.2.3 Salinity

Changes in salinity often modify population distributions and biotic community structure (Carriker, 1967). Salinity variation in lagoon is due to the influx of saltwater during high tides. Increased in salinity have been shown to cause shifts in biotic communities, limit biodiversity, exclude less-tolerant species and cause acute or chronic effects at specific life stages (Weber-Scannell and Duffy, 2007). Derry *et al.*, 2003 reported that the diversity of aquatic species decline as osmotic tolerances are exceeded with increasing salinity and an inverse relation exist between salinity and aquatic biodiversity. Thiel *et al.*, (1995) observed that in the Elbe estuary in Germany as salinity decreased upstream, species number, species diversity, evenness and frequency of occurrence of marine fish species all decreased.

2.10.2.4 Dissolved Oxygen (DO)

Dissolved oxygen deficiency, or hypoxia, is of critical importance to the health of aquatic life and the oxygen concentration of aquatic medium varies with temperature, atmospheric pressure, salinity, turbulence and photosynthetic activities of algae. The solubility of DO decreases as temperature and salinity increases and as pressure decreases (Annang, 2000). Diaz and Rosenberg (1995) observed that should DO concentrations become slightly lower, catastrophic events may overcome the systems and alter the productivity base that

leads to economically important fisheries and amenities. Aquatic biota exposed to low DO concentrations may be more susceptible to the adverse effects of other stressors such as disease, toxic chemicals, and habitat modification (Holland *et al.*, 1977). Connell & Miller, (1984) showed that DO consumption and production are influenced by the presence of plant and algal biomass, and light intensity and temperature subject to diurnal and seasonal variations.

Low DO conditions can increase the vulnerability of the benthos to predation, as the infaunal animals extend above the sediment surface to obtain more oxygen (Holland *et al.*, 1987). Concentrations below 5 mg/l may affect the functioning and survival of biological communities and below 2 mg/l may lead to death of most fishes (Chapman & Kimstach, 1992). Biney (1986) reported DO range for lagoons in Ghana from 0.0 -8.0 mg/l.

2.10.2.5 TDS/TSS

Total Dissolved Solid (TDS) is a measure of inorganic salts, organic matter and other dissolved materials in water (US EPA, 1986). The concentration and composition of TDS in natural waters is determined by the geology of the drainage, atmospheric precipitation and the water balance (evaporation-precipitation) (Wetzel, 1983). Changes in TDS concentrations in natural waters often result from industrial effluent, changes to the water balance (by limiting inflow, by increased water use or increased precipitation), or by salt-

water intrusion. Total dissolved solids cause toxicity through increases in salinity, changes in the ionic composition of the water and toxicity of individual ions (Weber-Scannell and Duffy, 2007). A study conducted by Weber-Scannell and Duffy, (2007) on the effects of TDS on aquatic species with reference to Salmonid species observed that increased TDS affect different life stages in fish especially during the fertilization period.

Total suspended solids can influence macrophytes and algae, primarily through affecting the amount of light penetration through the water column. The reduction in light penetration through the water column will restrict the rate at which periphyton, emergent and submersed macrophytes can assimilate energy through photosynthesis which will impact directly on primary consumers (Bilotta & Brazier, 2008). It can also indirectly affect the abundance of phytoplankton through acting as vector of nutrients such as phosphorus (Heathwaite, 1994) and toxic compounds such as pesticides and herbicides from the land based surface to the water body (Kronvang *et al.*, 2003). TSS can affect benthic invertebrates by subjecting them to abrasion and scouring. This can damage exposed respiratory organs or make the organism more susceptible to predation through dislodgement (Langer, 1980). Graham (1990) demonstrated that suspensions of clay-sized particles can be trapped by epilithic periphyton and reduce its attractiveness for grazing.

Suspended solids affects free-living fish directly by clogging and being abrasive to their delicate gill structures (Cordone & Kelley, 1961; Ellis ,1944 ; Kemp, 1949). It also stresses or suppresses the immune system of fish leading to increased susceptibility to

disease and osmotic dysfunction (Ellis, 1981; Redding & Schreck, 1983; Redding *et al.*, 1987). Fish are known to respond to TSS fluxes, the fish themselves can also cause fluxes of suspended solids through activities such as bioturbation whilst foraging and through excretion of waste products. Matsuzaki *et al.*, (2007) demonstrated that the common carp (*Cyprinus carpio*) could have a dramatic influence on sediment and nutrient dynamics resulting in a modification of the littoral community structure and triggering a shift from a clear water state dominated by submerged macrophytes, to a turbid water dominated by phytoplankton.

2.10.2.6 Biological Oxygen Demand (BOD)

BOD measures the amount of oxygen consumed by microorganisms in decomposing organic matter in any water body. It also measures the chemical oxidation of inorganic matter (i.e. the extraction of oxygen from water via chemical reaction). (USEPA, 2011). There is an inverse relation between BOD and DO. As BOD increases, DO decreases, thus making oxygen less available for aquatic life. BOD is an indication of the organic load of a water body. Higher values indicate higher organic load hence the reduction in DO. Sources of BOD include leaves, wood debris, dead plants and animals, greywater and urban stormwater run-off.

2.10.2.7 pH

pH also a potential of hydrogen is defined as the negative logarithm of hydrogen- ion concentration (Pankratz, 2000). This is usually expressed as the hydrogen-ion concentration and measurement is done on a pH scale of 0 – 14. A value of 7 at 25°C indicates a neutral condition, 0-6.9 indicates increasing hydrogen ion (acidity) and increasing values indicate decreasing ion concentration (alkalinity). It catalysis chemical reactions in the water and sediment as well as metabolic activities in living aquatic organisms. Metcalf and Eddy (2003) observed that the concentration range suitable for the existence of most biological life is quite narrow and critical, it is from 6 to 9 whiles Alabaster & Lloyd, (1981) reported pH 5-9 is not lethal to fishes. Although each organisms has an ideal pH for optimal growth and survival, for most aquatic organisms' pH of 6.5-8.5 is the optimum (Addy *et al.*, 2004).

2.10.2.8 Chlorophyll *a*

Chlorophyll *a* concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters and can be an effective measure of trophic status (Nixon, 1995). They are potential indicators of maximum photosynthetic rate (Eyre and Ferguson, 2002). High levels often indicate poor water quality and low levels often suggest good conditions (Brando *et al.*, 2012). Factors that influence Chlorophyll *a* include nutrients, temperature, light intensity, tidal regimes and flushing rate.

2.10.2.9 Total Organic carbon (TOC)

Total organic carbon has a major influence on both the chemical and biological processes that take place in sediments. TOC content in sediment has been used as an indicator of pollution and eutrophication rate (Folger 1972; EPA, 2002). Organic matter is a primary source of food for benthic organism. Sources of organic carbon include organic matter from overland runoff, primary productivity within the lagoons, and decomposition of plant debris and shoreline erosion which eventually settle to the bottom and are incorporated into the sediments. High organic matter can lead to the depletion of oxygen in the sediment and overlying water, which can have a deleterious effect on the benthic and fish communities.

2.11 ANTHROPOGENIC FACTORS

Land-use changes, freshwater withdrawal from ground and surface water sources, sedimentation, point and nonpoint water pollution, shoreline hardening, and overfishing are examples of anthropogenic stressors that can have profound and sudden impacts on coastal ecosystems (U.S. Environmental Protection Agency, 2007; Khan, 2007; Rodriguez *et al.* 2007; Bilkovic and Roggero, 2008; Hollister *et al.*, 2008 *a,b*,). Laleye and Entsua-Mensah (2009) identified water pollution, habitat loss due to deforestation, mining and agricultures as the greatest threats to freshwater fishes in West Africa.

2.11.1 Pollution

Pollution from point sources or from run-offs from industries, farms, domestic activities, mines impact greatly on coastal fish and fisheries communities. Pollution results in loss of species hence loss of the genetic pool or change in the genetic composition. Aquatic pollution is both chemical and physical (Laleye and Entsua-Mensah, 2009). In 2002, Scheren and Ibe observed that continuous and substantial inputs of pollutants / contaminants owing to natural variations and human, activities around urban lagoon systems increases the negative impacts on living aquatic resources, and consequently, decreasing the socio-economic opportunities directly dependent on these natural resources.

Biney (1982) identified pollution from domestic activities as the major cause of deterioration in water quality in Ghanaian lagoons. This, he attributed to inadequate provision of basic sanitary facilities in most coastal settlements. Thus sewage and garbage are either deposited on lagoon banks or beaches. Pollution can affect lagoons directly by increasing the amount of toxic chemicals, or indirectly. The decrease of water quality reduces the suitability of the lagoon habitat for fish (Alabaster & Lloyd, 1982). In an assessment of the state of pollution of some lagoons and estuaries in Ghana, 12 were classified as polluted to various extents (Biney, 1982). The Korle and Chemu were grossly polluted. The eight estuaries studied were generally clean or only slightly polluted. Ekundayo (1977) reported that the eutrophication of Lagos lagoon was due

primarily to extensive pollution by large quantities of industrial and domestic wastes and faecal pollution.

2.11.2 Over Fishing

Removal of species through concentrated over-fishing in a particular species modifies the physical nature of the habitat or pollution of the system, all result in changes to the community or trophic structure of the ecosystem (Blabber, 2000). The consequences of heavy fishing pressure on fish populations include changes in the size structure and species composition of catches. Large predatory fishes and intermediate fishes are replaced by short-lived species. This is clear in the predominance of *Sarotherodon melanotheron* in most lagoons in Ghana (Entsua-Mensah, 2002).

Graham *et al.*, (2007) observed that fishing can change the size distribution of species resulting in decline in abundance of small size classes and increasing in some larger size classes. Increased fish harvesting leads to changes in fish community structures and distributions, with an overall reduction in recruitment. Overfishing also causes a decline in average fish size and often lowers trophic levels of fish communities following the disappearance of larger species (Laleye and Entsua-Mensah, 2009).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study sites

The coastline of Ghana is endowed with various natural resources. Many activities are carried out along the coast; fishing, oil exploration, thermal energy generation and salt extraction. These activities couple with environmental and climate changes adversely impact on the fisheries and other wetlands along the coast. The coast of Ghana has been categorized into three geomorphic units, namely the west coast, the central coast and the east coast (Ly, 1980). The west coast ends from Ghana's border with Cote d'Ivoire to the estuary of the Ankobra River. It covers 95 km of stable shoreline and comprises of fine sand with gentle beaches backed by coastal lagoons. Rocky headland and littoral sand barriers enclosing coastal lagoons characterize the central coast. It stretches for about 321 km from the estuary of Ankobra River near Axim to Prampram. The third division, the east coast is made up of 149 km of shoreline from Prampram to Aflao. It is mainly sandy and characterized by the deltaic feature of the Volta River. The geology of the coastal plains of Ghana has been divided into three main sections by Dickson & Benneh (1980).

The south-east coastal plain is up to 80km wide and the land is flat with a general elevation of less than 75 m. Between Accra and Songor lagoon the coast is sometimes cliffed and is composed of mid Devonian sandstone, grits shales. Further eastwards of the

coastline is fairly smooth and is characterised by sandbars. It includes the Volta delta and the Keta lagoon. This portion of the coast is made up of recent unconsolidated sand clay and gravel. The central plain is composed of red continental deposits, limonitic sand, sandy clay and gravel. The study sites are located within the central coast. The coastal plain has two rainy seasons; the principal one reaching its maximum in May-June and the minor seasons begins in mid-August and ends in October. The mean rainfall is about 735 mm. The main economic activities in the catchment of the lagoons are fishing and salt winning. The study was conducted in the Laloi and Oyibi lagoons in the Greater Accra and Central regions of Ghana respectively. They sites were chosen due to its easy accessibility and economic importance. The sites are located at Kpone and Nsuekyiri (near Winneba).

MAP OF THE STUDY AREA - LALOI LAGOON

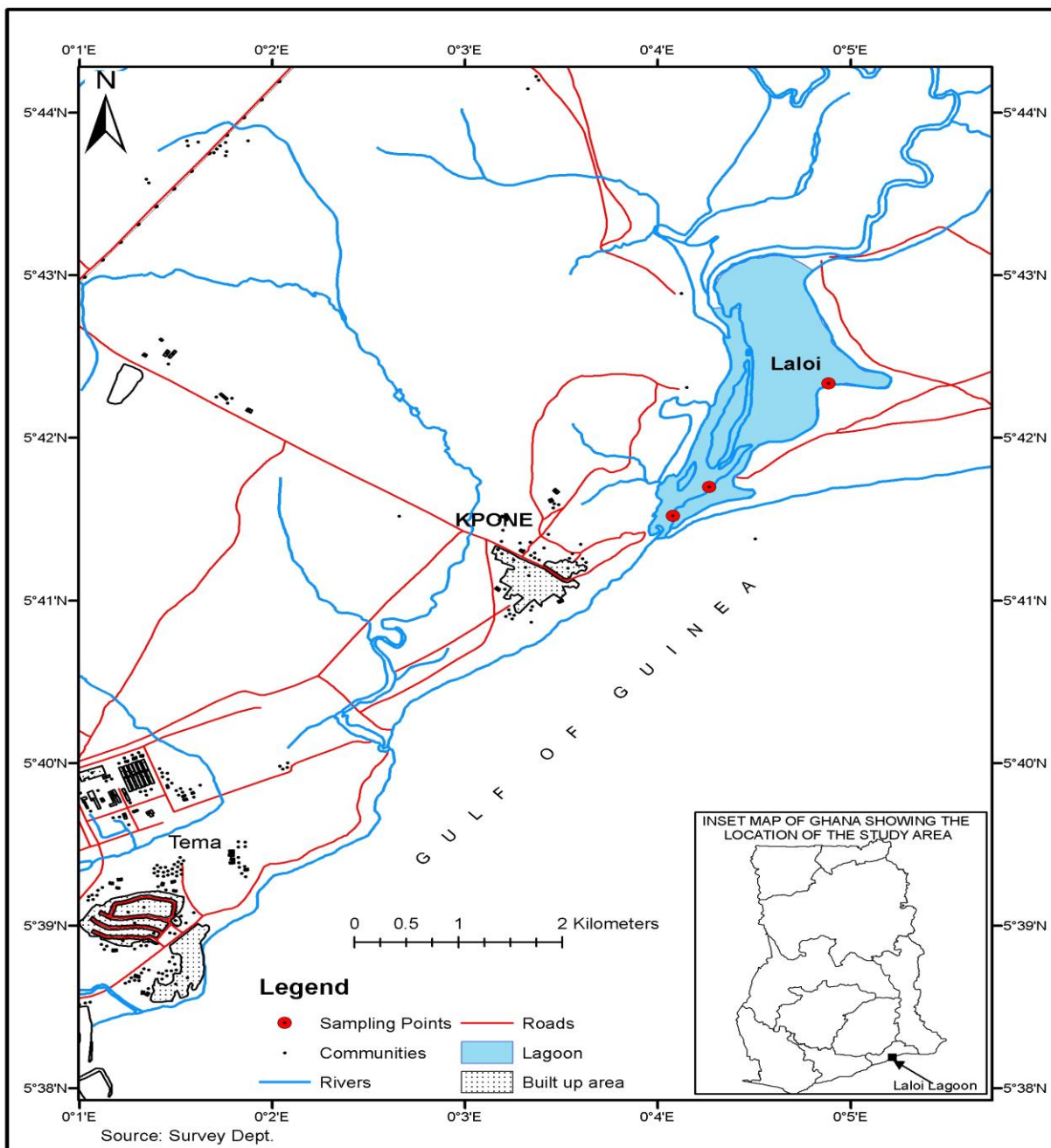


Figure 3.1 Map of Laloi lagoon showing the sampling points.

MAP OF THE STUDY AREA - OYIBI LAGOON

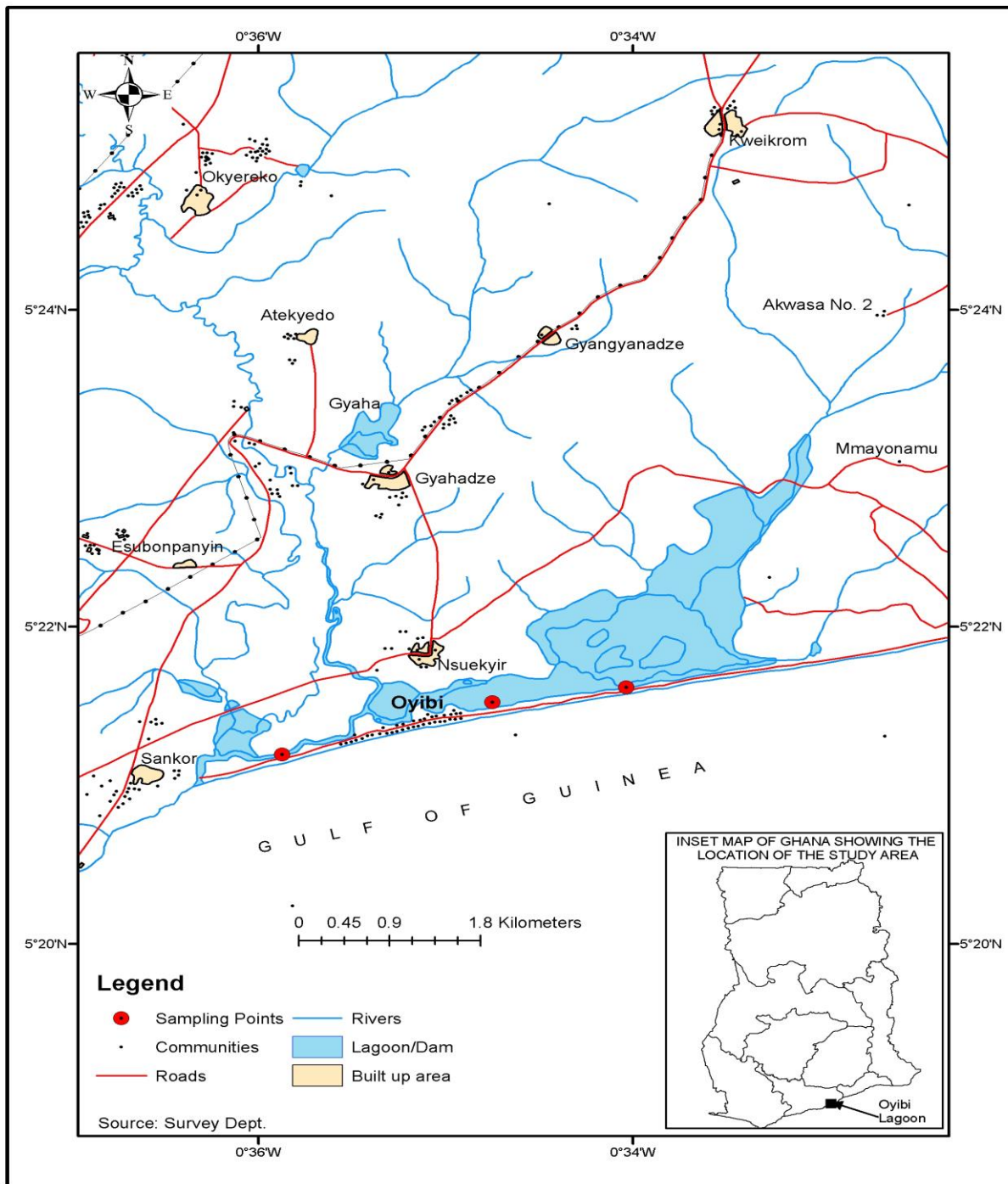


Figure 3.2 Map of Oyibi lagoon showing sampling points

3.1.1 Laloi Lagoon

The Laloi lagoon falls within latitude 5.42.30 N and longitude 0.04.35 E with total area of 0.695 km² (Gordon *et al.*, 1998). The lagoon is located at Prampram and enters the sea at Kpone which lies in the Tema Export Processing zone. It serves as an important economic role in the community by providing fish for domestic purposes and for income. The mangrove is of critical degradation (Entsua-Mensah, 1996). Associated with the mangrove, *Avicennia* spp is the succulent grass *Sesuvium portulacastrum* and *Paspalum vaginatum*. The main economic activity carried out at the site is salt mining and fishing. The lagoon is opened all year round and it is not fished on Tuesdays. Fish landed from the lagoon is not fried but can only be boiled or smoked. The main fishing gears employed are the cast nets, drag nets and traps mainly for crabs. The traps are often used by boys for the blue-swimming legged crab, *Callinectes* sp. The trap is baited and allowed to float in the lagoon. The lagoon is fed by the Gao lagoon.



Plate 3.1 Degraded mangroves at Laloi.



Plate 3. 2 Laloi lagoon at low tide.



Plate 3. 3 The Trap used for blue swimming crabs in the Laloi lagoon

3.1.2 Oyibi Lagoon

The Oyibi lagoon falls within latitude 5°21' N and longitude 1°36' E with a size of 0.300 km² and an average depth of 0.5 m (Gordon *et al.*, 1998). It lies at the mouth of the Ayensu River and close to Winneba. The lagoon enters the sea at Warabeba, a fishing village with the women mostly fishmongers and Essuekyir at the northern side of the lagoon. There is extensive mangrove cover around the lagoon with species of mangrove including *Avicennia germinans*, and *Rhizophora racemosa*. The main economic activity at the site is fishing and salt production, the lagoon water is not use in the production of salt but seawater is pumped into pans. The lagoon is not fished on Wednesdays and opened throughout the year. The main fishing gears employed in the lagoon are the cast and drag nets.



Plate 3.4 Extensive mangrove cover at Oyibi showing the prop roots.

3.2 Field methods

Sampling was done from January to May, 2012. Each of the sites was visited once every month during the six months period. Tide predictions were made using tide tables from the Ghana Ports and Harbour Authority (GHAPPHA). Water samples were collected from the riverine end, middle reaches and the seaward end during the period of low and high tides. This was to ascertain any effect of tidal influence on physicochemical parameters.

3.2.1. Fish Sampling Methods

Fisherfolks were hired to fish at each site. Fish samples were also bought from fisherfolks at each site to give a representative of the fish species at each site. The main fishing gears employed at the sites was the cast net of mesh size 2.5 cm . Fishing was done during both high and low tides. Fish harvested was sorted out according to species and stored in an ice-chest and transported to the laboratory for identification. Fish samples were collected from January to May.

a)



b)



Plate 3.5 a& b *Lutjanus* and *Mugil* sp encountered during the study period



Plate 3. 6 Measuring of physico-chemical parameters in-situ at Laloi

3.2.2 Water Sampling Methods

The physicochemical parameters measured were the nutrients, (nitrates, and phosphates), BOD, DO, chlorophyll a, salinity, pH, temperature, TSS and TDS. Sub-surface water samples were collected at three points (lower, middle and upper reaches) from each site and stored in a 250 ml tight plastic bottle for nutrient analysis. For BOD analysis, dark glass bottles were used. DO was determined using the Winkler method. Water samples collected were immediately fixed with 2 ml of Winkler 1 (Manganese sulphate) and Winkler 2 (Alkaline iodide –azide reagent) solutions and firmly corked, making sure no air bubbles were trapped in the bottle. It was kept on ice and transported to the laboratory for analysis. In transporting to the laboratory it was kept at a constant temperature in an

air tight container with ice cubes. Temperature and pH were measured in-situ using YOKOGAWA pH meter model PH 82. Salinity was measured using the ATAGO 2SE refractometer. HACH Spectrophotometer was used for the analysis. Water samples were taken from February to May.

3.2.3 Sediment Sampling Method

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

3.3. Laboratory Methods

3.3.1 Length-Weight Analysis

The total length (TL) of the dominant fish was measured from the tip of the snout to the extended tip of the caudal fin using a meter rule calibrated in centimeters. Fish weight was measured after blot drying with a tissue paper. Weighing was done with a table top weighing balance, to the nearest gram. The relationship between the length (TL) and weight (W) of fish was expressed by equation (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 estimated from a linear regression of the length and weight of fish after a logarithmic transformation of equation 1. The correlation (r^2), that is the degree of association between the length and weight was computed from the linear regression analysis.

The condition factor (CF) of the fish was calculated by the formula

$$\text{Condition Factor (CF)} = W / L^3 * 100\% \quad (\text{Pauly, 1983})$$

Fish was identified using identification keys of Schneider (1990), Dankwa *et al.*, (1998) and an online fish identification site FISHBASE , (www.fishbase.com).

3.3.2. Water Analysis

The water samples were allowed to equilibrate with room temperature prior to laboratory analysis. Chemical assays were carried out for nitrates and phosphates, using a direct reading spectrophotometer following protocols provided in the HATCH 2800 and 2007 manual and the standard methods for the examination of water and wastewater (AWWA,

1998). The sample blanks were prepared using deionized water to which reagents was added.

3.3. 2.1. Total Suspended Solids & Total Dissolved Solids

A photometric method was used in the determination of TSS. A 500 ml of the sample was blended at high speed for exactly 2 minutes. The blended sample was then poured into a 600 ml beaker and stirred. A 10 ml was poured into a sample cell, swirl to remove any gas bubbles and uniformly suspend any residue. TDS was analysed using the gravimetric method. The sample was filtered and the filtrate evaporated on a water bath. The residue left after evaporation was dried to a constant weight in an oven at 105⁰C. The increase in weight over that of the empty dish is the weight of the TD. The weight includes liquid, solids and materials that have passed through the chosen filter media that were not volatilized during the drying process (APHA, 1998).

3.3.2.1 .1 Nitrates and Phosphates

Analysis of nitrates was done using the cadmium reduction method. In this method, cadmium metal reduces nitrates to nitrite. The nitrite then reacts in an acidic medium with sulphuric acid forming an intermediate diazonium salt that couples with the acid to form an amber-coloured product, the intensity of which depends on the concentration of nitrates in the sample. 10 ml of each sample was measured into a sample cell and the contents of one NitraVer 5 nitrate reagent pillow powder was added and stopped. The sample was shaken

vigorously to aid in the dissolution of the reagents. The blank was prepared, wiped into the cell reader to zero the instrument. The prepared sample was then wiped and inserted into the cell reader.

Phosphates were analyzed using the ascorbic acid methods. Phosphates in the sample reacts with molybdate in an acidic medium to produce a phosphomolybdate complex ascorbic acid reduces the complex ion giving the molybdenum blue colour which is proportional in intensity to the concentration of phosphates in the sample. 10 ml of each sample was measured into a sample and then PhosVer 3 reagent pillow powder was added, corked and shaken vigorously for 30 seconds. A blank sample was prepared using 10 ml of the sample to zero the instrument. The prepared sample was then wiped and inserted into the cell holder.

3.3.2.1.2 DO and BOD Determination.

In the laboratory, 2 ml of concentrated sulphuric acid (H_2SO_4) was added to the water samples and shaken until dissolution was complete. 50 ml of the solution was taken and titrated with a standard concentration of 0.0125M sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) solution until a pale yellow colour was obtained. 2ml of starch indicator was added to the solution, which gave the solution blue colour and titration was continued until the solution became colourless (APHA, 1998). For BOD measurement, the initial DO was measured, and then incubated in the dark at 20°C for 5 days. After, the 5 days the DO was measured

again. The difference between the DO consumed by microorganisms during the incubation period and the initial DO is the BOD.

3.3.2.1.3 *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.



Plate 3. 7 Water analysis at the laboratory

3.3.2.1.4 Total organic carbon (TOC)

TOC was measured using a quantitative method, the wet oxidation method. 0.5g of the sediment was measured. A 10 ml of dichromate solution was added to the sample. 20 ml of concentrated H₂SO₄ was added to the sediment, swirled and allowed to stand for 30 minutes. 200 ml of distilled water, 10ml of orthophosphoric acid and 2 ml of barim diphenylamine sulphonate indicator was added to the sample in a 500 ml volumetric flask. The solution was then titrated with ferrous ammonium sulphate. The percentage carbon was calculated as follows:

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

v: volume of ferrous ammonium used in titration

N: Normality of Ferrous ammonium

W : Weight of sediment in grams.

3.4 Health and Safety Assurance

The following quality assurance procedures were adhered to

- Sampling bottles were washed thoroughly and then rinse with deionised water to get rid of all traces of soap.
- Blank samples were prepared using deionized water.
- Water samples were allowed to equilibrate with room temperature before analysis.

- Protective gloves and Laboratory coat was used to prevent damage from chemicals.

3.5. Data Analysis

Univariate and multivariate techniques were used to describe the environmental parameters and fish communities. A multi-metric fish index was used to describe the condition of the water bodies. These were the species diversity and composition, species abundance, trophic integrity and nursery function following after Harrison and Whitfield, (2004).

3.5.1 Metric selection

A metric is a measurable factor that represents some aspect of biological assemblage structure, function, or other community component (USEPA, 2000). Community structure and function is defined by biological measures such as species diversity, species dominance, faunal abundance and biomass, presence of indicator species, and trophic function or structure (Krebbs ,1985; Elliot *et al.*, 2002). The metrics was selected based on work done by Harrison and Whitfield (2004). A total of 10 metrics were selected from the 14 metrics this is due to the lack of information on the feeding habits and fisheries of the study sites.

3.5.1.1 Species diversity and composition

Species diversity, which tends to be reduced in stressed biotic communities (Odum,1983), is an attribute of faunal communities used in most biological assessments of environmental health. The total number of taxa (metric 1) provides the simplest measure of species diversity. The presence of rare or threatened species (metric 2) was selected on the basis that their occurrence imparts additional conservation value to the ecosystem. Because rare species are fragile, they may become endangered or even locally extinct with increasing anthropogenic stress (Costello *et al.*, 2002). The presence of exotic or introduced species (metric 3) represents a potential threat to naturally occurring taxa through competitive exclusion and predation. They also represent a direct measure of human interference.

3.5.1.2 Species Abundance

The proportion or relative abundance of species (metrics 5) in an estuary in relation to a reference fish community provides a quantitative assessment. Environmental stress generally results in a change in relative abundance from ‘diverse’ communities consisting of many species in relatively low proportions to ‘simple’ assemblages dominated by a few species (Odum, 1983; Fausch *et al.*, 1990). Linked to this is the concept of dominance; the number of taxa required to make up 90% of the total abundance (metric 6) represents a simple measure of dominance.

3.5.1.3 Nursery functions

Lagoons are important nursery sites for both marine species, as well as serving as important habitat for resident taxa (Wallace *et al.*, 1984; Whitefield, 1998). The number of estuarine or resident taxa (metrics 7) measures two groups of fishes that are probably most susceptible to lagoon degradation by virtue of their strong dependency or association with these environments. The number of estuarine-dependent marine taxa (metric 8) measures how well an estuary is fulfilling its role as a nursery habitat. An undisturbed estuary is expected to contain a relatively balanced fish community comprising representatives of both groups. An excessively low numerical abundance or unexpected high dominance by one particular group often indicates an imbalance or disturbance within a system (Begg, 1984a). The relative abundance of both estuarine resident species (metric 9) and estuarine-dependent marine species (metric 10) are complementary measures to quantitatively assess estuarine habitat quality and nursery function for these two major groups.

3.5.1.4 Trophic Integrity

Lagoons are among the most productive ecosystems on earth (Odum, 1983; McHugh, 1985). By acting as detritus traps, they provide abundant food resources for filter and deposit feeding invertebrate prey as well as a variety of fish species including detritivorous, herbivorous, zooplankivorous, benthic invertebrate feeders and piscivorous

taxa (Whitfield, 1998). For this study, the condition factor and chlorophyll a concentration was used for the measurement of the trophic integrity.

3.5.2 Univariate Analysis

The community structure were analyzed by means of abundance and diversity indices such as Shannon-Wiener diversity index (H'), Margalef's species richness (d) and Pielou's evenness index. (J) were calculated. The Shannon -Wiener diversity index is a combined measure of both species richness and evenness (Hamillton, 2005), a minimum value of 0 for this index shows a community with single species and it increases as species evenness and richness increases.

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

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

Where p = the proportion of the total count (or biomass) arising from the i th species.

The index was calculated using natural logarithmic base (\log_e). The Shannon Diversity Index usually falls between 1.5 and 3.5 and rarely surpasses 4.5 (Margalef, 1972).

Pielou's evenness is an indication of the relative abundance of species in the community; (the number of individuals and 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 which would be achieved if all species were equally abundant.

Margalef's richness is an expression of the number of species making up 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 PRIMER v.6.0 software package (Plymouth Routine in Marine Ecological Research) (Carr, 1996).

Diversity indices summarize the numerical associations of organisms and allow populations to be compared; they are generally 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).

3.5.3 *Multivariate Analysis*

3.5.1. *Bray-Curtis Similarity Index*

Multivariate analysis was done using PRIMER v.6.0 software package (Plymouth Routine In Marine Ecological Research) (Carr, 1996). The similarity matrix for the classification among the two sites was calculated as Bray-Curtis similarity indices (Bray & Curtis, 1957). The results were then graphically 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 pair of sampling units are completely different to 1 when sampling units are identical. The Bray-Curtis similarity indices allows all species to contribute to the definition of similarity whilst retaining some of the information on the prevalence of a species ensuring that the commoner species are generally given greater weight than the rare ones.

In the standardization of the data on species diversity a 4th root transformation was applied to fish abundance data in order to preserve information concerning relative abundance but also to minimize differences in scale among variables (Clarke, 1993; Anderson and Underwood, 1997). The similarity indices of species composition between stations (Clarke & Green, 1988) does not consider the double absences frequently found in the data and it's calculation is also unaffected by difference in sample size.

3.5.4 Metric calculation.

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

CHAPTER FOUR

RESULTS

4.1 Fish Composition and Abundance

A total of 19 species were identified consisting of 17 finfishes and 2 shellfishes. The finfishes belong to 14 families and 17 genera and the shellfish belong to 2 families and 2 genera. The dominant species for the Laloï Lagoon was *Mugil cephalus* and that of Oyibi was *Sarotherodon melanotheron*. *Callinectes latimanus* and *Penaeus* sp were the only shellfishes recorded during the period of the study. The only shellfish recorded at Laloï was *Callinectes latimanus* and that of Oyibi lagoon were *Callinectes latimanus* and *Penaeus* sp. The total number of individuals recorded at Oyibi was 532 and that of Laloï was 437. The number of species recorded at Oyibi were 15 fin fishes and 2 shell fishes. A lower number of species was recorded at Laloï comprising 12 fin-fishes and a shell-fish. The various species encountered at each site is presented in Table 4.1.

Species encountered at Oyibi was composed of *S. melanotheron* making up 56% of the total species followed by *Caranx hippos* (17%), *Mugil cephalus* (7%), *Lutjanus fulgens* (6%), and *Tilapia guineensis* (4%). Species encountered at Laloï was made up of *M. cephalus* (41%), *S. melanotheron* (20%), *Caranx hippos* (3%), *L. fulgens* (16%), *Eucinostomus melanopterus* (5%), *C. latimanus* (5%) and *T. guineensis* (3%).

Table 4.1 Fish species found in the Oyibi and Laloi lagoons

Family	Species	Common name	Laloi lagoon	Oyibi lagoon	% Composition	Category
Bothiade	<i>Syacium microrum</i>	rock sole	X	X	0.9	MA
Carangidae	<i>Caranx hippos</i>	horse mackerel	X	X	10	MA
Cichlidae	<i>Sarotherodon melanotheron</i>	black-chinned tilapia	X	X	39	ER
	<i>Tilapia guineensis</i>	guinean tilapia	X	X	4	FW
	<i>Hemichromis fasciatus</i>	banded jewelfish	X		0.1	FW
	<i>Oreochromis niloticus</i>	nile tilapia		X	0.1	FW
Clupeidae	<i>Ethamalosa fimbriata</i>	bonga shad		X	0.8	MA
Cyprinodontidae	<i>Epiplatys sexfasciatus</i>	sixbar panchax		X	0.3	FW
Eleotridae	<i>Eleotris vittata</i>	eleotrid	X	X	0.6	ER
Elopeidae	<i>Elops lacerta</i>	ten pounder		X	0.2	ER
Gerreidae	<i>Eucinostomus melanopterus</i>	flagfin mojarra	X	X	3	MA
Gobidae	<i>Chonophorus lateristriga</i>	west african freshwater goby		X	0.2	FW
Lutjanidae	<i>Lutjanus goreensis</i>	Goreen snapper		X	1	MS

Table 4.1 cont'd

	<i>Lutjanus fulgens</i>	golden african snapper	X		11	MS
Mugilidae	<i>Mugil cephalus</i>	flat head grey mullet	X		22	ER
	<i>Mugil curema</i>	white mullet	X	X	0.7	ER
Penaidae	<i>Peneaus sp</i>	shrimp		X	1	
Portunidae	<i>Callinectes latimanus</i>	blue-legged swimming crab	X	X	3	ER
Serranidae	<i>Epinephelus aeneus</i>	common white grouper	X		0.8	MA
Lethrinidae	<i>Lethrinus atlanticus</i>	atlantic emperor	X		0.1	MA
Scaridae	<i>Callyodon hoefleri</i>	parrot wrasse	X		0.5	MA

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

4.2 Metric selection

4.2.1 Nursey functions

The number of marine adventitious species found in the Oyibi lagoon was 7 species and 6 was recorded in Laloi. The highest number of estuarine resident species recorded was 5 and a least of 3. The highest was found in the Oyibi lagoon and the least in the Laloi lagoon. The number of freshwater species found at both sites was 2. The result is represented in Figure 4.1.

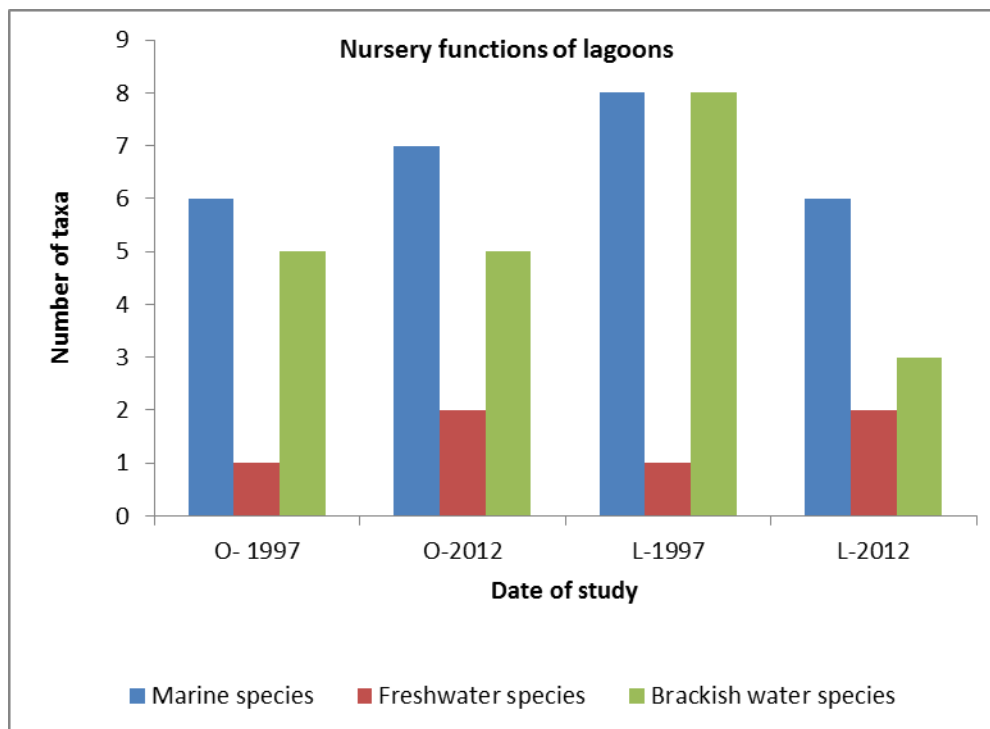


Figure 4.1 Comparison of the number of taxa of the study sites in 1997 and 2012. **KEYS: O: Oyibi, L: Laloi. (1997 data: Dankwa *et al.*,)**

4.2.2 Species abundance

The relative abundance of species differed among the two sites. For the different categories of species found, brackish species were in the majority, followed by marine species and then freshwater species. 65% of the species found in Oyibi were brackish species, 30% marine species and 6% freshwater species. For Laloi, 60% of the species found were brackish, 28% marine and 8% freshwater. For the measurement of dominance, 6 taxa (*Mugil cephalus*, *S. melanotheron*, *Lutjanus fulgens*, *Eucinostomus melanopterus*, *Callinectes latimanus* and *Tilapia guineensis*) were recorded at Laloi making up 90% of the total abundance. Five taxa (*S. melanotheron*, *Caranx hippos*, *Mugil cephalus*, *L.fulgens* and *Tilapia guineensis*) were observed to dominate the total abundance at Oyibi.

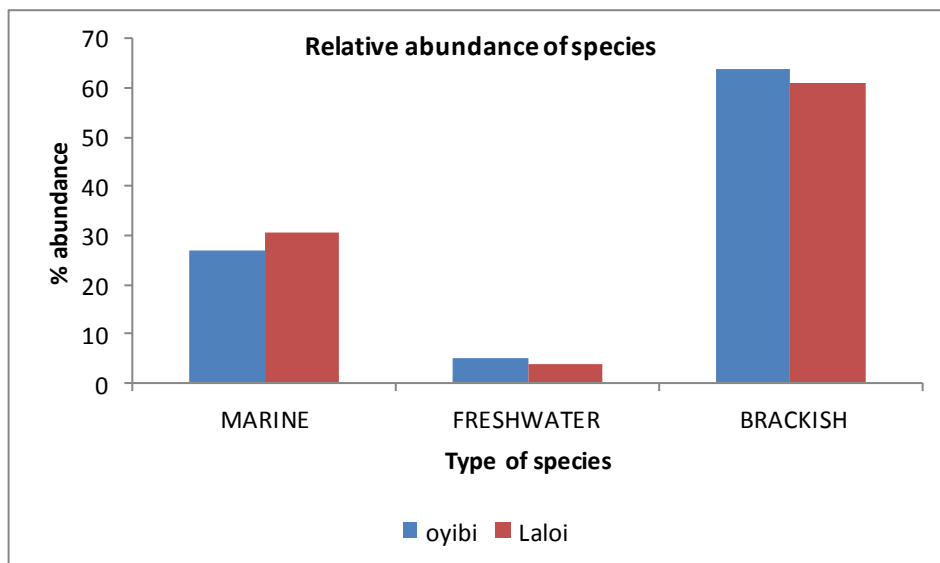
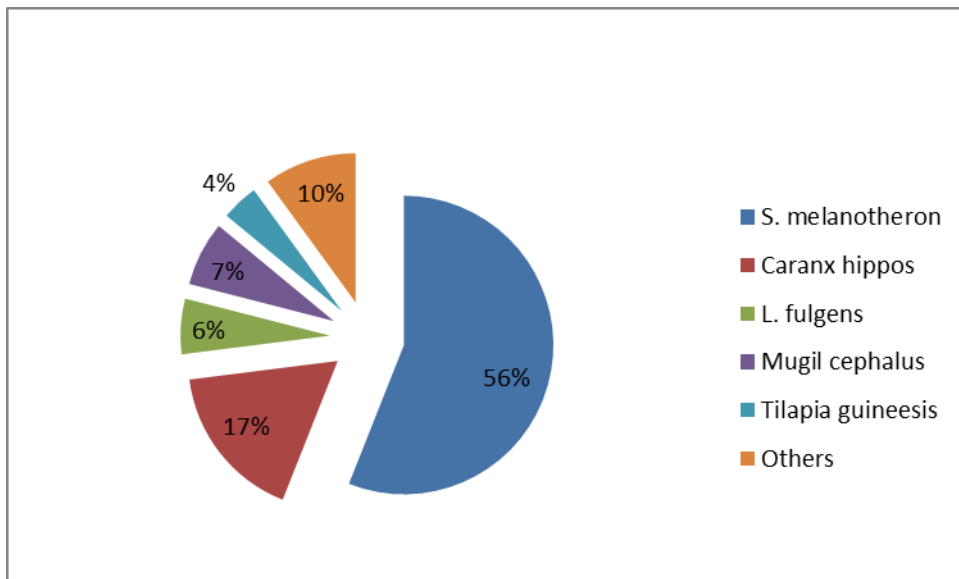


Figure 4.2 Comparison of the relative abundance of the various categories of species found in the Laloi and Oyibi lagoons.

a)



b)

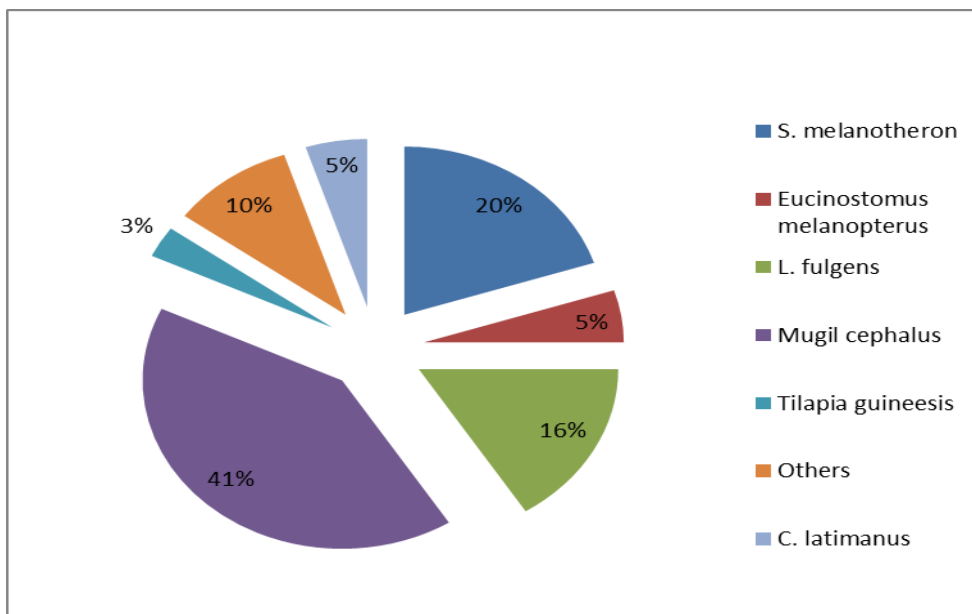


Figure 4.3 a & b Relative abundance of species found in the (a) Oyibi and (b) Lalo lagoons.

4.2.3 Trophic Integrity

Chlorophyll *a* concentrations were high at Oyibi than Laloi. For Oyibi lagoon, the highest chlorophyll *a* level was 0.20 mg/l recorded in riverine end in the month of April at high tide and the least value recorded was 0.00028 mg/l in the month of May at the middle portion. The average for Oyibi lagoon during the entire study period was 0.012 ± 0.036 mg/l. The average recorded for high and low tides were 0.0194 ± 0.05 mg/l and 0.0045 ± 0.003 mg/l. Average values recorded for Oyibi were 0.0025 ± 0.063 mg/l for the riverine end, 0.0034 ± 0.003 mg/l for the middle section and 0.0072 ± 0.008 mg/l for the seaward end.

For Laloi lagoon, the highest chlorophyll *a* level was 0.015 mg/l recorded in riverine end in the month of March at low tide and the least value recorded was 0.0010 mg/l in the month of April at the seaward end at low tide. The average for Laloi lagoon during the entire study period was 0.0048 ± 0.0040 mg/l. The average recorded for high and low tides were 0.0040 ± 0.0027 mg/l and 0.0056 ± 0.0049 mg/l values recorded for Laloi were 0.0073 ± 0.0051 mg/l for the riverine end, 0.0052 ± 0.0025 mg/l for the middle section and 0.0017 ± 0.00057 mg/l for the seaward end. The result is represented in Figure 4.4.

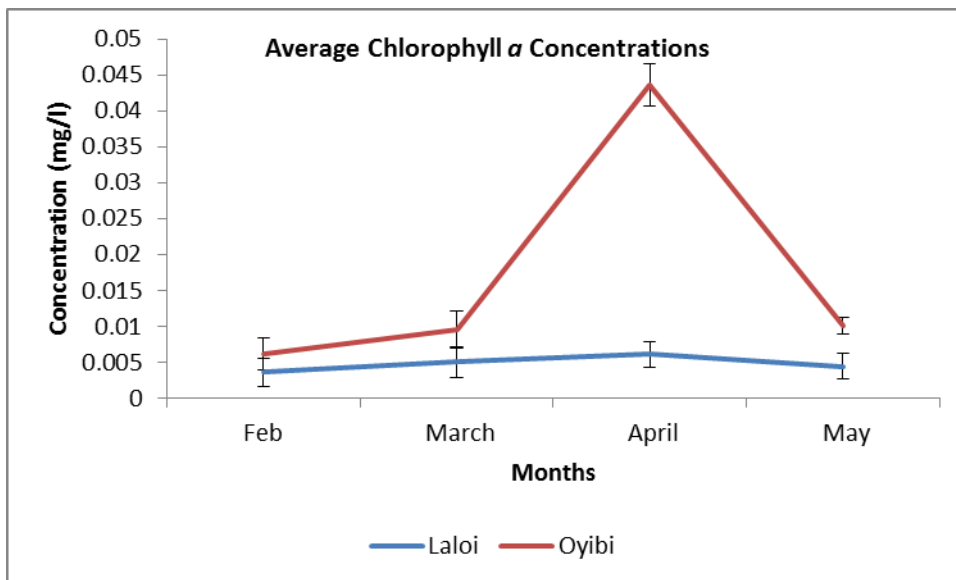


Figure 4.4 Average Chlorophyll *a* in the Oyibi and Laloi lagoons. (vertical bars = \pm SD)

4.2.4 Metric calculation

From the metrics assigned, a score of 34 was obtained for Laloï indicating a poor site rating, suggesting that it was under severe stress and a score of 40 was obtained for Oyibi indicating a moderate site rating, suggesting that it was under moderate stress.

Table 4.2 Estuarine Fish Community Index Calculation for the lagoons

Estuarine Fish Community Index Metric	SCORE	
	OYIBI	LALOI
Species diversity and composition		
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
Species abundance		
5. Species relative abundance	3	3
6. Number of species that make up 90% of the abundance	3	3
Nursery function		
7. Number of estuarine resident taxa	5	3
8. Number of estuarine-dependent marine taxa	1	1
9. Relative abundance of estuarine resident taxa	5	5
10. Relative abundance of estuarine-dependent marine taxa	5	5
Trophic Integrity		
11. Condition factor	3	1
12. Chlorophyll a	3	1
Total	40	34

4.3 Species Diversity

The Shannon Wiener Index (H') calculated for Oyibi range between 0.42 to 1.64. The highest value of 1.64 and a least value of 0.42 recorded at Oyibi were in the months of April and February respectively. The average recorded for Oyibi during the entire study period was 1.57 ± 0.13 . Laloi recorded the highest value of 1.51 and the least value of 1.24 in the months of May and February respectively. The average for Laloi was 1.81 ± 0.53 .

Pielou's species evenness index (J) calculated for Oyibi had the least value of 0.36 in the month of May and the highest value of 0.71 in the month of April. The average value recorded for Oyibi during the entire study period was 0.57 ± 0.13 . For Laloi, the highest value was recorded in the month of April and the least value recorded in the month of February. The average recorded for Laloi during the entire study period was 0.67 ± 0.10 .

The Margalef's species richness index (d) recorded for Oyibi had highest value recorded in the month of March and the least value in the month of February. The average value recorded for Oyibi during the study was 2.39 ± 0.63 . The highest value of the species richness for Laloi was recorded in the month of February and the least value recorded in the month of April. The average value recorded for Laloi during the entire study was 2.30 ± 0.28 . The results are represented in Figures 4.5- 4.7. The species diversity indices for the entire study are represented in Figure 4.8.

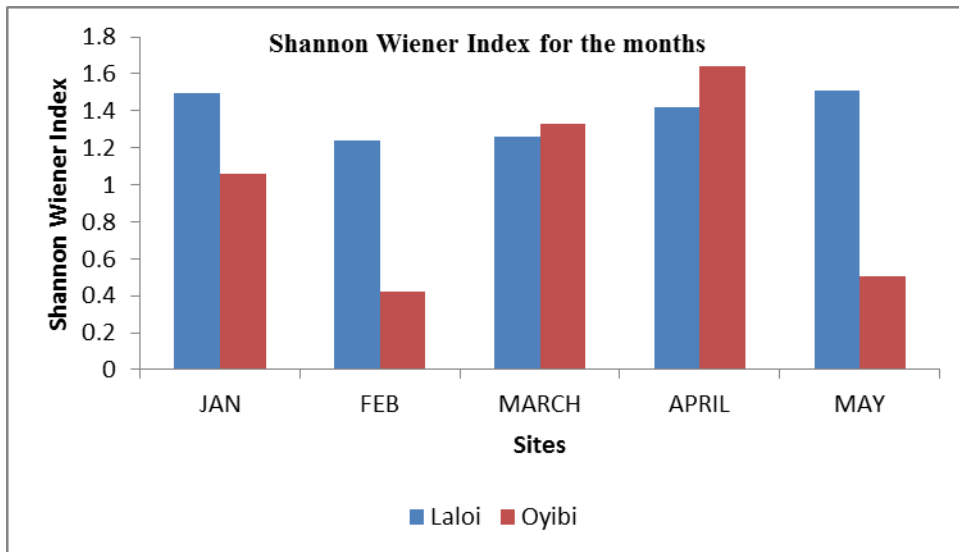


Figure 4.5 Shannon Wiener Index for the Oyibi and Lalo lagoons.

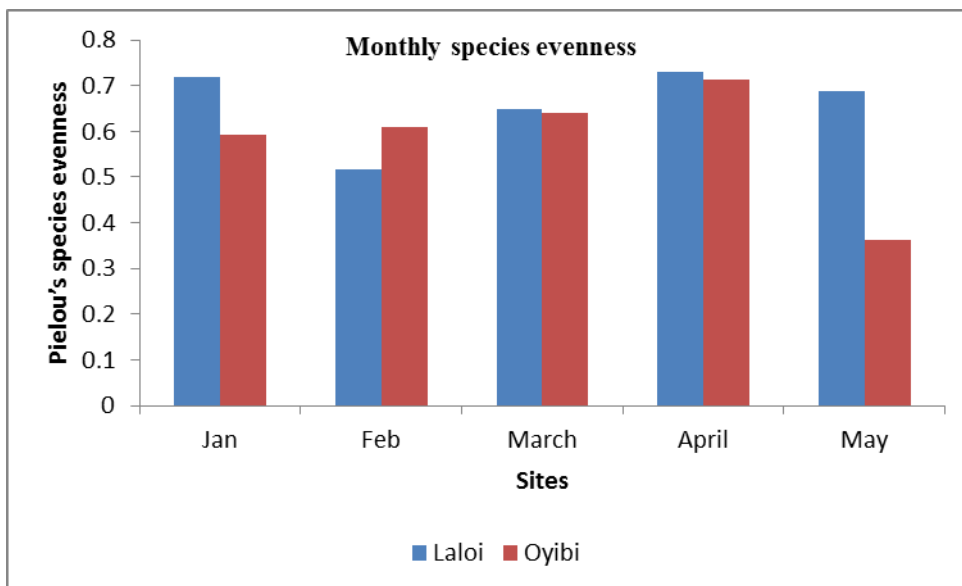


Figure 4.6 Pielou's species evenness for the Oyibi and Lalo lagoons.

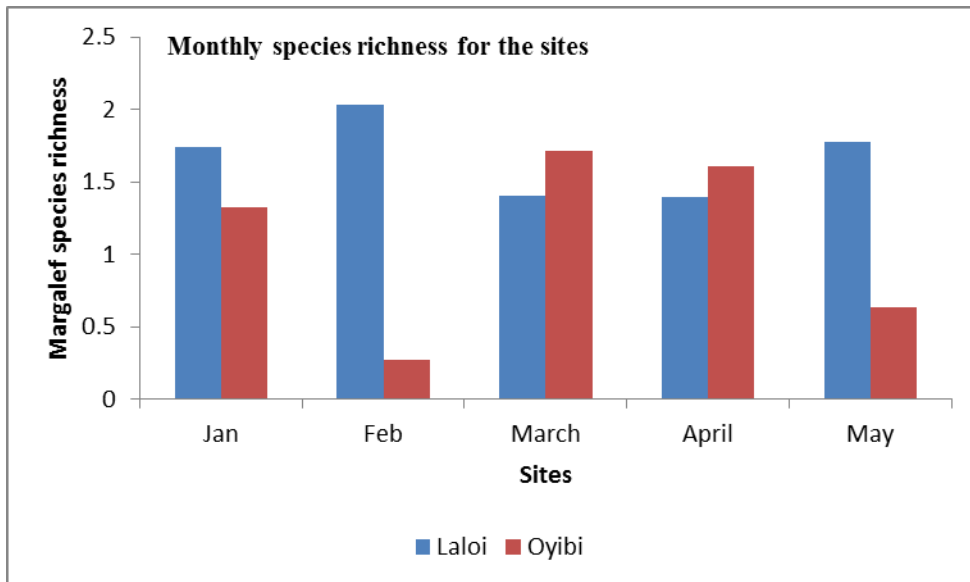


Figure 4.7 Margalef species richness for the Oyibi and Lalo lagoons.

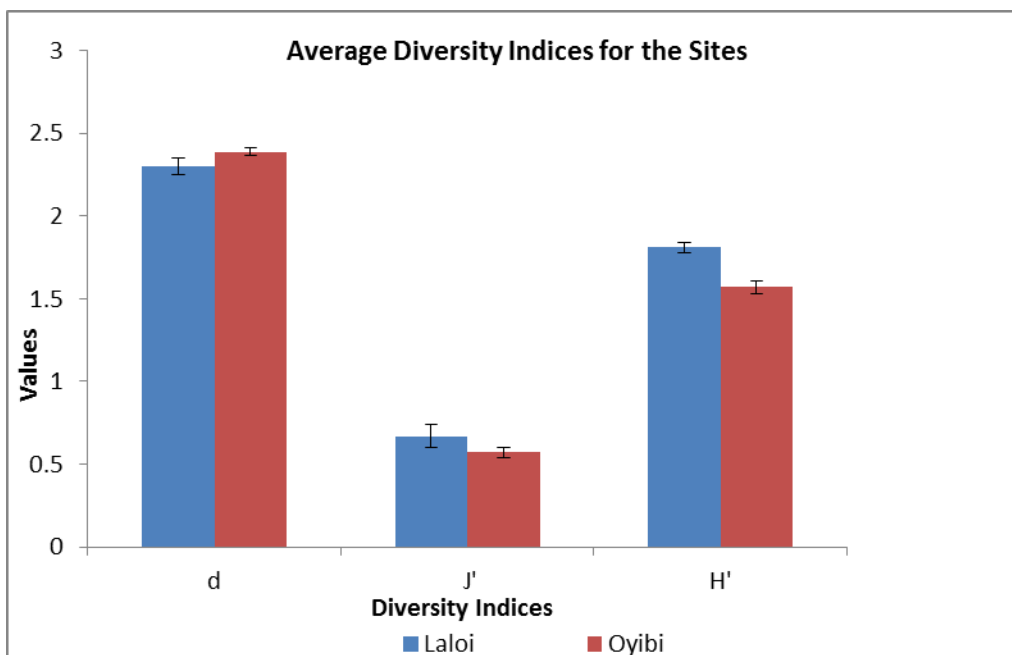


Figure 4.8 Average Diversity indices for the Oyibi and Lalo lagoons. (vertical bars = \pm SD). **KEYS:** **d:** Margalef's species richness index, **J':** Pielou's species evenness, **H':** Shannon Wiener Index

4.4 Physico-chemical parameters

Temperature recorded in the Oyibi lagoon ranged between 22.2°C and 32.4 °C with an average 27.7 ± 0.60 °C for the entire study. The minimum value of 22.2 °C was recorded at the seaward end in the month of May during low tide. The highest temperature of 32.4 °C was recorded at the riverine end in the month of March. The average temperature recorded during both high and low tides were 27.9 ± 3.34 °C and 27.3 ± 2.59 °C respectively. For Oyibi lagoon, temperatures were high at the riverine end than the middle and seaward end. Average temperatures recorded for these sections of the lagoon were 28.2 ± 3.31 °C, 27.1 ± 2.33 °C and 27.6 ± 3.34 °C respectively.

Temperature recorded in the Laloi lagoon ranged between 21.3 °C and 33.6 °C with an average of 26.7 ± 3.17 °C for the study period. The minimum value of 21.3 °C was recorded at the middle sections of the lagoon in the month of April during low tide. The highest temperature of 33.6°C was recorded at the riverine end in the month of March during high tide. The average temperature recorded for 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 recorded for these sections of the lagoon were 27.1 ± 3.77 °C, 26.8 ± 3.53 °C and 26.2 ± 2.49 °C respectively.

The pH recorded for the entire study ranged between 7.0 and 9.0 for the Oyibi lagoon with an average of 7.97 ± 0.40 . The highest pH value recorded for the Oyibi lagoon was

8.70 recorded in the month of May at the riverine end during low tide. The minimum value of 7.20 was recorded at the middle section during the month of February at low tide. The average pH values recorded for the Oyibi lagoon during both high and low tides were 8.07 ± 0.39 and 8.02 ± 0.43 respectively. Average pH values recorded for these sections of the lagoon were 7.82 ± 0.39 , 7.73 ± 0.32 and 8.34 ± 0.47 respectively.

The pH recorded ranged between 8.0 and 8.6 with an average of 8.60 ± 0.25 for the Laloi lagoon. The highest pH value of 8.9 was recorded in the month of May at the middle section during low tide. The minimum value of 8.0 was recorded at the seaward end during the month April at high tide. The average pH values recorded for the Laloi lagoon during both high tide and low tide were 8.50 ± 0.25 and 8.60 ± 0.26 respectively. Average pH values recorded for these sections of the lagoon were 8.60 ± 0.22 , 8.6 ± 0.17 and 8.4 ± 0.31 respectively.

BOD recorded in the Oyibi lagoon ranged between 0.20 mg/l and 2.8 mg/l with an average value of 1.60 ± 0.64 mg/l for the entire study. The highest value of 2.8 mg/l was recorded at the seaward end of Oyibi for the month of May during low tide. The least value recorded for the Oyibi lagoon was 0.3 mg/l in May at the riverine section during high tide. Average BOD values recorded these sections of the lagoon were 1.61 ± 0.80 mg/l, 1.57 ± 0.57 mg/l and 1.65 ± 0.63 mg/l respectively. DO values recorded in the Oyibi lagoon ranged between 3.3 mg/l and 6.5 mg/l with an average of 4.7 ± 0.97 mg/l for the Oyibi lagoon. The highest value of 6.5 mg/l was recorded in the month of April at the

seaward end during high tide. The least value of 3.3 mg/l was recorded in the months of February and April during both high and low tide. Average DO values recorded for these sections of the lagoon were 4.19 ± 0.53 mg/l, 4.66 ± 1.22 mg/l and 5.47 ± 0.76 mg/l respectively. DO values were highest at high tide than low tide. The average values recorded for both high tide and low tide were 5.0 ± 0.86 mg/l and 4.68 ± 1.08 mg/l respectively.

BOD recorded in the Laloi lagoon ranged between 0.1 mg/l and 4.5 mg/l with an average of 1.80 ± 1.04 mg/l for the entire study. The highest value of 4.3 mg/l was recorded at the seaward end of the Laloi lagoon for the month of May during high tide. The least value recorded for the Laloi lagoon was 0.1mg/l in April at the seaward end during low tide. Average BOD values recorded for these sections of the lagoon were 1.60 ± 0.82 mg/l, 1.40 ± 0.96 mg/l and 2.30 ± 0.97 mg/l respectively. BOD values were higher during high tides than low tides. DO values recorded in the Laloi lagoon ranged between 3.0 mg/l to 7.5 mg/l with an average value of 5.1 ± 0.98 mg/l for the entire study. Average values for DO recorded for Laloi during high tide and low tide were 2.09 ± 1.26 mg/l and 1.39 ± 0.64 mg/l respectively. The highest value of 7.2 mg/l was recorded in the month of April at the seaward end during high tide. The least value of 3.6 mg/l was recorded in the months of February at the riverine section during low tide. Average DO values recorded for these sections of the lagoon were 4.7 ± 0.86 mg/l, 5.20 ± 0.87 mg/l and 5.20 ± 1.21 mg/l respectively.

Salinity recorded in the Oyibi lagoon ranged between 5⁰/₀₀ and 40⁰/₀₀ with an average of 22.0 ± 7.46⁰/₀₀ during the entire study period. The seaward end at Oyibi recorded the least value of 7⁰/₀₀ in the month of March during low tide. The highest value of 39.5⁰/₀₀ was recorded for the Oyibi lagoon in the month of May during low tide. Salinity recorded for these sections of the lagoon were 23.6 ± 2.30⁰/₀₀, 22. ± 2.851⁰/₀₀ and 20.3 ± 12.77⁰/₀₀ respectively. The average salinity values for Oyibi during the high and low tides were 20.6 ± 6.08⁰/₀₀ and 23.5 ± 6.08⁰/₀₀ respectively.

Salinity recorded in the Laloï lagoon ranged between 20.0⁰/₀₀ and 40⁰/₀₀ with an average of 37.0 ± 3.40⁰/₀₀ during the entire study period. The middle portion at Laloï had the least value of 22.5⁰/₀₀ in the month of April during low tide. The highest value of 39.04⁰/₀₀ was recorded for the Laloï lagoon in the month of February during high tide at the middle portion. Salinity recorded for these sections of the lagoon were 37.4 ± 1.56⁰/₀₀, 36.3 ± 5.63⁰/₀₀ and 36.3 ± 1.75⁰/₀₀ respectively. The average salinity values for Laloï during the high and low tides were 37.8 ± 1.47⁰/₀₀ and 36.2 ± 4.54⁰/₀₀ respectively.

TDS recorded for the Oyibi lagoon ranged between 0.15mg/l and 37.0 mg/l with an average of 11.9 ± 11.74 mg/l for the entire study. The highest value of 36.3 mg/l was recorded at the seaward end in the month of May at low tide. The least value of 0.17 mg/l was recorded in the middle portion of Oyibi in the month of March at high tide. Average TDS values for these sections of the lagoon were 14.3 ± 13.42 mg/l, 8.2 ± 7.50 mg/l and 13.1 ± 13.88 mg/l respectively. The average TDS values recorded the lagoon during high and low tides were 10.7 ± 10.67 mg/l and 13.1 ± 13.08 mg/l respectively.

TDS recorded for the Laloi lagoon ranged between 15.0 mg/l and 152.0 mg /l with an average value of 46.7 ± 13.16 mg/l for the entire study period. The highest value of 151.5 mg /l was recorded at the seaward end in the month of April at high tide. The least value of 15.1 mg/l was recorded in the middle portion of Laloi in the month of May at high tide. The average TDS values recorded for these sections of the lagoon were 46.1 ± 24.46 mg/l, 46.0 ± 32.32 mg/l and 48.1 ± 44.35 mg/l respectively. The average TDS values recorded for 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.

TSS recorded for the Oyibi lagoon ranged between 10 mg/l and 105 mg /l with an average value of 31.1 ± 21.90 mg/l for the entire study period. The highest value of 101 mg /l was recorded at the riverine end in the month of February at low tide. The least value of 11 mg/l was recorded in the middle portion of Oyibi in the month of April at high tide. The average TSS values recorded for these sections of the lagoon were 49.4 ± 28.68 mg/l, 18.4 ± 5.07 mg/l and 25.5 ± 11.21 mg/l respectively. The average TSS values recorded for Oyibi lagoon during high and low tides were 31.1 ± 19.70 mg/l and 31.1 ± 24.79 mg/l respectively.

TSS recorded for the Laloi lagoon ranged between 5.0 mg/l and 80mg/l with an average value 19.7 ± 14.81 mg/l for the entire study. The highest value of 77.0 mg /l was recorded at the seaward end in the month of March at high tide. The least value of 6.0 mg/l was recorded in the middle portion of Laloi in the month of May at high tide. The average TSS values recorded for these sections of the lagoon were 18.5 ± 4.11 mg/l, 15.1 mg/l ± 6.22

and 25.4 ± 24.56 mg/l respectively. The average for the Laloi lagoon during high and low tide during the entire study were 23.3 ± 19.94 mg/l and 16 ± 5.64 mg/l respectively. The results for the physicochemical parameters are represented in Figures 4.9– 4.15.

Nitrates levels recorded for the Laloi lagoon ranged between 0.30 mg/l and 5.2 mg/l with an average value of 1.77 ± 1.24 mg/l for the entire study. The highest value of 4 mg/l was recorded at the riverine end in the month of May during high tide and the minimum value of 0.30 mg/l were recorded at the middle portion and seaward end during low tide in the month of May. Nitrate values recorded were higher during low tide than high tide. The average for the entire study during both high and low tides were 1.82 ± 1.35 mg/l and 1.72 ± 1.17 mg/l respectively. Average Nitrates values recorded for these sections of the lagoon were 1.69 ± 1.55 mg/l, 1.14 ± 0.56 mg/l and 2.03 ± 1.27 mg/l respectively.

Nitrate levels recorded for the Oyibi lagoon ranged between 0.20 mg/l and 19.9 mg/l with an average value of 3.25 ± 4.59 mg/l for the entire study period. The highest value of 19.9 mg/l was recorded at the riverine end in the month of February during high tide and the minimum value of 0.20 mg/l were recorded at the middle portion during low tide in the month of April. Nitrates values recorded were higher during low tide than high tide. The average for the entire study during both high and low tides were 2.93 ± 3.98 mg/l and 3.58 ± 5.29 mg/l respectively. Nitrates levels were higher at the riverine end than the seaward end. Average Nitrates values recorded for these sections of the lagoon were 6.6 ± 6.93 mg/l for the, 1.55 ± 1.08 mg/l and 1.6 ± 0.84 mg/l respectively.

Phosphate levels recorded for the Laloi lagoon ranged between 0.07mg/ and 1.98 mg/l with an average value of 0.61 ± 0.35 mg/l for the entire study period. The highest value of 1.98 mg/l was recorded at the riverine end in the month of April during high tide and the minimum value of 0.07 mg/l was recorded at the seaward end during low tide in the month of April. Phosphate values recorded were higher during high tide than low tide. The average for the entire study during both high and low tides were 0.69 ± 0.43 mg/l and 0.53 ± 0.24 mg/l respectively. Phosphate levels were higher at the riverine end than the seaward end. The average values recorded for these sections of the lagoon were 0.74 ± 0.52 mg/l, 0.58 ± 0.19 mg/l and 0.51 ± 0.24 mg/l respectively.

Phosphate levels recorded for the Oyibi lagoon ranged between 0.15 mg/l and 1.12 mg/l with an average value of 0.61 ± 0.24 mg/l for the entire study period. The highest value of 1.12 mg/l was recorded at the seaward end in the month of April during high tide and the minimum value of 0.15 mg/l was recorded at the seaward end during low tide in the month of April. Phosphate values recorded were higher during low tide than high tide. The average for the entire study during both high and low tides were 0.66 ± 0.24 mg/l and 0.56 ± 0.24 mg/l respectively. Phosphate levels were higher at the riverine end than the seaward end. Average values recorded for these sections of the lagoon were 0.65 ± 0.31 mg/l, 0.60 ± 0.13 mg/l and 0.57 ± 0.28 mg/l respectively. The results for the nutrients for the entire study are shown in Figures 4.16 to 4.23.

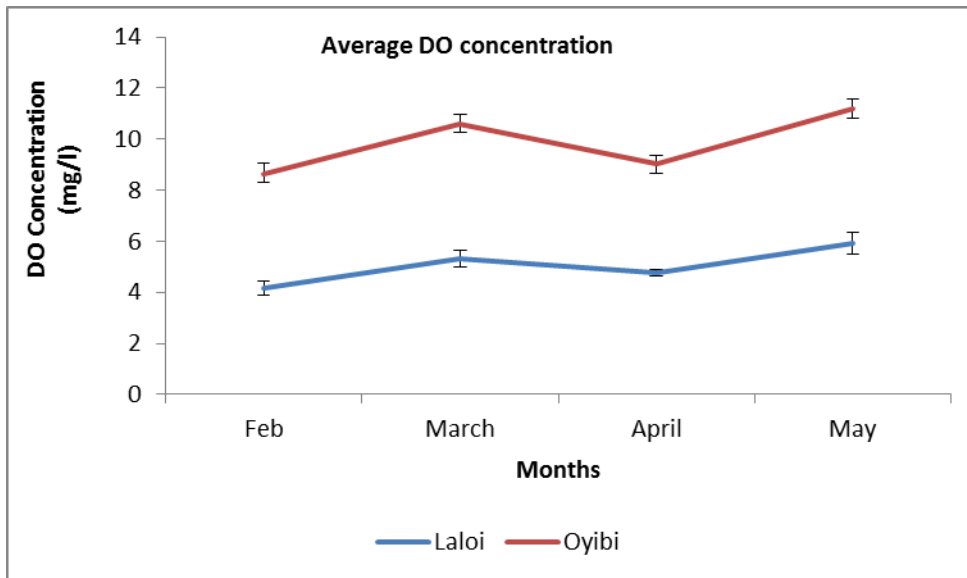


Figure 4.9 Average DO concentrations in the Oyibi and Laloi lagoons. (vertical bars = \pm SD)

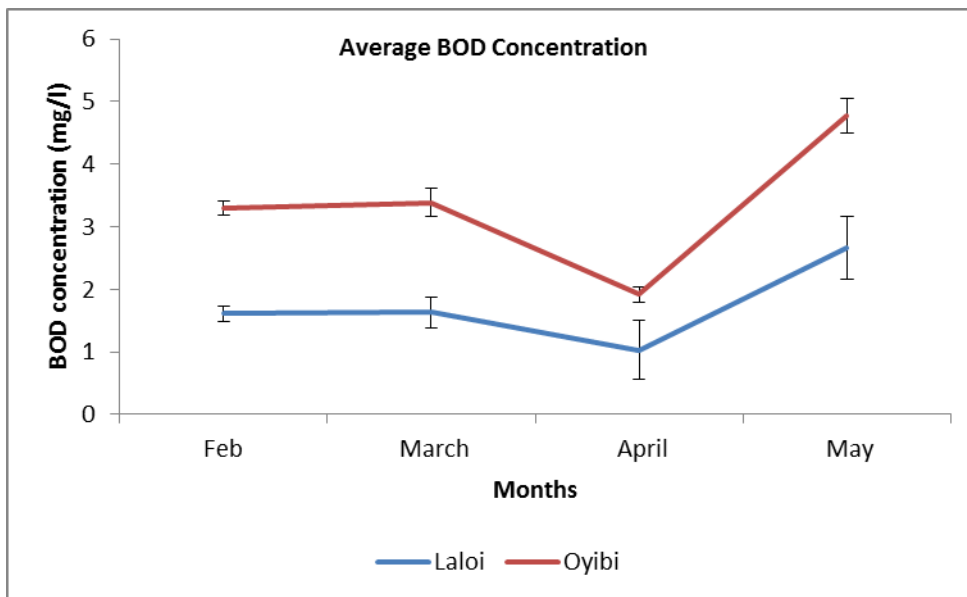


Figure 4.10 Average BOD concentrations in the Oyibi and Laloi lagoons. (vertical bars = \pm SD)

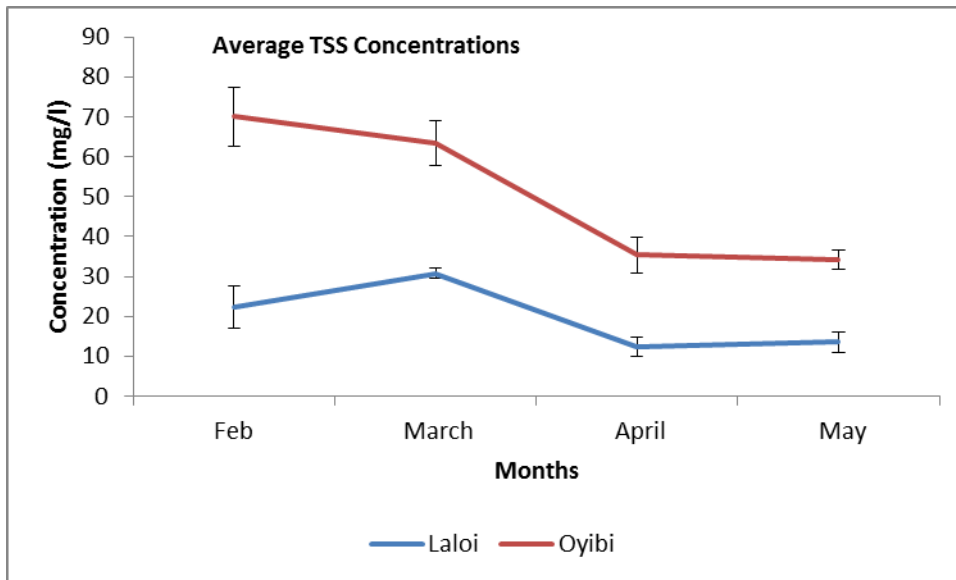


Figure 4.11 Average TSS concentrations in the Oyibi and Laloi lagoons. (vertical bars = \pm SD)

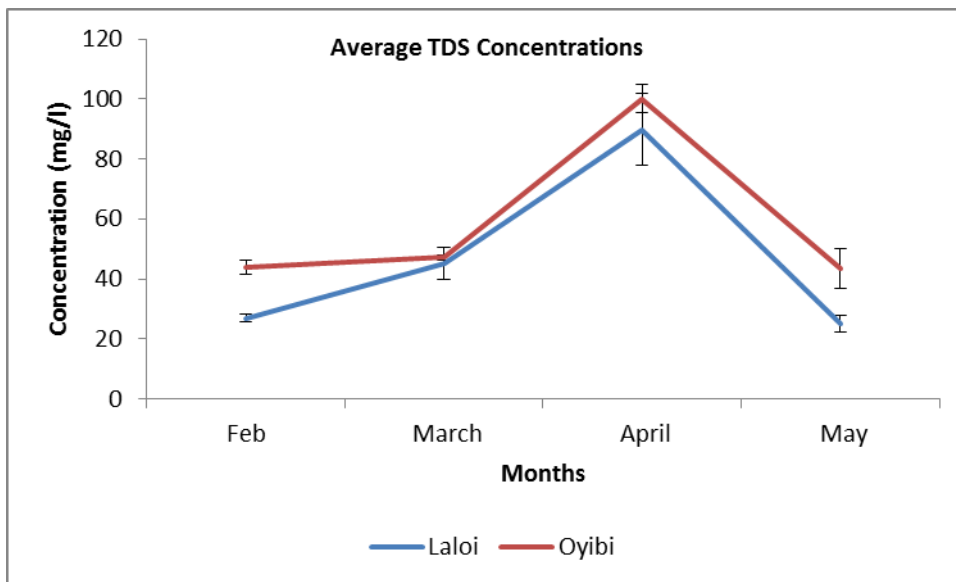


Figure 4.12 Average TDS concentrations in the Oyibi and Laloi lagoons. (vertical bars = \pm SD).

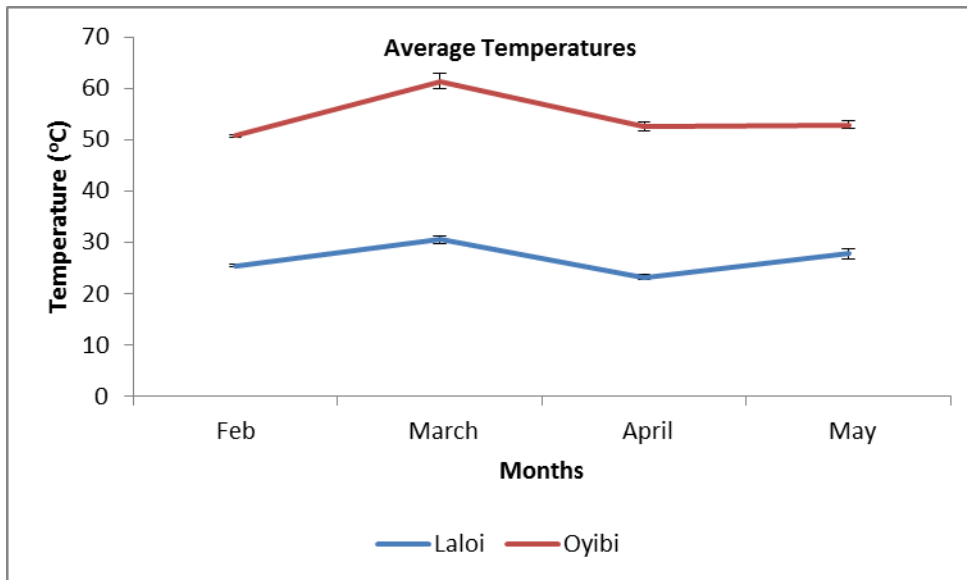


Figure 4.13 Average temperatures in the Oyibi and Laloï lagoons. (Vertical bars = \pm SD).

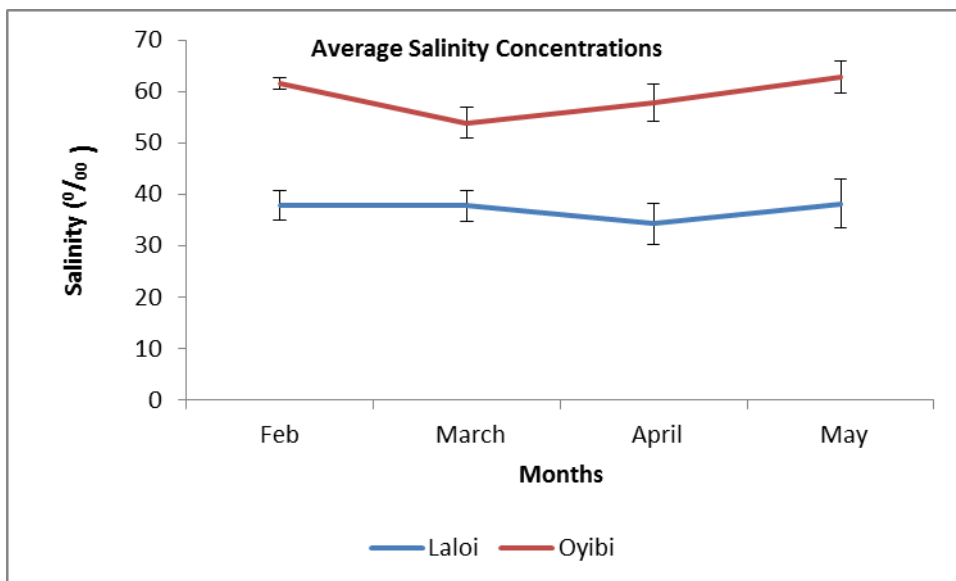


Figure 4.14 Average salinity concentrations in the Oyibi and Laloï lagoons. (Vertical bars = \pm SD).

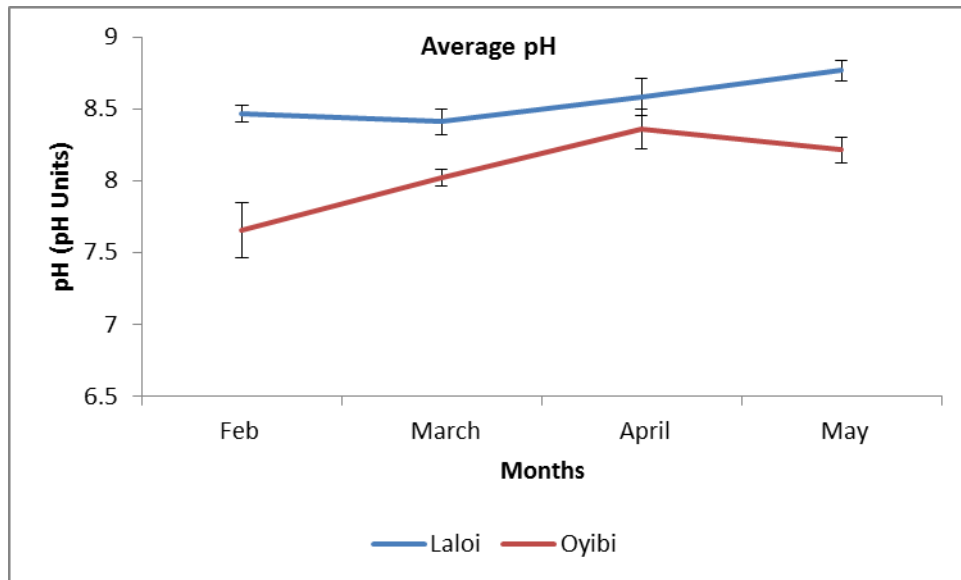
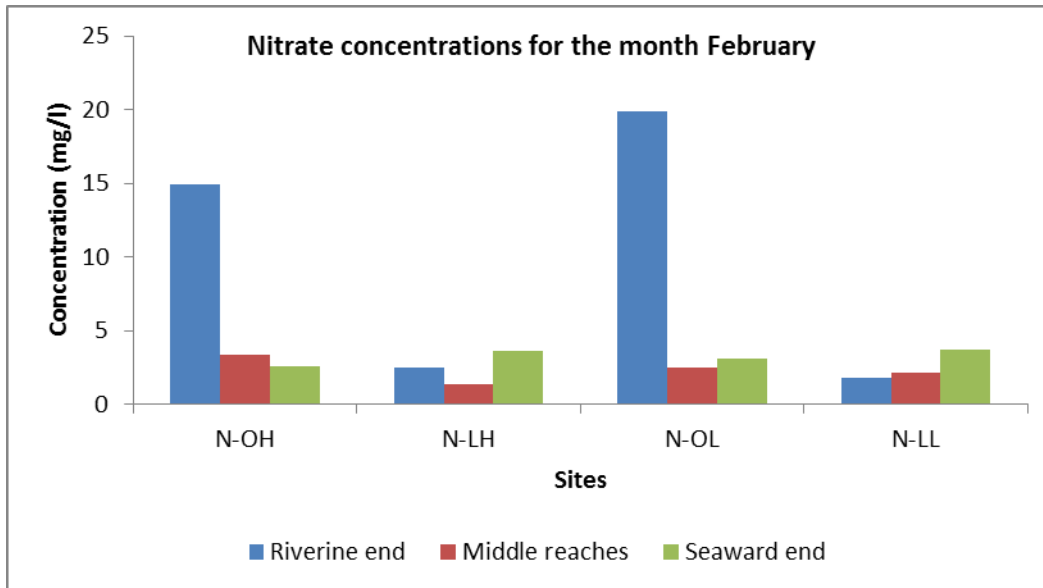


Figure 4.15 Average pH in the Oyibi and Laloi lagoons. (vertical bars = \pm SD)

a)



b)

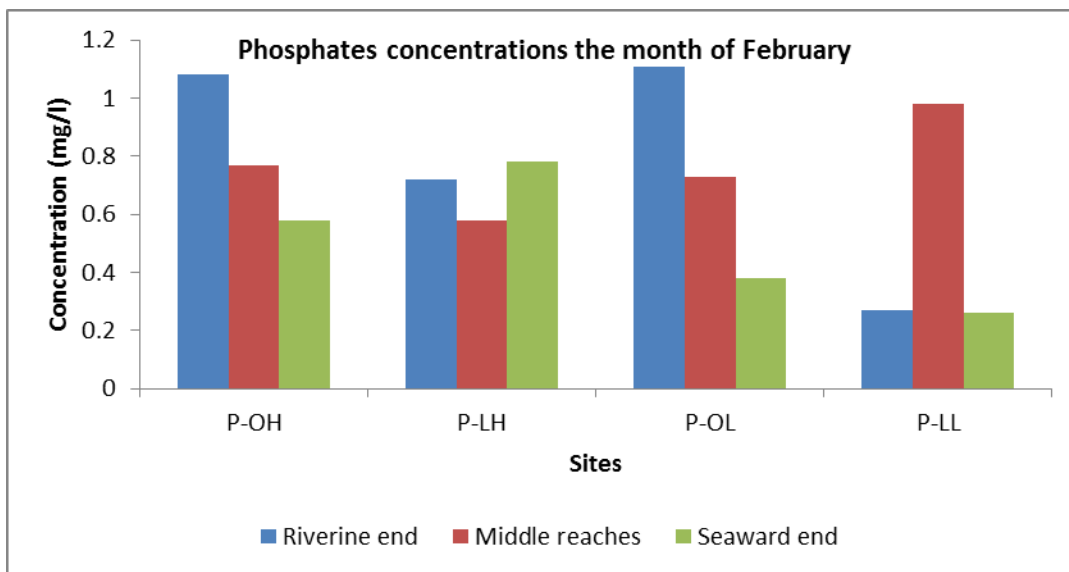
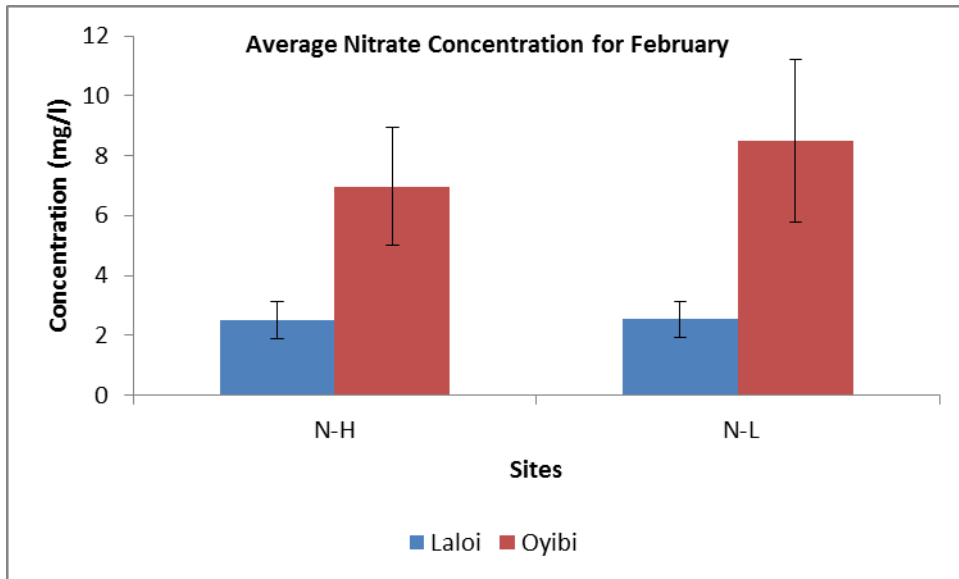


Figure 4.16 a & b Nitrates and Phosphates concentrations in the Oyibi and Laloï lagoons for the month of February. **KEYS: N: Nitrates. P: Phosphates L: Laloï. O: Oyibi. H: High tide. L: Low tide.**

a)



b)

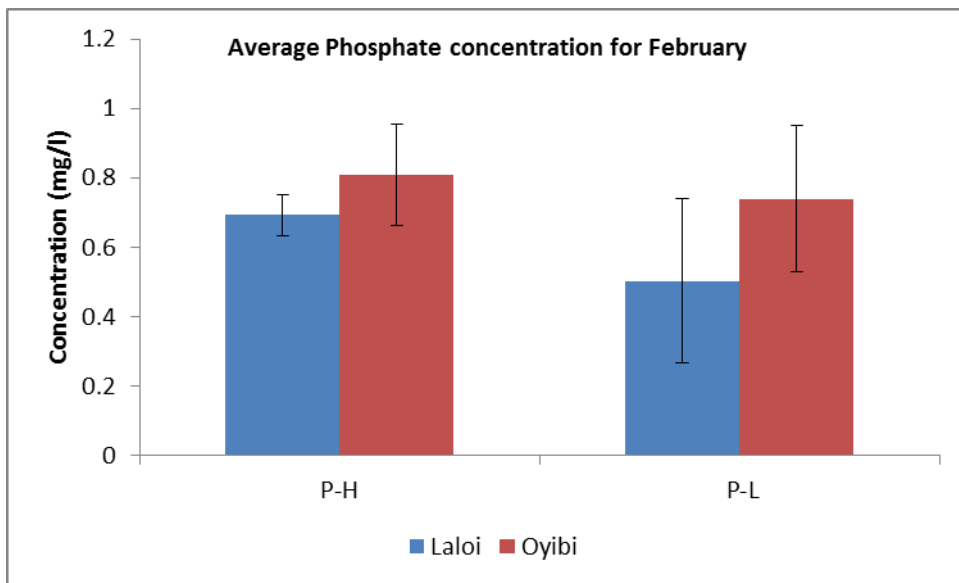
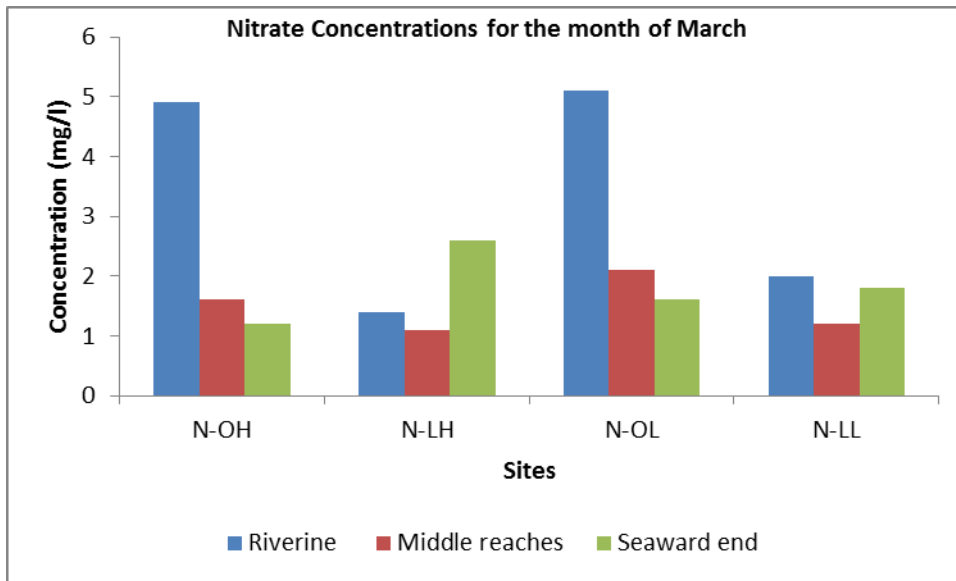


Figure 4.17 a & b Average Nitrates and Phosphate concentrations in the Oyibi and Laloi lagoons for the month of February. (vertical bars = \pm SD). **Phosphates. N: Nitrates H: High tide. L: Low tide**

a)



b)

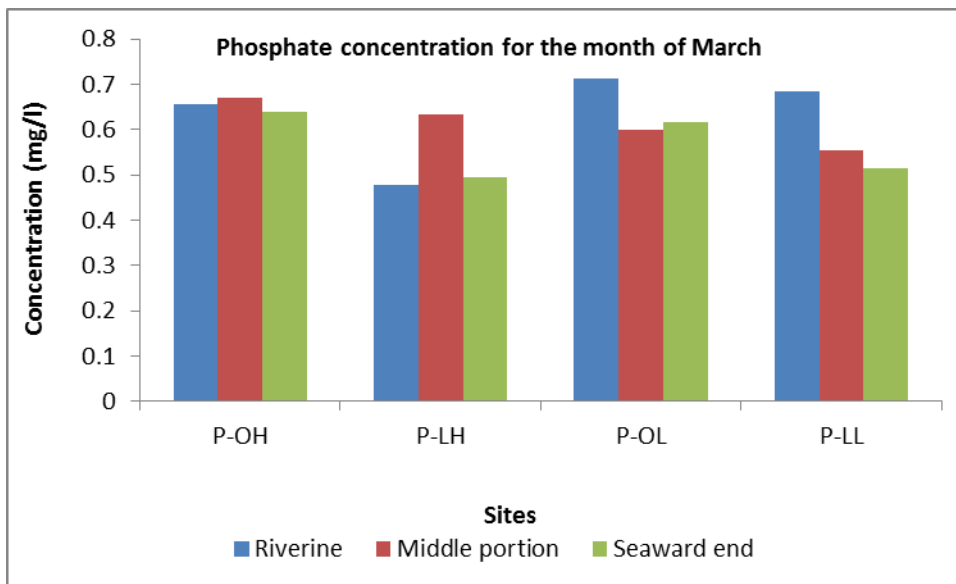
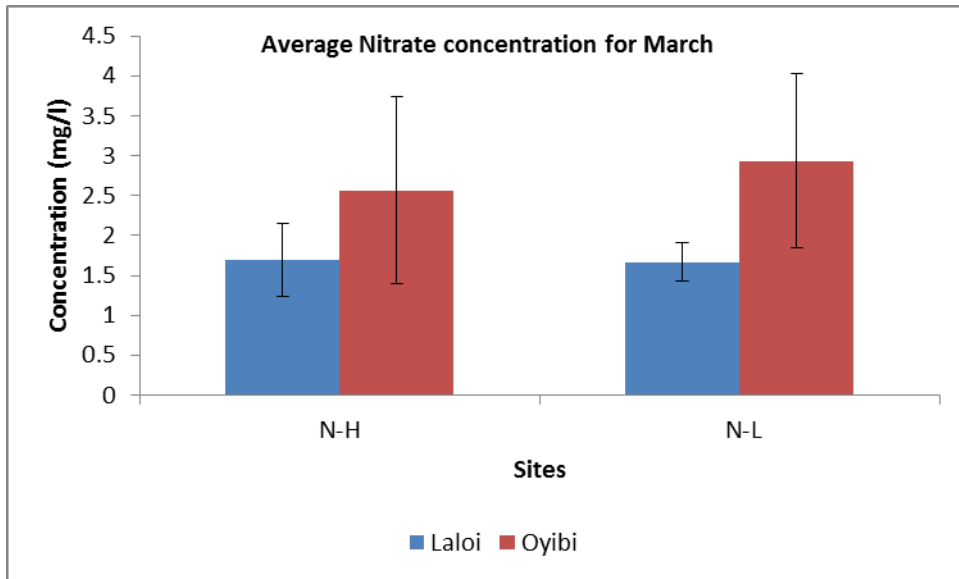


Figure 4. 18 a & b Nitrates and Phosphates concentrations in the Oyibi and Llaloi lagoons for the month of March. **KEYS: N: Nitrates. P: Phosphates L: Laloi. O: Oyibi. H: High tide. L: Low tide**

a)



b)

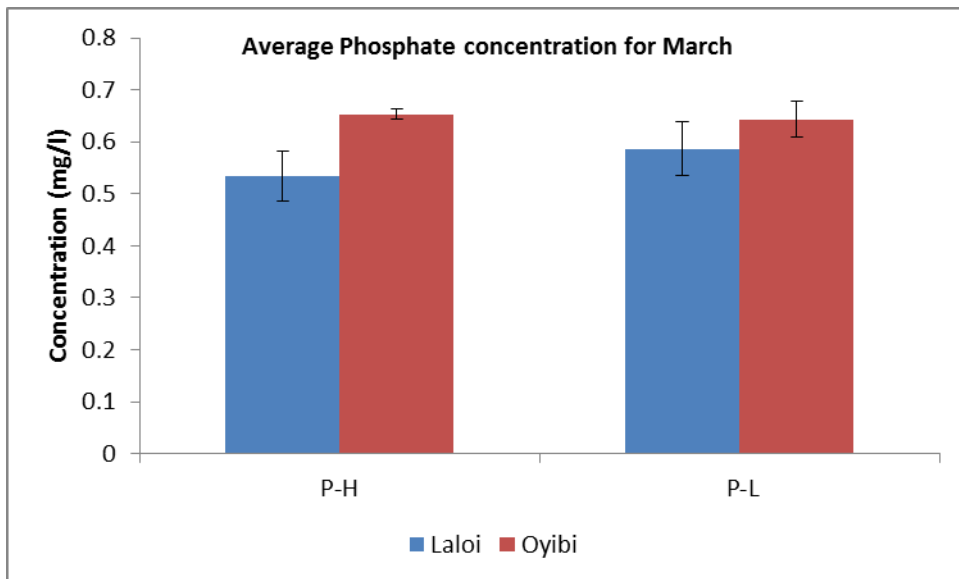
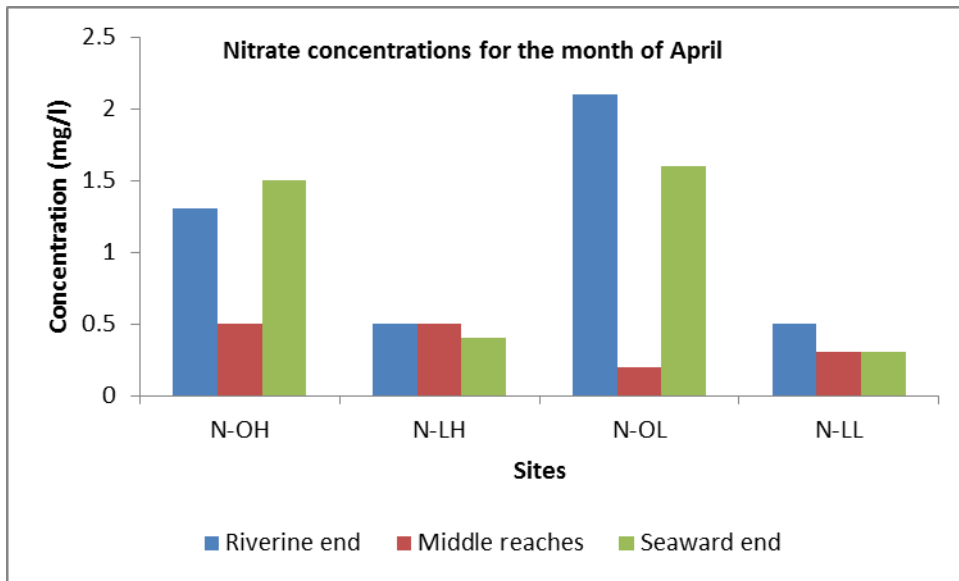


Figure 4. 19 a& b Average Nitrates and Phosphate concentrations in the Oyibi and Laloi lagoons for the month of March. (vertical bars = \pm SD) KEYS: **P: Phosphates. N: Nitrates H: High tide. L: Low tide.**

a)



b)

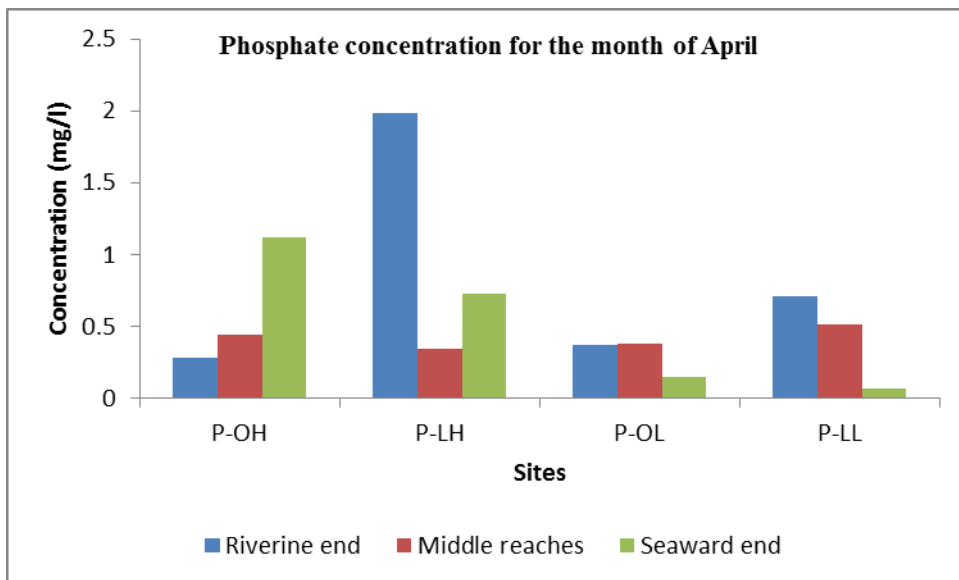
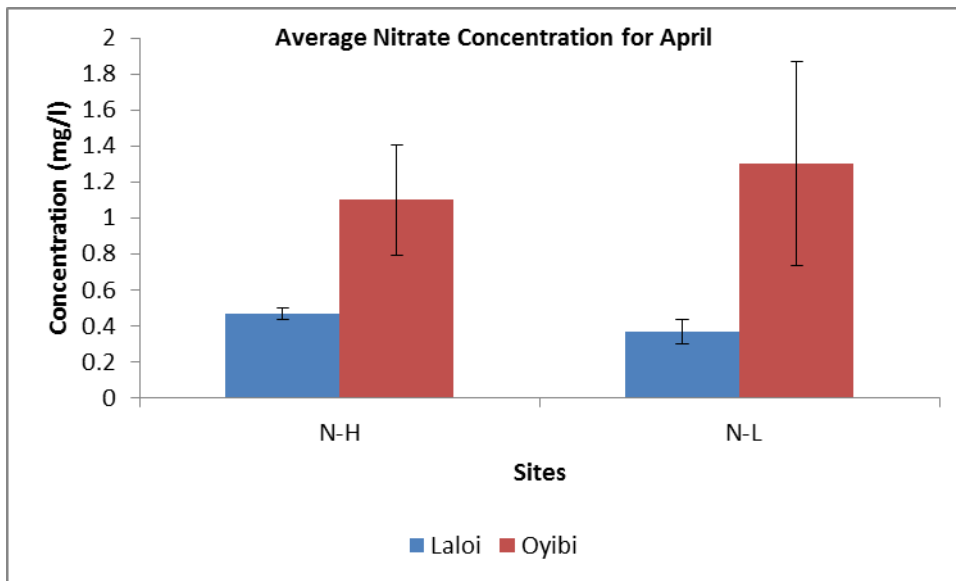


Figure 4. 20 a & b Nitrates and Phosphates concentrations in the Oyibi and Laloï lagoons for the month of April. **KEYS: N: Nitrates. P: Phosphates L: Laloï. O: Oyibi. H: High tide. L: Low tide**

a)



b)

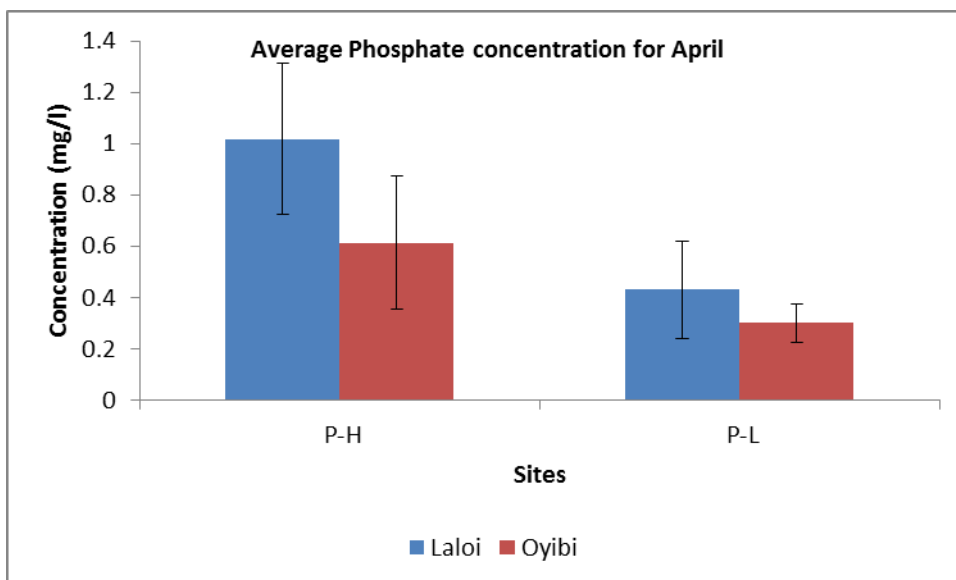
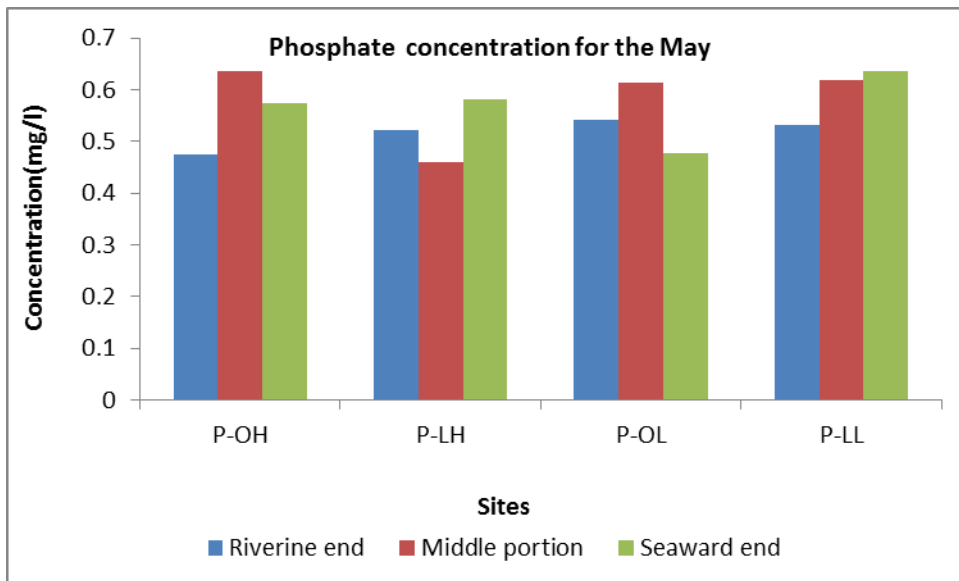


Figure 4.21 a & b Average Nitrates and Phosphate concentrations in the Oyibi and Laloi lagoons for the month of April (vertical bars = \pm SD) **KEYS: P: Phosphates. N: Nitrates H: High tide. L: Low tide.**

a)



b)

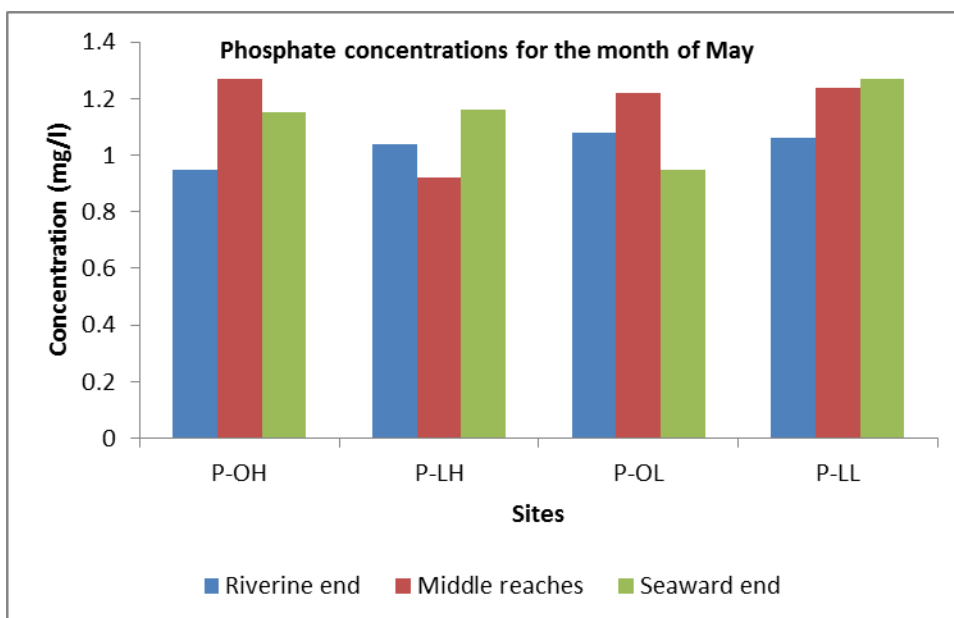
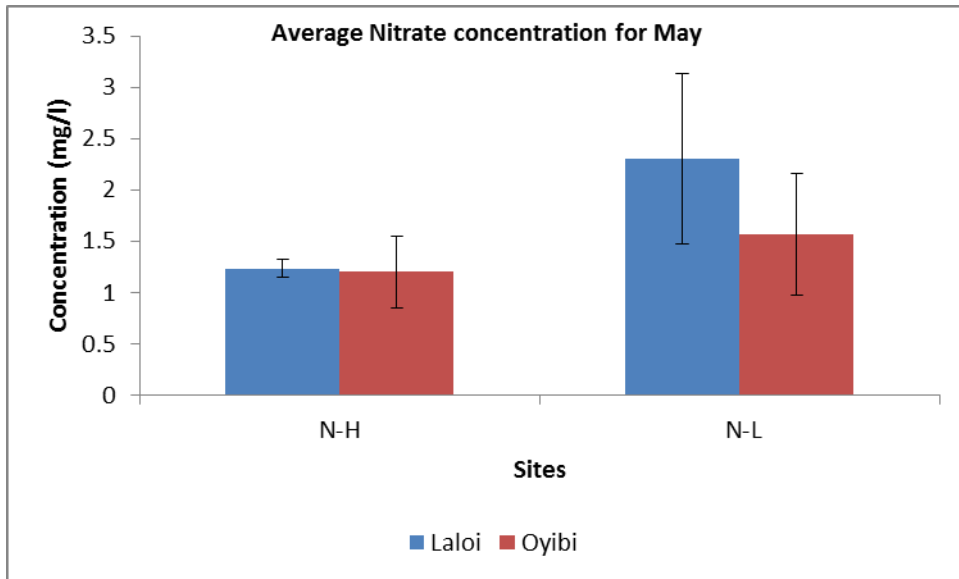


Figure 4.22 a & b Nitrates and Phosphates concentrations in the Oyibi and Laloi lagoons for the month of May **KEYS: N: Nitrates. P: Phosphates L: Laloi. O: Oyibi. H: High tide. L: Low tide**

a)



b)

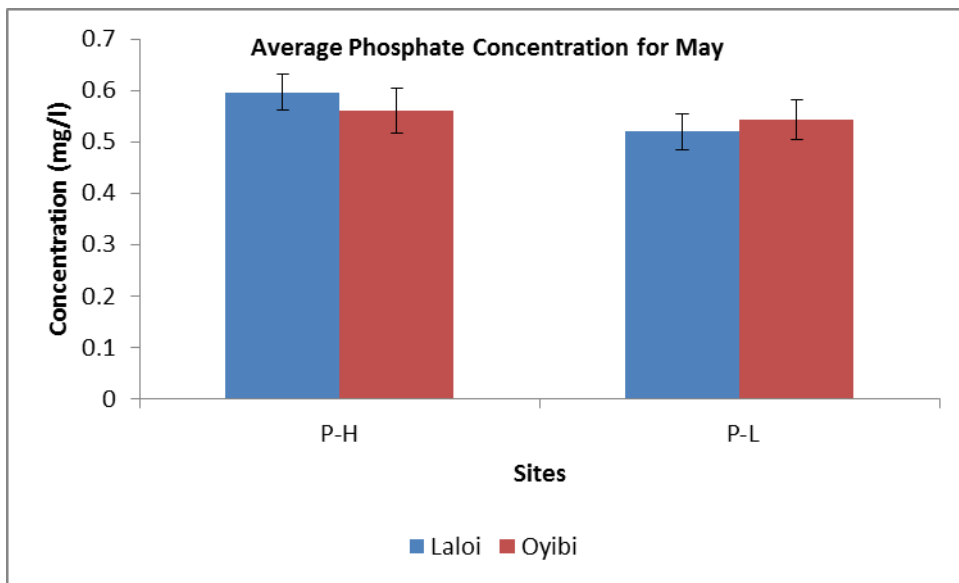


Figure 4. 23 a & b Average Nitrates and Phosphate concentrations in the Oyibi and Laloi lagoons for the month of May (vertical bars = \pm SD). **KEYS: P: Phosphates. N: Nitrates H: High tide. L: Low tide.**

4.5 Length- Weight Relationship

From the length –weight relationship, the Condition factor of *Sarotherodon melanotheron* recorded for the Oyibi lagoon ranged between 1.50 and 2.40 with an average value of 2.07 ± 0.20 for the entire study period. The highest condition factor recorded was 2.3 in the month of March and the least value of 1.84 in the month of January. The Condition factor recorded for the Laloi lagoon ranged between 1.40 and 2.0 with an average value of 1.72 ± 0.12 for the entire study period. The highest condition factor recorded was 1.85 in the month of May and the least value of 1.49 for the months of January and February. The condition factor obtained for the entire study period is represented in Figure 4.24.

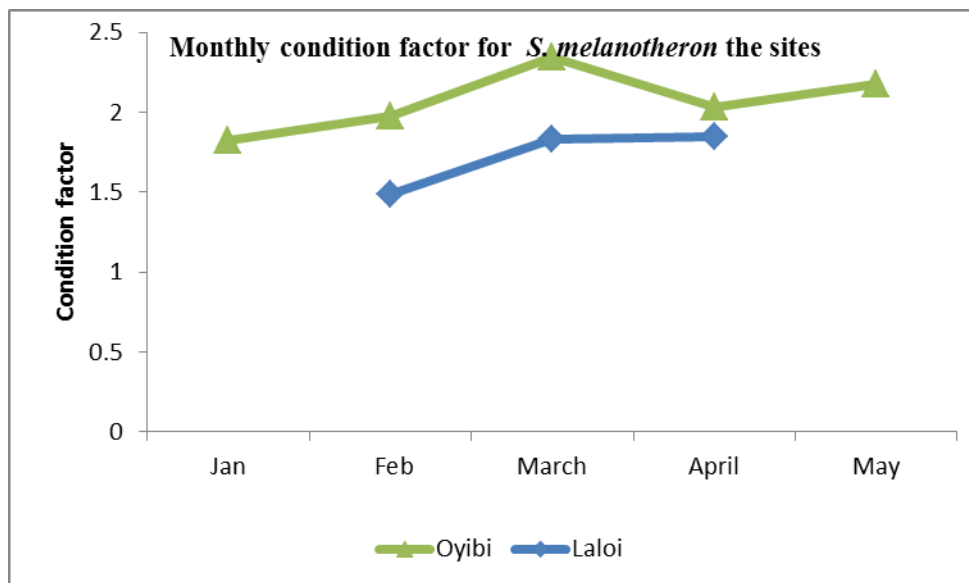


Figure 4. 24 Condition Factor for *S. melanotheron* in the Oyibi and Laloi lagoons for the entire study period.

4.6 Similarity Analysis

A Bray–Curtis similarity analysis (Bray & Curtis,1957; Cormack,1971; Everitt,1980) of species abundance data using group averaged linking of Bray-Curtis similarities calculated on standardized fourth root transformed data was used to show similarities in sites sample. From the analysis, sites which exhibit similarities in terms of species composition and abundance will cluster close together. Figures 4.25 shows the dendrogram for hierarchical clustering of the similarities between months for the sites. Most of the clustering occurred between the 35% and 70 % Bray-Curtis similarity scale for the months while clustering was observed above the 60 % scale for the entire study. The dendrogram shows the similarity in species composition on monthly basis and the over-all similarity in species composition between the sites.

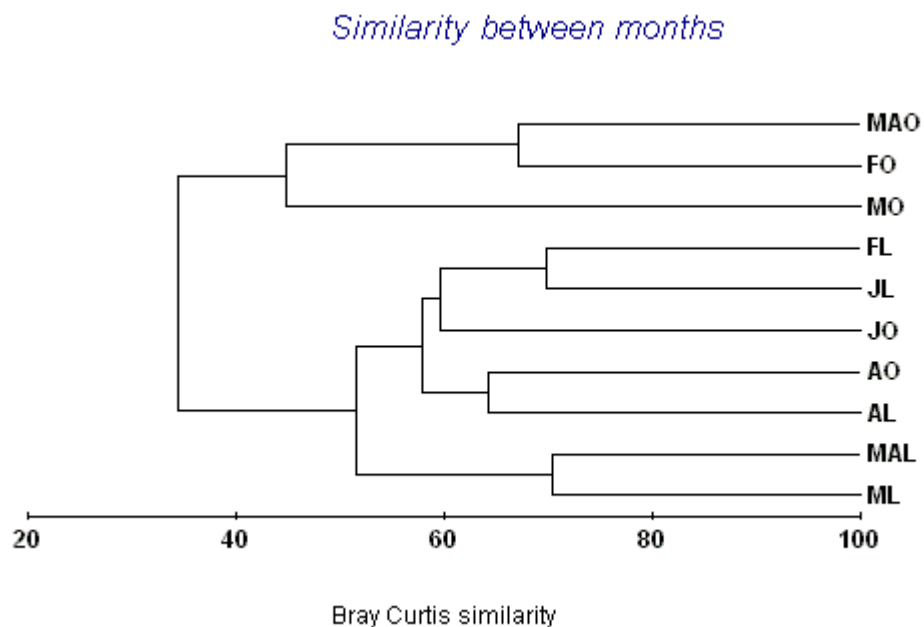


Figure 4.25 Bray-Curtis similarity between sampling months. **KEYS: J: January; F: February; M: March; A: April; MA: May, L: Laloi, and O: Oyibi.**

4.7 Total Organic Carbon

Total organic carbon recorded for the Oyibi lagoon ranged between 15% and 20% with an average value of $16.92 \pm 0.23\%$ for the entire study period. Total organic carbon was high at Oyibi than Laloï. For Oyibi lagoon, the highest percentage of organic carbon was 17.18% at the seaward end and the least value of 16.74% recorded in middle portion. Values recorded for these sections of the lagoon were 16.86% , 16.74% and 17.18% respectively. Total organic carbon recorded for the Laloï lagoon ranged between 10% and 13% with an average value of $12.24 \pm 1.68\%$ for the entire study period. For Laloï lagoon, the highest percentage of organic carbon was 13.73% at the seaward end and the least value of 10.42% recorded in middle portion. Values recorded for these sections of the lagoon were 12.57% , 10.42 % and 13.73% respectively. Results for the total organic carbon are represented in figure 4.26.

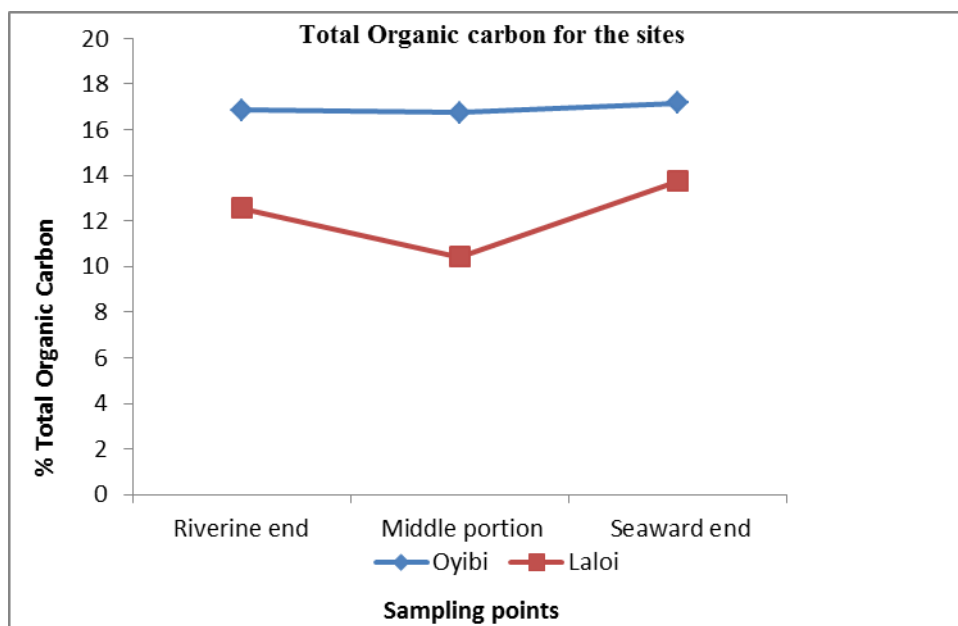


Figure 4.26 Total Organic carbon for the lagoons during the study period

CHAPTER FIVE

DISCUSSION

5.1 Species composition and abundance

A total of 18 species were identified during the study period consisting of 16 fin-fishes and 2 shellfishes. *Sarotherodon melanotheron* constitutes a very important part of lagoon fisheries in Ghana (Eyeson, 1983; Blay & Ameyaw, 1993; Koranteng, 1995) and make up about 80% -90% of all fishes caught in lagoons (Pauly, 1975, 1976; Denyoh, 1982; Ntiamo-Baidu, 1991). The species encountered were similar to those that occur in almost all coastal lagoons in Ghana as described by (Dankwa & Entsua-Mensah, 1996; Koranteng *et al.*, 1998 & Entsua-Mensah, 2003). The shellfish, *Callinectes latimanus*, and *Peneaus* sp were the only shell fish encountered during the study.

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

Species encountered can also be classified using ecological guilds described by Elliot and Dewaily (1996) and Entsua-Mensah (1998) as follows:

- Truly lagoon resident species and spends entire life in lagoon (ER).
- Marine adventitious visitors that appear irregularly in the lagoon but have no apparent lagoonal requirements (MA)
- Diadromous (Catadromous and Anadromous migrant species) that use the lagoon to pass between salt and freshwater for spawning and feeding (CA)
- Marine juvenile migrant species which use the lagoon primarily as nursery ground, usually spawning and spending much of their adult life at sea but often returning seasonally to the lagoon (MJ),
- Freshwater adventitious species which occasionally enter brackish water from freshwater but have no apparent requirements (FW) and
- Marine seasonal migrant species which have regular seasonal visits to the lagoon usually as adults (MS).

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

The highest number of species was recorded at Oyibi with Laloi having the least number of species. Out of the 29 shell and fin fish species, 15 was recorded at Oyibi and 12 at Laloi. Comparing the result to the baseline studies conducted by Dankwa *et al.*, (1997), there has been a significant change in the number of species. Dankwa *et al.*, (1997) recorded the number of species at Oyibi to be 12 and that of Laloi to be 15. There has been an increase in the number of species in Oyibi and a reduction in the number of species at Laloi from 12 to 16 and 17 to 14 respectively. Dankwa *et al.*, (1997) observed that both closed and opened lagoons with extensive mangrove cover had high species diversity. These lagoons were Domini (24 species), Kpani (28 species), Oyibi (12 species), Kpeshie (15) and Brenu and Kako (12 species) . This ascertains that mangroves provide feeding and breeding sites for various fish species. The high mangrove forest at Oyibi can be attributed to the effectiveness of traditional beliefs in management and conservation. Ntiamoah-Baidu (1991) in comparing the size composition of *S. melanotheron* and *T. fuscatus* in Djange and Sakumo lagoons clearly showed the traditional beliefs and associated taboos can be effective tools for conservation if they are adhered to.

The difference in species composition and abundance in both lagoons can be due to the variation of physicochemical parameters such as salinity, pH, temperature, environmental characteristics of the habitats, the size of local human populations, the type of fishing gear, effort and the associated fishing pressure. *S. melanotheron* was confined more to the

upper reaches of the Oyibi lagoon than the lower reaches and in Laloï the middle and upper reaches. The marine stenohaline mostly occurred in the lower reaches when the tides came in.

The salinity tolerance and preference can influence the distribution and abundance of fish species. Yanez-Arancibia (1978) working in Mexican estuarine lagoons recorded major declines in fish species diversity, densities and biomass when salinities rose above $34^{0}/_{00}$ or declined below $15^{0}/_{00}$. Wallace (1975) showed that species diversity and abundance in the estuarine lake St. Lucia in South Africa declined during hypersaline periods and Thiel *et al.*, (1995) also observed that as salinity decreased upstream, species diversity decreases. Salinity recorded showed no significant difference between the two lagoons and has no impact on the fisheries as described by (Anang, 1979) of the range $\sim 34.5^{0}/_{00}$ and $35.5^{0}/_{00}$. The increase in salinity towards the eastern coast of Ghana is as a result of variation in rainfall patterns (Entsua- Mensah, 2003). Salinity was lowest at the seaward end of the Oyibi lagoon due to dilution from the Ayensu River.

The pH recorded was optimal for the growth and survival of most aquatic species (Addy *et al.*, 2004). The highest dissolved oxygen (DO) at the seaward end is as a result of mixing and the turbulence by the sea. The TDS values recorded were below the background values of (50.0-1000 mg/l) and hence could not be harmful to fisheries. From the TSS values, it was above the background levels of 0.5-10.0 mg/l hence could affect primary production by attenuating light penetration. The reduction in light penetration

through the water column could restrict the rate at which periphyton, emergent and submersed macrophytes can assimilate energy through photosynthesis which will impact directly on primary consumers (Bilotta & Brazier, 2008).

Land use practices around these lagoons can be a contributing factor to the increased nutrients concentrations in these lagoons. The major land use practices along these lagoons are farming, salt mining, harvesting of mangroves for firewood and housing construction. The high nitrates and phosphates concentration in both lagoons is an indication of increased human activities in the catchment area and the high loading from the rivers into the lagoon. High nitrate concentration at the riverine end of Oyibi lagoon can be due to agricultural activities and other domestic activities and has been described as mildly eutrophic by (Ansa- Asare *et al.*, 2007) using the Carlson's TSI scale of 56) and the seaward being moderately clear with a TSI of 42. This can also be attributed to their proximity to population centers and because of their historical importance as sources of protein and as places for disposal of human waste (Kennish, 2002).

Human population density alone has also been shown to account for a significant amount of the variation in riverine transport of nitrogen (Howarth, 1988) and phosphorus (Caraco, 1995) from a wide variety of large watersheds. High levels of phosphates can be possibly due to domestic and industrial effluents entering the lagoon from the surrounding area. This may not favour development of fishes in the lagoons because at a certain threshold of

phosphates, phytoplankton diversity is known to decline, thereby affecting primary productivity (Biney, 1990).

Biological oxygen demand (BOD) has been used as a measure of the amount of organic materials in aquatic solution with maximum values due to high organic matter. Biney (1982) considered lagoons with BOD concentration below 4 mg/l as unpolluted and those in excess of 12 mg/l as grossly polluted. The high BOD values recorded at the riverine sections of both lagoons can be attributed to the increased human activities at these sections. The lowest value of BOD recorded in the month of April in the Laloi lagoon was due to the decrease in temperatures. Decreased temperatures tend to retard the rate of reproduction of organisms that break down organic matter. For the entire study period, high levels of BOD were recorded at Laloi than Oyibi. The high levels of BOD in the Laloi lagoon can be attributed to the location of the Laloi which is in an urban area and hence increase human pressure on its resources. The poor water quality is an indication of pollution.

There is a positive correlation between primary productivity and fish production (Boyd, 1990). Chlorophyll *a* concentrations provide indication of the trophic status, maximum photosynthetic rate and water quality. For the entire study period, the seaward end of both lagoons recorded the least concentrations of chlorophyll *a*. This can be attributed to the tides or influx of seawater. Tidal mixing lowers the residence time of algae in the photic

zone and also causes 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 increased chlorophyll *a* concentration increases species abundance and biomass and hence the increased number of species and biomass from the Oyibi lagoon can be attributed to high chlorophyll *a* concentrations recorded in the lagoon.

5.2 Metric selection

Lagoons are highly variable ecosystems, relatively few species are able to live and breed within them (Whitfield, 1998). From the study, the number of resident species in Laloï decreased from eight to three species. This supports the assumption that additional environmental stress caused by pollution results in the reduction in the number of species (Harrison and Whitfield, 2004). The decline in brackish water species in Laloï can be attributed to increased environmental stress. This supports the hypothesis that relative abundance of species decrease in disturbed systems (Harrison and Whitfield, 2004). For Oyibi lagoon, the number of estuarine-dependent marine taxa recorded showed a clear improvement over time while that of Laloï decreased. The assumption that disturbed systems have simple communities, dominated by a few taxa, while more natural systems have a more diverse community with many species dominating was not supported by the study. This is because, the Laloï lagoon recorded more taxa that makes up 90% of the total abundance (total taxa) than the Oyibi lagoon. The lack of information on the total number of individual species in the reference study on these lagoons fisheries was a

major setback to the metric selection. The total for Laloi is 34 and Oyibi is 40. From the metric evaluation and other biological data (condition factor and length-weight relationship), Oyibi was observed to be moderately stressed and Laloi poorly stressed.

The high Chlorophyll *a* concentration at Oyibi can be attributed to the deposition of organic matter to the sediment by mangroves and high nutrient concentrations. This also supports the fact that the growth of planktonic algae in a water body is related to the presence of nutrients principally nitrates and phosphates (Brando *et al.*, 2006). This was supported by the high nitrates and phosphates concentrations recorded in the Oyibi lagoon. Excessive water column productivity, expressed by high chlorophyll *a* concentrations, can supply large amounts of easily decomposable organic matter to the sediments as observed by Duarte (1995). Elevated chlorophyll *a* levels indicate high numbers of phytoplankton and free floating macroalgae (Duarte, 1995) and can translate into changes in animal and plant species diversity (Nielson and Jernakoff, 1996).

5.3 Species Diversity

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

In Laloi, the high species richness can be attributed to the number of fishers that exploit different niches. On the average, there were five fishers at Laloi while for Oyibi, there were 3 fishers. Fishing contributes to the declining abundance of species that spend all or part of their life cycle in estuaries (Secor & Waldman, 199; Lotze *et al.*, 2006).

The diversity of fish species within an area is partly a function of the number of available niches and partly area size (Wootton, 1990). From the average for the entire study, Oyibi had the highest species richness, this can be attributed to the presence of extensive mangrove forest that provides microhabitats for species (Connor *et al.*, 1997). The size of the catchment area has been identified as an important factor governing both fish species diversity and abundance in South African estuaries (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 affect species diversity in aquatic systems (McCauly *et al.*, 1988; Gatto, 1991; Ginzburg & Akçakaya, 1992; McCann *et al.*, 1998 & Hart, 2002) .

5.4 Length-Weight Relationship

The Length- weight relationship give information on the condition and growth patterns of fish (Bagenal & Tesch, 1978). From the length-weight relationship, the fishes were isometric in their growth. Isometric growth is when the length increases in equal

proportions with body weight and with a regression coefficient of 'whiles values greater or less than '3' indicate allometric growth (Gayando & Pauly, 1997). The values of the condition factor of *S. melanotheron* compare favorably with that from Muni, Sakumo and Densu of values (2.61-2.77) as observed by Koranteng (1995) and Fosu lagoon of value 2.65 as observed by Blay & Asabere-Ameyaw (1993).

The highest value for the coefficient of growth was recorded in the month of January (Oyibi) and April (Laloi). The highest value recorded in the month of January can be attributed to the upwelling season in the coastal waters (January- February). The mixing up of surface and bottom waters increase nutrients salts such as phosphates and nitrates which increase primary productivity. The highest value recorded in April (Laloi) can be attributed to the rainfall that occurred on the day of sampling. Rainfall affects fisheries by making nutrients available and influencing salinity regimes. A study conducted by Koranteng (1995) on the Sakumo II lagoon, observed that rainfall affects condition factor and species diversity. In his study, he observed that the number of species decreased from 59 in March to 26 in June causing 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 gives information when comparing two populations living in certain feeding, density, climate and other condition; 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* increased during the entire study period. The increase in the condition factor can be attributed to seasonal variability of the environment, food availability (Mommson, 1998; Henderson, 2005) or habitat suitability (Nieto-Navarro *et al.*, 2010). The high nutrient concentration at Oyibi boosting primary productivity can be a factor accounting for the high condition factor of the fishes. Biological factors such as nutrition and reproduction can also be possible cause for the discrepancies in the condition factor. Increased values may imply the accumulation of fat and gonadal development (Le Cren, 1951) while lowest values may imply the transfer of resource to the gonads during the reproductive period (Vazzoler, 1996).

5.5 Similarity Analysis

The Bray-Curtis similarity analysis showed that there was no variation in species within the months of sampling. There was a significant similarity between the sites. This is because lagoons experience great environmental variation in salinity, temperature, dissolved oxygen, and turbidity due to the influx of fresh and marine waters. These fish species that utilize lagoons must be able to cope with these rapid and extensive environmental changes (Whitfield, 1999). Whitfield (1999) postulated if fishes in estuaries respond to the environment in a consistent manner, then the communities occupying similar types of estuaries in a particular region would be expected to reflect the similarity.

5.6 Total Organic Carbon

The low numbers of *Sarotherodon melanotheron* encountered in the Laloi lagoon can be attributed to the low organic matter content in the sediment of the lagoon which also confers with fisher folks at the site revealed that for the past three years, *S. melanotheron* was missing in catches as compared to previous years. *S. melanotheron* are bottom feeders and low organic matter content implies less food for the species. Pauly (1976) found the stomachs of adult *S. melanotheron* to contain the fine fraction of bottom mud, comprising inorganic granules of 50–100 μ diameter, pennate diatoms and organic detritus. The high levels of organic matter in the sediment at Oyibi can be attributed to the extensive mangrove cover. Organic carbon is an organic pollutant. The high total organic carbon in these lagoons can be attributed to human excreta, domestic wastes and litter from the mangroves forests. The decomposition of these wastes in the water column releases organic carbon which accumulates in the sediments. The high total organic matter recorded at the seaward end can be attributed to the tidal influx. Tide induces flow and transport of sediments (Blondeaux and Vittori, 2005). According to Byun and Wang (2003) sediment transport and its deposition may be strongly affected by tide-induced residual currents. During high tide, ocean water brings in sediments and leaves them behind when tide goes out (SlideShare Inc., 2009)

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Species diversity was found to be highest in the lagoon with extensive mangrove cover (Oyibi) than in the lagoon without mangroves (Laloi). The size of lagoon was also found to be a possible factor that affects the abundance and distribution of species.

The flat head grey mullet (*Mugil cephalus*) and the black-chinned tilapia (*Sarotherodon melanotheron*) were the two most abundant species during the study. *Mugil cephalus* dominated catches in the Laloi lagoon and *Sarotherodon melanotheron* dominated catches in the Oyibi lagoon. *S. melanotheron*, *Lutjanus fulgens* and *Eucinostomus melanopterus* were the most abundant species collected for the Laloi lagoon. *Caranx hippos*, *L. fulgens*, and *M. cephalus* constituted a major part of fishes caught in the Oyibi lagoon. The carangid, *Caranx hippos* contributed much of the biomass of fishes collected from both lagoons. Total fish abundance was greatest in the rainy season than the dry season.

From the metrics assigned, Oyibi had a moderate site rating, suggesting that it was under moderate stress. The main stress factors identified were garbage dumping, defecation, land use changes and increased human pressure. Laloi lagoon had a poor site rating, suggesting that it was under severe stress. The main stresses identified were overfishing,

mangrove degradation, garbage dumping, defecation, mangrove harvesting and increased human settlements along the banks of the lagoon. From the multi-metric index assigned, it is an effective method that does reflect the status of lagoon fish communities and the overall ecosystem conditions.

Oyibi lagoon with extensive mangrove cover had high Chlorophyll *a* level and high condition factor of fish species. Anthropogenic activities and tidal influx are possible factors that affect nutrients in coastal lagoons. Tidal regime was found to be an important factor that influences physiochemical –parameters in coastal lagoons. Total organic carbon in sediments was an important factor in determining the abundance of *S. melanotheron*.

6.2 Recommendation

It is recommend that continuous monitoring of coastal lagoons should be carried out and also studies should be conducted in different lagoons along the coastline of Ghana to identify a pristine lagoon that can be used as a reference community. Food and feeding habits are important aspects of fisheries management studies e.g predator-prey relationships and stomach content of major fish should be identified and weighed to determine the trophic status in the lagoons.

Catch-per-unit-effort (CPUE) should be included to know the exploitation levels for management options. Further studies should include proximate analysis such as heavy metals in the fishes landed at these coastal lagoons and fishing should be carried out both at high and low tides to determine their possible effects on the distribution and abundance of species.

Lagoons in Ghana are not guided by any legislature and hence the abuse of these lagoons for both liquid and solid waste disposal without any kind of treatment. Existing regulations in relation to mesh size used by the fishermen (most of the mesh sizes are below the recommended 25mm) should be enforced by the agencies. The Directorate of Fisheries under the Ministry of Food and Agriculture should liaise with the Ministry of Tourism to develop lagoons into tourist sites especially the designated RAMSAR sites. This would bring foreign exchange to Ghana during the breeding seasons of migratory birds.

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