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UNIVERSITY OF CAPE COAST

CHANGING DYNAMICS OF COASTAL LAGOONS: A CASE STUDY OF THE FOSU AND THE ESSEI LAGOONS IN GHANA

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BY

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Thesis Submitted To The Department of Geography and Regional Planning of the College of Humanities and Legal Studies, University of Cape Coast, in Partial fulfilment of the Requirements for the Award of Doctor of Philosophy Degree in Geography and Regional Planning

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the results of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:..Date..12/10/16

Name: Kofi Adu- Boahen

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature..........................Date..12–10–16

Name: Prof. L. A. Dei

Co-Supervisor's Signature:..............................Date.12–10–16

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ABSTRACT

Coastal lagoons globally suffer from persistent environmental degradation due to myriad anthropogenic and natural factors. Hence management of lagoons is most effective when it is based on a sound scientific understanding of the causes such as the distribution of physico-chemical and biodiversity parameters. Using Fosu and Essei Lagoons in Ghana as a case, this study investigated the changing dynamics of coastal lagoons in the central coastal plains of Ghana. The integrated method was employed to assess the ecological status of the lagoons, using results of field investigations, stakeholder in-depth interviews, laboratory analyses, GIS and remote sensing techniques. The results revealed a wide range of factors affecting the changing dynamics of the physical features of the Fosu and the Essei Lagoons. Natural and anthropogenic factors included sewage discharges from domestic and industrial areas, urban surface and agricultural run-offs and from the action of sea waves and tides. There were also over-laps in the management of the lagoons. A bottom-up approach to coastal lagoons management in Ghana has therefore been recommended. Traditional authorities have been given the power to regulate or manage water resources in collaboration with other stakeholders. In this case, scientific knowledge and local knowledge should be applied simultaneously or synergistically to ensure sustainable use and management of the lagoons.

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DEDICATION

To my family, Mama Okuku, Okuku One, Okokro and Aseda.

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LIST OF ACRONYMS

AAS	Atomic Absorption Spectrophotometer
ArcGIS	GIS software by ERSI
BoM	Bureau of Meteorology
CBD	Convention on Biological Diversity
CBOs	Community Based Organisation's
CBRM	Community-Based Resource Management
CCMA	Cape Coast Metropolitan Assembly
CSIR	Centre for Scientific and Industrial Research
CZM	Coastal Zone Management
DO	Dissolved Oxygen
DPSIR	Driver-Pressure-State-Impact-Response
EA	Ecosystem Approach
EBM	Ecosystem-Based Management
EEA	European Environment Agency's
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Agency
FON	Friends of the Nation
GESAMP	Group of Experts on the Scientific Aspects of Marine
GIS	Geographic Information System
GPS	Global Positioning Systems
ICM	Integrated Coastal Management
ICZM	Integrated Coastal-Zone Management
IDG	In-depth Interview Guide
IDIs	In-depth Interview's

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IEM	Integrated Environmental Management
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use Land Cover Change
MCL	Maximum Contaminant Level
NGO	Non-Government Organization
OECD	Organisation for Economic Cooperation and Development
Ph	Acidity and Alkalinity
STMA	Sekondi Takoradi Metropolitan Assembly
TDO	Total Dissolved Oxygen
TDS	Total Dissolved Solids
UCC	University of Cape Coast
UK	United Kingdom
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WHO	World Health Organisation
WMO	World Meteorological Organization
WRI	Water Research Institute

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CHAPTER ONE

INTRODUCTION

Background of the Study

Coastal lagoons are shallow aquatic environments located in the transitional zone between terrestrial and marine ecosystems, which span from freshwater to hypersaline conditions depending on the water balance (Kjerfve, 1994). The formation, presence, and the ecosystem processes of coastal lagoons are controlled by the interactions between stressors and fluxes of material from the land, ocean and the atmosphere (Kjerfve, 1994). Crossland, Kremer, Lindeboom, Marshall-Crossland and Le Tissier (2005), and Eisenreich (2005) contend that natural threats that have had the largest impact on coastal lagoons were accelerated in the last decades by subsidence and sea eustatism. The threats include changes in the regime of precipitation, runoff and sea storms. Due to these threats and changes in the hydro-geomorphological conditions, the form of coastal lagoons is recognised as highly dynamic environments (de Wit et al., 2001).

Inspite of the changes that occur along coastal lagoons, there is evidence that within certain thresholds, lagoonal communities and ecosystems could be resilient to environmental changes, and can buffer against certain external stresses. On the other hand, resilience and buffering capacities do not follow linear behaviour, they sometimes undergo sudden responses, which can result in rapid regime shifts (Scheffer, Carpenter, Foley, Folke & Walker, 2001) that may cause irreversible changes in the lagoon environment (Schramm, 1999).

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Coastal lagoons provide essential ecosystem services that include the support of rich biodiversity. For example, they act as spawning grounds for marine fish and invertebrates, and serve as resting place for many species of migratory birds. Coastal lagoons have long been exploited by local inhabitants for their natural resources, in particular for fishing and aquaculture. Lagoons in Ghana for example are important, for they provide benefits and values to coastal population (Gordon, 1998). They provide valuable resources such as large quantities of fish and crabs that are caught and processed for trade and for local consumption. Reeds are cut for thatch, and for weaving mats and vegetables are grown in sandy garden-beds irrigated with water drawn by hand from wells along the edges of the lagoons (Gordon, 1998). Unfortunately, lagoons are under strong anthropogenic pressures from their watersheds; they receive freshwater inputs rich in organic and inorganic nutrients carried from heavily exploited rural, urban and industrial areas upstream.

Over the last two decades, coastal lagoons have experienced increasing pressure from tourism (Amlalo & Ahiadeke, 2004). In many cases, maritime activities such as those carried out in ports and harbours, aquaculture and fishing activities cause lagoon pollution. Other impacts are land-use changes around lagoons; these magnify the impacts of climate change on the lagoon ecosystem and could be disastrous to the welfare of coastal communities. Land-use change, freshwater withdrawal from ground and surface water sources, sedimentation, point and non-point water pollution, shoreline hardening, and overfishing are examples of anthropogenic stressors that can have profound and sudden

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impacts on coastal ecosystems (U.S. Environmental Protection Agency, 2007; Khan, 2007; Rodriguez, August, Wang, Paul, Gold & Rubinstein, 2007; Bilkovic & Roggero, 2008; Hollister, August & Paul, 2008a).

Impacts of a changing climate on coastal lagoons are already beginning to emerge (Steffen, 2006). For example, the World Metrological Organisation (WMO, 2005) states that, with the exception of 1996, the 10 years between 1996 and 2005 were the hottest years on record. For example in Australia, 2005 was the hottest year on record, with a temperature of 1.09°C higher than the 1961-1990 average (Bureau of Meteorology, 2007). Consequently, mean sea level, on global scale, has increased over the past century, due primarily to (Cabanes, Cazenave, & Le Provost, 2001), glacial melting (Walsh, Betts, Church, Pittock, McInnes, Jackett, 2004).

Coastal lagoons in Ghana have been experiencing a lot of changes and challenges emanating from human activities. Land use changes in the form of pressure from tourism, population increase due to urbanisation, inputs of organic and inorganic nutrients from upstream and fishing activities are having a negative impact on coastal lagoons. Climate change has also caused wide range of changes to coastal lagoon environments (including physical, chemical and ecological nature of the lagoons (Church, White & Arblaster, 2005). It is therefore necessary to investigate the changing dynamics of coastal lagoons to address the impact of these changes on the lagoons.

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Statement of the Problem

Coastal lagoons are shallow coastal water bodies that very often provide services which include fisheries, flood assimilation and protection of biodiversity. Unfortunately, coastal lagoons are fragile, vulnerable and easily disturbed by natural and anthropogenic factors. A preliminary survey of some lagoons along the coast of Ghana by the present researcher showed that human activities have created ecological pressure on the natural habitats of fish and other marine organism living in and around them. The result of the factors is that some of the lagoons are disappearing and others shrinking. Some have been heavily polluted whilst others are expanding. As a result the aesthetic values of some of the lagoons and their status as Ramsar sites are being lost to (Aheto, Mensah, Okyere, Mensah, Kafui & Opoku-Agyarkwah, 2010).

This observation has been noted by de Wit *et al.*, (2001), who said that the hydro-geomorphological conditions of coastal lagoons are dynamic. Over the last two decades, coastal lagoons have come under increasing anthropogenic and natural pressures. For example, urbanisation and increasing population have contributed to further land reclamation and water demand that have resulted in the deterioration of water quality (Aheto, et al., 2010; Boateng, 2008).

The ability to monitor and manage future changes in coastal lagoons depends on integrated understanding of the physical and biological conditions affecting the lagoon ecosystems (Kjerfve, 1994). This is because of the remarkable changes in some of the lagoons along the central coastal plains of Ghana particularly, those in the urban areas due to the wastes from human

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activities that are thrown flow directly into the lagoons without any prior treatment. The Fosu Lagoon of Cape Coast in the central region of Ghana for example is now considered by the (UNEP, 2006) as a "Dead Zone" an attribute that describes lagoons where pollution threatens fish, other marine life and the people who depend on them.

From the above, sustaining public interest and stakeholder participation on environmental issues will create opportunities for conserving and restoring areas that seeks to provide the required ecological goods and services for the benefit of man. Also there is inadequate scientific data on managerial policies that clearly demarcate the various land uses and land cover types around the Fosu and Essei Lagoons. The available management procedures are poorly documented in the case of relevant information on the socio-economic context including information on the anthropogenic factors around lagoons. Understanding the processes and products of interaction in coastal environments is very complicated (Ramachandran, 2002). A careful assessment of changes that occur in the coastal environments and in coastal ecosystems forms a major milestone for effective coastal ecosystem management and leads to sustainable utilization of coastal resources (Appeaning & Adeyemi, 2013). All these could be achieved only through the collection of accurate, reliable and comprehensive set of scientific data. It is against this background that this study was undertaken to investigate the changing dynamics of coastal lagoons using the Fosu (Central Region) and the Essei (Western Region) Lagoons in Ghana as a case studies.

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Purpose of the Study

The study sought to investigate the changing dynamics of the Fosu and the Essei Lagoons in Ghana.

Objectives of the Study

The specific objectives of the study were to:

1. Examine the changing physical features of the Fosu and the Essei Lagoons in Ghana.
2. Assess the state of water quality of the Fosu and the Essei Lagoons
3. Ascertain the factors causing the changing physical features of the Fosu and the Essei Lagoons; and
4. Develop sustainable plan for the preservation and management of the Fosu and Essei Lagoons in Ghana.

Research Questions

To achieve the stated objectives, the following research questions were formulated in order to carry out the study;

1. What is the nature of the changing physical features of the Fosu and the Essei Lagoons?
2. What is the state of water quality of the Fosu and the Essei Lagoons
3. What factors are causing the changing physical features of Fosu and Essei Lagoons?
4. Are there any sustainable plans for the preservation and management of the Fosu and Essei Lagoons in Ghana?

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Assumptions of the Study

The study is based on the assumptions that;

- The physical and chemical changes that occur in the Fosu and Essei Lagoons are due to natural causes (climate thus wet and dry seasons).
- The physical and chemical changes that occur in the Fosu and Essei Lagoons are due to anthropogenic features (farming, industrial and residential activities).

Significance of the Study

This study is important for both theory and policy consideration. In terms of theory, the study will add to existing literature and knowledge on the changing dynamics of the Fosu and Essei Lagoon. In terms of policy, the study will inform practitioners in coastal zone management about the constraints and opportunities for the proper use and management of coastal lagoons. The study will contribute to the solution of (coastal) lagoon pollution in Ghana and elsewhere. The result of the study will form basis for finding methods for solving coastal lagoon pollution.

The study is in consonance with the national and global efforts that protect existing water bodies. Faced with dwindling, polluted, and near extinct water resources, nations are searching for collective efforts to safeguard the remaining water bodies. Since, the study is related to the efficient use of lagoons; it will contribute to the efforts to protect water bodies.

The study will contribute to the existing literature on coastal lagoons. It will serve as reference material for students who are concerned with coastal zone management and coastal geomorphology in Ghana and elsewhere. Furthermore,

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the results of the study will be made public so that academics and professionals can have access to the results.

It has been pointed out that few studies have examined the geomorphological processes and functional status of lagoons in the country from the perspective of coastal zone management. Most studies have focused on the value of the lagoons for fish and birds (Gordon, 2000). It is therefore imperative to study the geomorphic processes that affect coastal lagoons and to broaden our understanding of the functional status as well as biodiversity interactions within the coastal environments. Thus the information from the study will be useful in determining the ecological health of lagoons and also facilitate their bio-monitoring. Baseline data will however be useful in monitoring the Fosu and the Essei Lagoons.

Finally, it will bring to bear the processes causing the changing dynamics of coastal lagoons as a result of global climatic change. It is therefore hoped that government and non-governmental organizations will be encouraged to undertake monitoring and evaluation of the coast to ensure that planning process is indeed adhered to in the various coastal zones in Ghana.

Delimitation of the Study

The study was designed to investigate the changing dynamics of the Fosu and the Essei Lagoons in Ghana. The study sites were limited to Cape Coast (Fosu Lagoon) and Sekondi (Essei Lagoon). The issues that formed the basis of investigation were the changing physical feature of the Fosu and Essei Lagoons, their water quality index, the factors causing the changing physical features of the

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lagoons, land use cover change, and issues of conservation and management of the lagoons.

Limitations of the Study

The study was bedevilled with some shortcomings. The primary shortcoming was the inability of the Multi-parameter water quality checker to give accurate information on the turbidity of the two Lagoons. Again heavy metal concentration analysis was not done on the Essei Lagoon due to the little fishing activities in the lagoon. The presumption was that the lagoon was polluted and few fish types live in it. Otherwise, the instrument was able to indicate the other parameters needed for interpretation. Malfunctioning of the machine prolonged the data collection period; the instrument was eventually replaced. The replacement did not affect the quality of the data collected. Similarly, bio-accumulation was not undertaken which affected the research.

Organisation of the Study

The thesis is organised into seven chapters. Chapter One contain the background of the study, problem statement, objectives of the study, research questions and the significance, and the organisation of the study. Chapter Two examines related literature on coastal lagoons. The chapter also examines several approaches to coastal lagoons management such as DPSIR, ecosystem approach to management, integrated environmental management, and integrated coastal zone management. The systems approach in geomorphology is also treated. The chapter ends with the consideration of conceptual and theoretical issues. Chapter Three describes the research methodology; it consists of the study area, study

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design, sources of data, data collection procedure and the analytical techniques employed. Chapter Four is devoted to the results and discussion of some of the findings. Chapter Five is devoted to the water quality status of the Fosu and the Essei Lagoons. Chapter Six contains the discussions on the factors causing the changing physical features the Fosu and Essei Lagoons. Chapter Seven provides the summary of findings, conclusions, recommendations and suggestion for future research.

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CHAPTER TWO

REVIEW OF RELATED LITERATURE

Introduction

This chapter concerns itself with the review of the related literature. A review of relevant geomorphological, hydrological and oceanographic characteristics of coastal lagoons and the factors causing the geomorphological processes have been discussed. This was done in an attempt to obtain an informed understanding of the underlying processes. The fundamental premise was that physical characteristics and dynamics of lagoons depend primarily on the nature of the channel connecting the lagoon to the adjacent ocean. The chapter also describes several approaches to coastal lagoons management; the conceptual and theoretical issues of the study are discussed.

Nature and Factors Affecting Coastal Lagoons

The Meaning of the Coast

The coastal environment can be classified descriptively, based on sediment composition, coastal features, and hydrodynamic energy. Rock, cliff, and gravel coasts comprise 75 to 85 percent of the world's coastlines (van Rijn, 1998). According to van Rijn (1998), sandy (10 to 15%) or muddy (5 to 10%) coasts are less common. Morphological classification of coasts includes dune, barrier island, delta, cliff, coral reef, mangrove, lagoon and marshy coasts. Inman and Nordstrom (1971) classified coastlines based on their morphology and tectonic setting or processes. According to the authors, leading edge coasts occur along converging/collision margins, often rocky with cliffs and a narrow

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continental shelf. Along passive margins, coasts are classified as trailing edge, typically sandy (although sometimes muddy) with wide continental shelves. Marginal sea coasts occur along depositional edges of shallow marginal seas and are protected by island arcs. On the other hand, Davis and Hayes (1984) have presented a hydrodynamic energy-based coastal classification, based on the ratio of river-sediment discharge, wave climate and tidal regime. Hydrodynamically classified coasts are riverine, wave energy, tide energy and mixed energy. The coast is defined as the broader geographical area of which lagoons are located.

Types of Lagoons in Ghana

There are two main types of coastal lagoons encountered in Ghana. These are the 'open' and the 'closed' lagoons (Armah, 1991).The open lagoons have permanent opening to the sea and are normally fed by rivers that flow all year round. They occur mostly on the central and western parts of the coastline of Ghana where higher rainfall results in a more continuous flow of rivers and streams. The closed lagoons are separated from the sea by sand bars. They are more common on the eastern coast of the country where rainfall is low and seasonal. Some closed lagoons are open to the sea in the rainy season when floodwaters breakthrough the sand bars (Kwei, 1977), storm surges often break through the sandbars so that water from closed lagoons flow to the sea (Armah, 1991). During festivals and in the raining seasons the sandbars are manually breached to reduce the risk of flooding the adjacent settlement where this is considered a threat.

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There are three types of lagoons based on their dynamics. The first type is referred to as choked lagoons; these consist of a series of connected elliptical cells that are connected by a single long narrow entrance channel, and are found along coasts characterised by strong waves and significant littoral drift (Kjerfve, 1994; Kjerfve & Knoppers, 1991). Choked coastal lagoons are characterised by long flushing time, dominant wind forcing, and intermittent stratification events due to intense solar radiation or runoff events. In arid or semi-arid regions of the world, choked coastal lagoons often become permanently or temporarily hypersaline (Moore & Slinn, 1984).

The second type of lagoons are those consisting of a large and wide water body, usually oriented shore-parallel and have two or more channels or inlets. This type of restricted coastal lagoons has a well-defined tidal circulation, is influenced by winds, is mostly vertically well mixed and exhibit salinities from brackish water to oceanic salinities. Flushing times of this restricted type of lagoon are usually considerably shorter than for choked coastal lagoons.

The third type of lagoon is referred to as leaky lagoons. These are elongated bodies of water that lie parallel to the coast. They are characterised by numerous wide tidal waves and unimpaired water exchange with the ocean.

Physical Characteristics of Lagoons

Coastal lagoons are typically found along low-lying coastlines that have tidal range of < 4 m (Martin & Dominguez, 1994). Lagoons constitute 13 percent of coastal regions globally; they range in area from < 0.01 km² to > 10,000 km²,

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and are typically < 5 m deep (Bird, 1994; Kjerfve, 1994). Coastal lagoons are formed and maintained through sediment transport processes (Kjerfve, 1994).

The process of sedimentation eventually fills lagoons (Nichols & Boon, 1994). Lagoon barriers are constantly eroded by waves and wind, hence thus require continuous sediment deposition for their maintenance (Bird, 1994). Water quantity and quality in lagoons is determined by the rate at which the lagoon loses or gains water from evaporation, precipitation, groundwater input, surface runoff, and exchange with the sea (Allen, Mandelli & Zimmermann, 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, which is the rate at which water enters, circulates through, and exits lagoons, is an important physical property which controls the retention time of water-borne constituents. Lagoons tend to have low flushing rates because of restricted exchange with the ocean and thereby contribute to primary productivity and high pollutant concentrations (Spaulding, 1994). Determinants of the flushing rate include the size and shape of the lagoon, the level of connectedness with the sea, tidal range, and freshwater flow (Phleger, 1981).

The effects of lagoon's geomorphology on their hydrodynamics have been widely studied (Jewell, Walker & Fortunato, 2012; Picado, Dias & Fortunato, 2010).

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The results from the studies show that tidal propagation is strongly dependent on the bathymetric and geometric configuration of the lagoon.

Ecological Characteristics of Lagoons

Coastal lagoons are productive ecosystems that contribute to the overall productivity of coastal waters; they by support a variety of habitats, such as salt marshes, seagrasses, and mangroves. They also provide essential habitat (for many fish and shellfish species) such as seagrass beds which are common feature of soft-substrate lagoons on the Atlantic coast. Where seagrass beds occur, Zostera marina (eelgrass) is the most dominant species whereas Thalassia testudinalinum (turtle grass) is the most dominant species (Bertness, 2007).

Such beds play important role in influencing the shape and stability of shorelines, they regulate dissolved oxygen (Nixon & Oviatt, 1972) and filter suspended matter (Bertness, 2007). They can enhance the biodiversity of lagoons by providing physical refuge from predation. They also serve as nursery and feeding habitats for a variety of organisms (Harris, Buckley, Nixon & Allen, 2004). On the Atlantic coast of Africa salt marshes are one of the most prevalent habitats in lagoons (Bertness, 2007) and are some of the most productive natural vascular plant communities in the world. Because of their relatively low flushing rates, coastal lagoons are favourable habitats for primary producers (phytoplankton and aquatic plants) (Bertness, 2007).

Nutrients are transported to lagoons from surface water and groundwater flows, and through exchange with the ocean. Because nutrient availability often limits primary productivity, coastal lagoons can foster high rates of primary

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production, thereby supporting high rates of secondary production compared to other aquatic ecosystems (Nixon, 1995). However, primary production that exceeds the demands of consumers can lead to eutrophication (Valiela et al. 1992). Eutrophication is characterized by excessive phytoplankton and macroalgal blooms and subsequent hypoxia, reduced light penetration (Anderson, Gilbert & Burkholder, 2002; McGlathery, 2001), 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).

Distinctive Physical Features of Coastal Lagoons

Among the most important morphometric features of coastal lagoons are pass dimensions, lagoonal width to length to depth ratios, bottom topography and mean depth. Inlet dimensions control the exchange of water that includes dissolved and suspended material which it contains. This in turn determines flushing rates and residence times. Bottom topography, including both natural and man-made channels, plays important role in guiding tidal and non-tidal circulation of the lagoon. Mean depth is the most important of the three geometric factors. Lagoons are shallow, with a large horizontal shape and mean depth ratio. The horizontal shape influences the volume of water in the lagoon (Dronkers, 2005). Kjerfve, (1994) had observed that shallow water is especially responsive to heating and cooling processes as a result of the (depth of the shallow water) over diurnal time scales.

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Distribution of Coastal Lagoons in the World

Nichols and Boon (1994) assert that coastal lagoons occur all over the world and on every continent except the Antarctica. Together with flats and marshes, they occupy about 11 percent of the world's coastline, the longest single stretch being the 2800 km stretch of Leaky lagoons, landward of Barrier Islands on the east coast of the USA. Lagoons are most common on low-lying aggrading coastal plains with a history of submergence during the last 10,000 years Nichols and Boon (1994). An abundant supply of sediment is required for barrier building to impound a lagoon, while adequate exposure to wave action is necessary to transport the sediments. In the view of Nichols and Boon (1994), microtidal coasts (tide ranges less than 2m) are the most favourable for barrier beach building by waves and for consequent lagoon containment. In direct contrast, macro-tidal environments (tidal range greater than 4m) have few barrier-lagoon systems because of stronger tidal currents. Example of some of some large barrier beach shores are the New Zealand Tasman and Golden Bays where tide range are up to and above 4m.

Nichols and Boon (1994) have noted that there is a close association between lagoon types and climate. For instance Mid-latitude lagoons are found in catchments and basins that have annual surplus of precipitation over evaporation. This leads to vigorous stream flow from catchments that have moderate sediment (a range of 10-100 tons/km^2/year is suggested) yields. Sedimentation in the lagoon is thus dominantly fluvial in origin.

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Entrance Processes and Morphodynamics of Lagoons

Figure 1 shows the summary of processes involved in entrance morphodynamics. Lagoons exhibit two hydrodynamic regimes. One occurs when the entrance is open, and the other when the entrance is closed (Ranasinghe & Pattiaratchi, 2003). When the entrance is open, lagoons exhibit regular tidal behaviour. When the entrance is closed, however, lagoons operate more as reservoirs, with water levels responding to catchment runoff, direct rainfall, evaporation and percolation. When closed, water levels within lagoons may vary up to 3 metres, depending on the crest level of the entrance sand bar (Ranasinghe & Pattiaratchi, 2003). Lagoons move from one hydrodynamic regime to the other as a result of entrance morphodynamics (Figure 1).

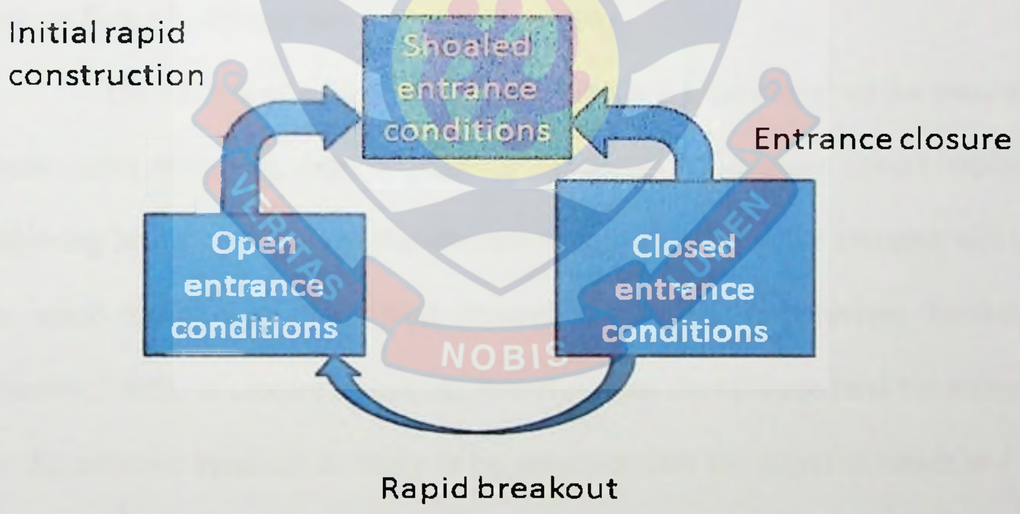

Figure 1: Entrance Morphodynamics of Lagoons

Source: Author's Construct, 2014

The nature of a lagoon entrance is a function of (i) the wave climate (ii) incoming tidal conditions (iii) ebb tide currents and (iv) discharge of floodwaters. The first two tend to wash sand into the entrance and close the channel while the

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last two tend to wash sand out of the entrance through scour (Elwany, Flick & Hamilton, 2003; Hanslow, Davis, You & Zastawny 2000; Gordon, 1990). Lagoon entrances get breaching by rising water levels within the lagoon overtopping the entrance sand berm. Hence entrance breakouts often occur during heavy rainfall which results in the increase of lagoon water levels. The break through start with the initial development of a small pilot channel across the berm to the ocean. Over a period of approximately 2.5 to 3 hours (Gordon, 1990), the high currents flowing through the pilot channel scour enough sand to form a sizable channel. The discharge of waters from the lagoons is then controlled by the difference in water level (head difference) between the lagoon and the ocean (Gordon, 1990). The sand scoured from the entrance to create the channel is deposited in the surf zone to form an offshore sand bar (Sheedy, 1996).

The closure of a lagoon's entrance entails the 'recovery' of the entrance beach berm following lagoon entrance breakout. If closure occurs rapidly following breakout, it is more that the sediment used to fill in the entrance will be the same material as that which scoured out during the previous breakout (Sheedy, 1996). If closure is delayed, however, then the offshore sand bar formed by the entrance breakout is likely to be reworked into the adjacent beach and it will become longshore sand transport that then becomes more responsible for filling in the entrance. According to Sheedy, (1996) the length of time that a lagoon's entrance is closed has been given the new term Entrance Closure Index (ECI). The ECI is calculated over a long term period, and as such, represents typical, average entrance conditions of a lagoon.

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Climate Change and Coastal Lagoons

The assertion that the world's coastlines and lagoons will be impacted by the effects of future climate change is now beyond doubt (IPCC, 2007). The effects of climate change on sea level rise, waves and numerous other natural phenomena is continually becoming better understood through ongoing investigations by large individuals and international collaborative projects. IPCC (2007) opined that, of all the world's ecosystems that will be affected by climate change, coasts and lagoons will arguably receive the most severe and profound impact, particularly the rise in the mean sea level.

There are numerous studies in the literature on the impact of climate change, particularly on sea level rise, lagoons and shorelines (Davidson-Arnott, 2010, Cowell, Thom, Jones, Everts & Simanovic, 2006), as well as estuaries and tidal inlets (Reeve & Karunarathna, 2009; Jones, 1994). Nevertheless, there still exist large gaps in knowledge on the impacts climate change will have on coastal environment. Consequently this section is devoted to the explanation of the effects of climate change on coastal lagoons.

Increase in Lagoon Depth

Another important impact of climate change on lagoons is increase in the water depth of the lagoon due to the increase in low tide (and high tide) levels. The high depth affects the benthic ecology which has already adapted to existing light conditions and geochemical processes within the lagoon (Haines, 2006). Large volume water over marine and deltas will likely result in vertical accretion of these primary deposition areas. Such accretion is expected to occur

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contemporaneously with the rate of sea level rise (i.e., up to ~10mm/yr) (Haines, 2006). Increased lagoon depths will theoretically reduce the potential for mixing by wind driven circulation and stirring of fine bed sediments. This may lead to greater potentials for stratification, particularly within existing deeper areas of lagoons.

Increased water depths, particularly within channels, may also diminish the impact of specific flow controls, such as shallow rock shelves and bars. If these controls previously helped to maintain a mostly open entrance condition, the lagoon may adopt a greater tendency for natural closure. Any changes to the connectivity between the ocean and the lagoon because of reduced breakout frequency may affect tidal flushing capacity of lagoons and the oceanic selection and dispersal behaviour of fish and prawns.

Shoreward Translation and Increase in Berm Height at Entrance

An increase in mean sea level will result in an upward and landward translation of ocean beach profiles (Hanslow, Davis, You & Zastawny, 2000). With respect to coastal lagoons, a sea level rise will cause the entrance sand berm to move inland and to build up to a higher level relative to local topography. The increase in berm height is expected to match the increase in sea level rise given that the berm is built primarily by wave run-up processes. The increase in entrance berm heights will be most apparent for mostly closed coastal lagoons. For such systems, lagoon water levels will therefore need to reach a higher level before inducing a natural breakout to the ocean (in the absence of artificial intervention) (Haines & Thom, 2007; Haines, 2006).

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As foreshores around lagoons are generally flat, they (lagoon) actually store more water before a breakout occurs since there is a non-linear relationship between coastal lagoon volume and water level. Hence, frequencies of breakouts get reduced. Potentially exacerbating of this outcome would be an increased evaporation from coastal lagoons given their larger water surface area. The elevated water levels within coastal lagoons, as a consequence of higher tide levels, will potentially result in a landward migration of fringing lagoon vegetation. If vegetation communities cannot migrate upslope, due to obstructions or topography, then the vegetation communities may be lost altogether.

Altered Entrance Morphodynamics

Hanslow, Davis, You, and Zastawny (2000) are of the view that an increase in mean sea level alters the existing dynamic balance of coastal lagoon entrances, and may change the length of time that the lagoon is open or closed. Depending on the position of lagoon entrance along the coast, broad scale responses of adjacent ocean beaches to sea level rise may result in sand accumulation inside the entrance of the channel. An overall increase in water level is also likely to induce accretion and possible landward progradation of marine flood delta.

Tidal range in a coastal lagoon, when the entrance is open, is dependent on the flow constrictions imposed by the entrance. Under the condition of higher sea level, and hence higher lagoon level, the same tidal prism (i.e. the total volume of water held between low tide and high tide, which moves into and out of the lagoon) can be met by a smaller lagoon tidal range (given the larger lagoon

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surface area under higher water level conditions). Hence, increase mean sea level will not automatically translate into an equivalent increase in lagoon level. Entrance morphodynamic processes involve complex interplay between beach processes in particular, longshore sediment transport processes, tidal flows, and episodic rainfall-induced breakout or entrance scouring events. It is therefore envisaged that the consequences of sea level rise on all these processes is difficult to predict and will most likely involve site-specific responses.

Increase in Global Temperature

In the last century, global air temperature has increased by 0.76 °C and is expected to increase by an additional 1.1–6.4 °C by 2100 (IPCC, 2007). Temperature increases will vary regionally and is influenced by natural climate variation (Smith, Cusack, Colman, Folland, Harris & Murphy, 2007; Keenlyside, Latif, Jungclaus, Kornblueh & Roeckner, 2008). The greatest warming is expected to occur in the high latitudes in winter (IPCC, 2007; Serreze, Holland & Stroeve, 2007).

According to IPCC (2007), temperature of the world's oceans has increased, on the average, by 0.3 °C and is likely to continue to increase through the next century. Because air temperatures increase more quickly over land than over oceans, coastal water temperatures are also likely to increase more rapidly (Harley et al., 2006). For example, in Narragansett Bay, Rhode Island where median depth is 6.4 m; (Boothroyd & August, 2008), the annual average surface water temperature has increased by 1.1 °C in the past 50 years (Nixon, Granger, & Buckley, 2003).

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This rate of increase is approximately four times greater than that of the ocean. Although much is not known about the long-term data for water temperature in coastal lagoons, the shallow nature and low flushing rates of coastal lagoons indicate that water temperatures in lagoons will increase even more rapidly than water temperatures in open estuaries.

Water temperature influences dissolved oxygen concentrations and the physiology of lagoon organisms, species' ranges and patterns of migration (Turner, 2003). Many marine species live near their threshold of thermal tolerance (Tomanek & Somero, 1999), within which even small changes in temperature can have large impacts on their viability. In addition, these ecosystems are more susceptible to increases in the colonization of invasive species that may thrive in warmer waters (Stachowicz, Terwin, Whitlatch & Osman, 2002). As lagoon temperatures increase, dissolved oxygen concentrations decrease (Joos, Plattner, Stocker, Kortzinger & Wallace, 2003; Bopp,Le Quéré, Heimann, Manning & Monfray, 2002), especially as seasonal stratification of water column isolates oxygen-depleted deeper waters from oxygen-rich surface waters (Joos *et al.* 2003; Bopp et al. 2002).

Reduced dissolved oxygen adversely affects aerobic biota especially benthic communities that are most severely stressed. In lagoons with high flushing rates, the influx of ocean water prevents stratification, because it causes the water column to mix. In restricted lagoons with low flushing rates and high nutrient inputs, increase in temperature increases the probability and severity of hypoxic events (D'Avanzo & Kremer, 1994). Chronic hypoxia in coastal waters

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has been linked to long-term changes in benthic community structure characterized by persistent shift in species composition to more hypoxia-tolerant species and an overall decrease in species diversity (Conley, Carstensen, Aertebjerg, Christensen, Dalsgaard, Hansen & Josefson, 2007).

The timing (phenology), thus changing characteristics, or growth stages of lagoon processes is also affected by temperature increases. For example, changes in air temperature affect the timing and the route of migrating birds that normally stop over coastal lagoons (Gatter, 1992). Developmental and reproductive timing in shellfish as evidenced by early gonad maturation and spawning in bay scallops is also associated with higher water temperatures (Sastry, 1963). Changes in plankton phenology have also been observed, with zooplankton becoming active earlier in the year following relatively warm winters (Edwards & Richardson, 2004). Increased grazing of phytoplankton by zooplankton has been observed to partially explain the declines in phytoplankton abundance associated with warmer temperatures (Oviatt, 2004). Warmer temperatures are also thought to contribute to declines in seagrass' abundance (Blintz, Nixon, Buckley & Granger, 2003).

Changes in Precipitation

Meehl et al. (2007) assert that there will be changes in precipitation intensity, timing, volume and form (snow or rain) because of Global Climatic Change. Although predictors agree that there will be an increase in extreme rainfall events such as drought–flood cycles (Committee on Environment & Natural Resources, 2008; Scavia et al; 2002), disagreement persists regarding the

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direction of expected changes in other components of the water cycles such as stream flow, evapo-transpiration, soil moisture and groundwater storage.

Regional changes in precipitation patterns have important effects on the physical and ecological characteristics of coastal lagoons through the alteration of freshwater inputs and associated changes in salinity and dissolved oxygen concentrations (Milly, Dunne & Vecchia, 2005). Intense precipitation events increase short-term freshwater inputs (Paerl et al., 2006) while locally decreasing salinity (Michener et al., 1997). Conversely, lower precipitation reduces freshwater inputs and hence results in higher salinity (Valiela, 1995). Salinity also is affected by changes in flushing rate, which may counteract the changes in freshwater inputs. Increased freshwater inputs contributes to the stratification of deeper lagoons (Justice, Rabalais & Turner, 1996), increasing the risk of hypoxia in bottom waters (Bopp et al. 2002; Joos et al., 2003). As such increases in variability and intensity of precipitation events produces increased spatially and temporally variability in salinity and dissolved oxygen concentrations in coastal lagoons.

Other effects of increased surface water inputs are increased delivery of sediments and nutrients to lagoons (Orpin, Ridd & Stewart, 1999). Increased nutrient inputs may accelerate eutrophication of lagoons, especially those with low flushing rates (McComb, 1995; Wazniak, Hall, Carruthers, Sturgis, Dennison & Orth, 2007). As with sea level rises, increased turbidity reduces light penetration and the photosynthetic activity of submerged aquatic vegetation, compounding the risk of eutrophication as nutrient dynamics are further altered (Lloret, Marin

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& Marin-Guirao, 2008). In addition, reduced light penetration can inhibit the feeding ability of visual predators (Horppila, Liljendahl-Nurminen & Malinen, 2004).

Impact of Storms on Lagoons

Storms affect lagoons through overwash events, and by erosion from wind and waves. There is disagreement among predictions concerning the extent and magnitude of changes in storminess with Global Climatic Change. Evidence of increase in intense tropical cyclone activities in the North Atlantic over the past 40 years (Meehl et al. 2007; Trenberth et al., 2007) supports predictions that the frequency (Holland & Webster 2007; Mann, Emmanuel, Holland & Webster, 2007) and intensity (Emanuel, 2005; Webster, Holland, Curry & Chang, 2005) of extreme weather events have been increasing and will continue to increase with warmer global temperatures. However, these predictions have been challenged by suggestions that the apparent trend in increasing storm frequency is an artefact of improved monitoring (Landsea, 2007) and by predictions that increased vertical wind shear could dampen the effects of increasing hurricane intensity (Vecchi & Soden, 2007). Meehl et al. (2007) suggest that a warmer climate will increase the overall intensity of tropical cyclones whereas the number of storms is expected to decrease globally by the end of the 21st century, the number of storms in the North Atlantic could increase by as much as 34% during this period (Oouchi, Yoshimura, Yoshimura, Mizuta, Kusunoki & Noda, 2006).

The consequences of sea level increase become acute during storm events because sea level increase and storms interact to erode barriers and produce high

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storm surges, rapidly redistributing barrier sediment (Fenster & Dolan, 1994). During periods of high storm surge, water moves rapidly over barriers in a process called overwash which delivers sediments eroded from the front of the barrier onto the back barrier flats and into lagoons (Leatherman, 1981). Increased storm intensity causes frequent breaches of barrier islands (Morton & Sallenger, 2003), which in turn increases the rate of exchange with the ocean, and consequently the flushing rate and salinity of lagoons (Bird, 1994; Smith, 1994). Whereas straightforward to assess the 'theoretical' impact of sea level rise on coastal lagoons, it is more difficult to quantify the potential magnitudes of change. Also, it is imprudent to consider the impacts of sea level rise in isolation to other potential climate change variables, such as changes in rainfall, wave and temperature. As such, it is difficult, if not impossible, to predict the likely result on coastal lagoons processes once all factors are taken into consideration.

Introduction to Anthropogenic Impacts on Coastal Lagoons

The high level of pollution in the aquatic environment in West African wetlands has been attributed to human activities. An investigation into water pollution sources in some lagoons in Ghana (Finlayson, Gordon, Ntiamoa-Baidu, Tumbulto & Storrs, 2000) has demonstrated that a good number of people have no access to toilet facilities and hence defecate along the coastline; this contribute to the pollution of some the lagoons along the coast. Also 80% of refuse generated within these areas were identified to be of domestic origin. Major threats to lagoons include water pollution, physical modification, over

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exploitation of aquatic resources such as fish, crabs and loss of production, as well as increasing population.

Population Increase and Coastal Lagoons

Coastal zones are dynamic natural systems where several socio-economic activities concur. During the 21st century, coastal areas changed dramatically due to pressures associated with economic and population growth (Buddemeier, Smith, Swaaney & Crossland, 2002). Activities such as agriculture intensification, urban sprawl, infrastructural expansion and industrial growth have left permanent marks on coastal areas. The effects of human interventions are evident over much shorter periods than those attributable to climate change; hence they can be identified with greater ease (Alvarez-Rogel, Cirujano & Sanchez-Carrill, 2007). Anthropogenic change to wetland ecosystems is primarily a 20th century process (Alvarez-Cobelas Jimenez-Carceles, Roca & Ortiz, 2001). Although this has been the most prominent anthropogenic effect over the past 50 years, there have been other, earlier effects related to human activity.

Nwankwo (2004) reports that the result of increasing population pressure, industrialization and poor waste management in Nigerian's coastal areas is that pollutants freely find their way into coastal waters through drains, rivers and creeks that act as conduits. According to Burke, Kura, Kassem, Revenga, Spalding and McAllister (2001), from 1990 to 1995 the number of people living within 100 km of the coast increased from roughly 2 billion to 2.2 billion. Future standpoints indicate that the population living along the coast will double in the

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next 30 years; it is expected that 75 percent of the world's population will reside in coastal areas by 2025 (EEA, 1999).

Global value of ecological services such as seagrasses, estuaries and coastal wetlands is estimated to be 10 times higher than that of terrestrial ecosystems (Constanza & Daly, 1998). As human population has increased in coastal areas, habitat conversion represents a major source of pressure on coastal ecosystems through an increasing demand for coastal resources (Airoldi & Beck, 2007). Human activities vary in their intensity of impact on the ecological condition of communities and in their spatial distribution across coastlines (Halpern, Selkoe, Micheli & Kappel, 2007).

Ocean-based activities extract resources, add pollutants and change species composition (Pauly et al., 2005). These changes represent potentials for disasters, as demonstrated by numerous reports of the collapse of several fisheries (Lotze et al., 2006; Jackson et al., 2001) and of the recent impacts of the 2004 Asian Tsunami and the 2005 Hurricane Katrina that were exacerbated by total losses of mangroves and wetlands (Adger, Hughes, Folke, Carpenter & Rockström, 2005). Population increase have encouraged exploitation of fisheries which changes natural marine ecosystems more rapidly and at a spatial scale larger than most human induced effects (Hilborn, & Litzinger, 2009). Almost half of the world's fish stocks are fully exploited. Another 22% overexploited fisheries which are often target apex predator (e.g., tunas, large groupers, and billfishes) for their high food and economic value (Hilborn et al., 2009). Such predators have a

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disproportionately large impact on the rest of the ecosystem because of their role as predators.

Urbanisation and Land Use Practices

Urbanisation both temporary and permanent has been going on along coastlines. As a result, there has been substantial modification of the coast with adverse effects on the quality of the environment. According to UNEP Chemicals, (2002), industrial activities are common along the Mediterranean basin for instance, and a number of highly industrialised spots are concentrated. Industrial activities in the area constitute sources of pollution through direct disposal, continental waste (UNEP Chemicals, 2002). The presence of these pollution hotspots, located mainly in semi-enclosed gulfs and bays near important harbours, big cities and industrial areas is the major problem in the Mediterranean Sea (EEA, 1999).

Studies by Thibaut (2005) on the effect of sewage outfall and pollution on macroalgae reveal the sensitivity of some brown perennial species to environmental pollution. Discharge from sewage treatment and industrial plants during several years have produced a change in the Mediterranean basin from perennial, stable benthic algae communities to a more stress-tolerant and opportunistic species (Middelboe & Sand-Jensen, 2000). The most eutrophic waters are therefore more numerous along the northern coastline such as in the Adriatic Sea (Sangiorgi & Donders, 2004). Here red tides, massive diatom, and dinoflagellate blooms sometimes associated with toxicity episodes, are well known along the north western Adriatic coast (Sangiorgi & Donders, 2004). Areas

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such as the Nile Delta are also eutrophic (Nixon,et. al., 2003). This problem has been increasing gradually over the last 2 to 3 decades, so much so that the regions of high algal pigment concentrations characteristic of eutrophic waters are clearly visible in satellite images.

Usage of Coastal Lagoons by Man

Veloso-Gomes and Taveira-Pinto (2002) have advised that since leisure and tourist development are in a phase of rapid growth, it is, necessary to reduce the seasonal fluxes and fixation of tourists on the coast so as to protect the natural values and avoid making regional imbalances worse. This according to the authors should not be associated with degradation of the quality of life as through chaotic traffic, pollution, destruction of biotopes, the disturbance of local communities, loss of landscape, property speculation, excessive land occupation and overuse of urban infrastructure, etc. The authors caution that while mass tourism includes bathing and beach recreation in a hectic atmosphere and a transformed landscape, patrons should recognise the right of many other people to enjoy the season in a calm atmosphere in an unchanged landscape; coastal zones classified as being of natural, scenic or historic interest should not suffer pressures that are incompatible with their status.

At present, tourism assumes relevant importance at the local, regional and national levels; but it has however had an extremely negative impact on coastal environment (Veloso-Gomes, 1997). Fortunately, developers of tourist facilities are starting to understand that quality-demanding customers do not return to facilities sited in degraded areas. The existence of unique and beautiful coastal,

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(estuarine and lagoon) landscapes can mean a big tourist attraction, but this attraction will disappear if the landscapes are not preserved. It is not possible to merely restrict and prohibit. It is necessary to selectively improve the points of access to beaches (Veloso- Gomes & Taveira-Pinto 2002).

Gas Emission into Coastal Lagoons

Methanogenes in the polluted lagoons have been found to be almost entirely governed by the magnitude of human perturbation (Suthers & Rissik, 2009). Erratic dumping of domestic sewage and industrial effluents into coastal ecosystems has caused brief periods of enhanced CH_4 emission (Ramesh, Purvaja, Parashar, Gupta & Mitra, 1997).The results obtained in the study by (Ramesh, Purvaja, Parashar, Gupta & Mitra, 1997) show a two-fold differences in annual CH_4 emission between the unpolluted and polluted coastal wetlands. The results suggest that anthropogenic additions of organic matter, in addition to increasing temperatures, can cause rapid formation of CH_4 in tropical coastal lagoons. Suthers and Rissik (2009) assert that the most critical nutrient for phytoplankton is nitrogen in the form of ammonium (NH4+), nitrite (NO2-) and phosphate (PO4-). Nitrogen tends to be the limiting nutrients in marine ecosystems, while phosphate is the limiting nutrient in the freshwater systems (Suthers & Rissik, 2009).

Management of Coastal Lagoons: A Theoretical Perspective

This section describes the theoretical perspective on coastal lagoon management along the world's coastal zone. Coastal lagoon management is an important issue in international debate for environmental and sustainable

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development because lagoons have become the major sites for the development of extensive and diverse economic activities. With the rapid increase in use of lagoons for fishing, aquaculture and tourism (Sousa, Garcia-Murillo, Morales & Garcia-Barron, 2009) and with the increasing urbanization of the littoral zone, local decision makers and managers are increasingly faced with pressing management issues (Conley et. al., 2009). Decision-making has therefore been complicated by the variety of parameters and end-users that need to be considered in order to achieve best lagoon management.

Ecosystem Approach to Lagoon Management

The ecosystem approach (EA) proposed under the CBD is a strategy for the integrated management of land, water and living resources. It promotes conservation and sustainable use of the environment in an equitable way (Christensen et al., 1996; Smith & Maltby, 2003). Progressive concepts of "ecosystem-based management" emphasise four common principles which state that effective management must: (1) be integrated among components of ecosystem, resource uses, and users, (2) lead to sustainable outcomes, (3) take precaution while avoiding deleterious activities, and (4) be adaptive in seeking more effective approaches based on experiences (Day & Yáñez-Arancibia, 2008; Boesch, 2006).

The ecosystem approach is "a comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of ecosystems, thereby achieving sustainable use

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of ecosystem goods and services and maintenance of ecosystem integrity"(Day & Yáñez-Arancibia, 2008).

Ecosystem management encourages community involvement in the effective management of species and habitats (UNEP, 2009). Ecosystem Management (EM) emphasises ecological interactions within an ecosystem, rather than human activities, and implies that it is possible to understand, control and manage entire ecosystems (Kappel, Martone & Duffy, 2006; Brodziak & Link, 2002). On the other hand, Ecosystem-Based Management (EBM) is an integrated, science-based approach to the management of natural resources that aims to sustain the health, resilience and diversity of ecosystems while allowing for sustainable use by humans of the goods and services they provide(Kappel, Martone & Duffy, 2006). The ecosystem approach has two main dimensions, vertical within a sector, (e.g., forestry or fisheries) and horizontal, (i.e., cross sectoral/integrated management). A goal of EBM includes learning how these biophysical and socio-economic spheres interact.

EMB includes the understanding of the linkages of activities between social and ecological components of the ecosystem by using institutional and scientific ways of managing multiple human activities within entire ecosystems (Kappel, et. al, 2006). Though human values are recognised, the model does not put much emphasis on local residents and hence in most cases, the purpose of which it is introduced, to resolve, are not achieved. As shown in Figure 2, the ecosystem and its components are indicated. Figure 2 shows that the components of the ecosystem are biotic and abiotic in nature and there is interaction among

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and between these components in the ecosystem. Other factors such as values, market, climate, policy and other activities are discussed. The interrelationships among the variables are also evaluated. The linkage is shown by the role of institutions that provide conventions, regulations, financing and organisational processes. The policies promulgated by institutions ensure the management and development of coastal zones which in effect protect or restore a degraded coastal lagoon. Similarly, market forces in the form of supply and demand affect the conditions in the coastal zone due to the competition for coastal resources. The interaction between the ecosystem components determines the survival of the habitat as indicated in Figure 2. There are other human activities such as sewage disposal, fishing and sand winning that affect the quality of the lagoons.

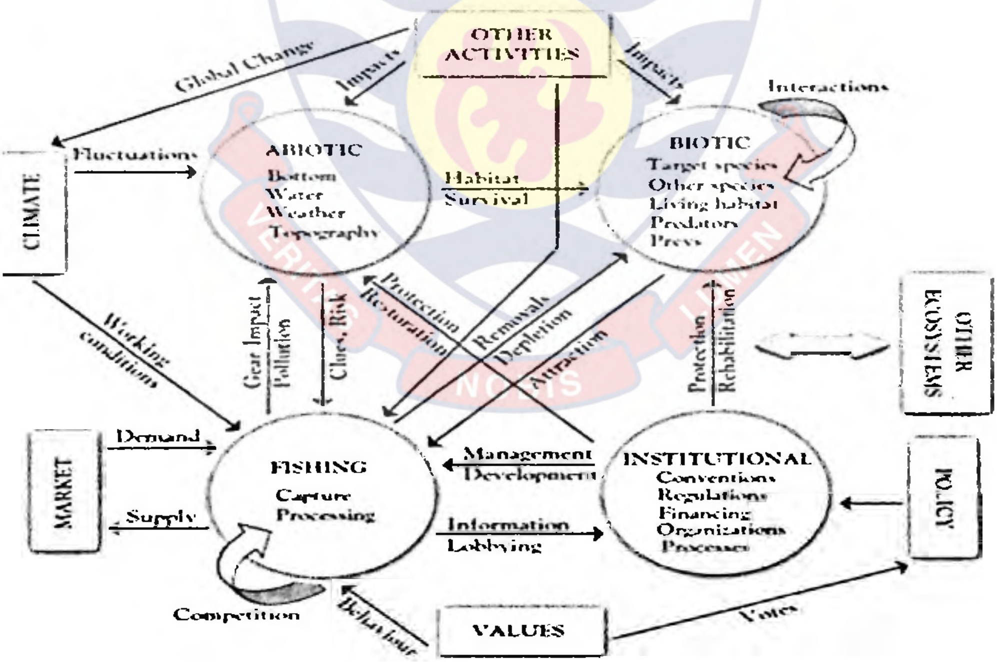

Figure 2: Ecosystem and Components

Source: Garcia, Zerbi, Aliaume, Do Chi & Lasserre, (2003)

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The Driver-Pressure-State-Impact-Response Framework (DPSIR)

DPSIR was first developed for environmental reporting by the OECD (2002) and it was further developed and adapted to the context of coastal management by Turner *et al.*, (1998). This scheme uses indicators to represent the elements of the chain, thus simplifying the information which is conveyed to broad groups of stakeholders and the general public in short, clear messages, thus enhancing the transparency of decision-making (OECD, 2002). Arthurton, Kremer, Odada, Salomons and Marshall-Crosslandet (2002) used the Driver-Pressure-State-Impact-Response framework to illustrate the linkage between the dual drivers/pressures of deforestation and cultivation and their impact on the coast. Figure 3showsthe root of environmental change are economic drivers, e.g. intensification of agriculture, shellfish farming and industrial activities, urbanisation and tourism development. In turn, drivers will generate pressures, e.g. land conversion and reclamation, nutrient emissions, waste disposal, dredging, etc. These pressures, along with other factors such as climate change, will alter the state of the environment. For example, changes in nutrient concentration will lead to increased risks of eutrophication and, subsequently, oxygen deficit and anoxia will cause loss of habitats and species diversity. Such environmental changes will in turn have an impact on human activities and welfare, for example through losses of aquaculture productivity or health impacts on coastal populations.

The effects of these impacts have to be measured using environmental economics instruments in terms of costs and benefits to society. Furthermore,

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suitable measures should be taken in order to manage for reducing pressures, to ameliorate the environmental state and hence to reduce impacts on human populations and activities. Predicting how future socio-economic changes in coastal lagoons might affect water quality, requires in the first place the ability to describe the present state of the whole system (lagoon), and the impacts of past and current socio-economic drivers and pressures on water quality and aquatic ecosystem features. Once the link between drivers, pressures and impacts is understood, policy responses may be formulated to reduce the pressures created by certain drivers and the impacts of certain pressures on water quality and ecosystem structure. However, policy implementations will certainly have wider implications that have to be assessed using future events.

Although the DPSIR framework is considered (Svarstad, Petersen, Rothman, Siepel & Watzold, 2008) suggested that DPSIR has shortcomings in its function as a neutral tool and is biased since it was designed to establish proper communication between researchers and stakeholders/policy makers with the need to research into effective incorporation of the social and economic concerns of all stakeholders

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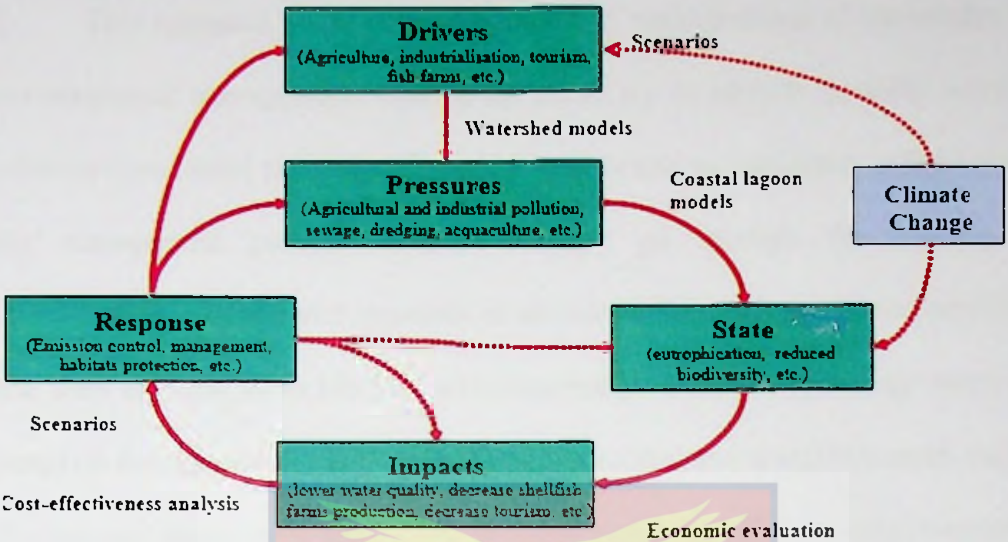

Figure 3: DPSIR Scheme Implemented in Coastal Zone

Arthurton, et al. (2002)

Integrated Environmental Management

The integrated approach to environmental management (IEM) is one of several area-based approaches to environmental management. IEM is based on the concept that environmental units at any scale or level need to be managed in an integrated manner through collaboration and participation of sectors, actors and institutions (Margerum, 2002). The idea is strong interaction between different actors and their participation that helps to build trust and mutual understanding needed to solve environmental problems. Figure 4 shows the linkage between the various stakeholders and their roles in coastal zone management. The stakeholders are the NGO's, government organisations, private sector, community based organisations and religious organisation. The integrated manner in which they are coordinated is shown in Figure 4.

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This approach helps in the generation of various forms of knowledge on environmental management. That is, all actors try to identify possible ways to solve environmental problems. The actors collaborate or participate effectively in the management process. Actors normally go through the process of identification, analysis and appraisal of all relevant natural and human activities and their interactions to identify environmental problems. They design solutions based on the current and future state of environmental and social resources, taking into account appreciable spatial and temporal scales for effective implementation of the solution and its monitoring and evaluation. By so doing integrated environmental management considers social, economic and institutional dimensions of proposed interventions. Compared to collaborative management, integrated environmental management is more holistic in terms of issues that are covered and the actors involved in designing solutions to environmental problems. IEM considers social, economic and institutional subjects at different levels of decision-making. The following are identified as success factors for the implementation of Integrated Environmental Management (Kessler, 2003);

- Existing laws and policies should support integrated approaches with policy objectives that allow for changes and inputs from stakeholders through an interactive process;
- Stakeholders should perceive potential benefits from improved collaboration and participation in solving environmental problems. This will enable them to acquire resources or assist them to know the benefits they will get from solving environmental problems and how their decisions can influence policy;

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- There is the need for a facilitator who should be acceptable to all parties and who should also have good communication skills and a clear knowledge about the particular problem and its context;
- There should be rules, instruments and tools required for open and transparent communication, decision, education, information dissemination, public consultation and conflict resolution; and
- Logistics (financial, technical, and human) is required for process to start and support the activities that would be implemented.

Integrated environmental management is related to management by various parties and, it is applied unknowingly in most cases. For example, if different parties come together to collaborate and participate in solving an environmental problem.

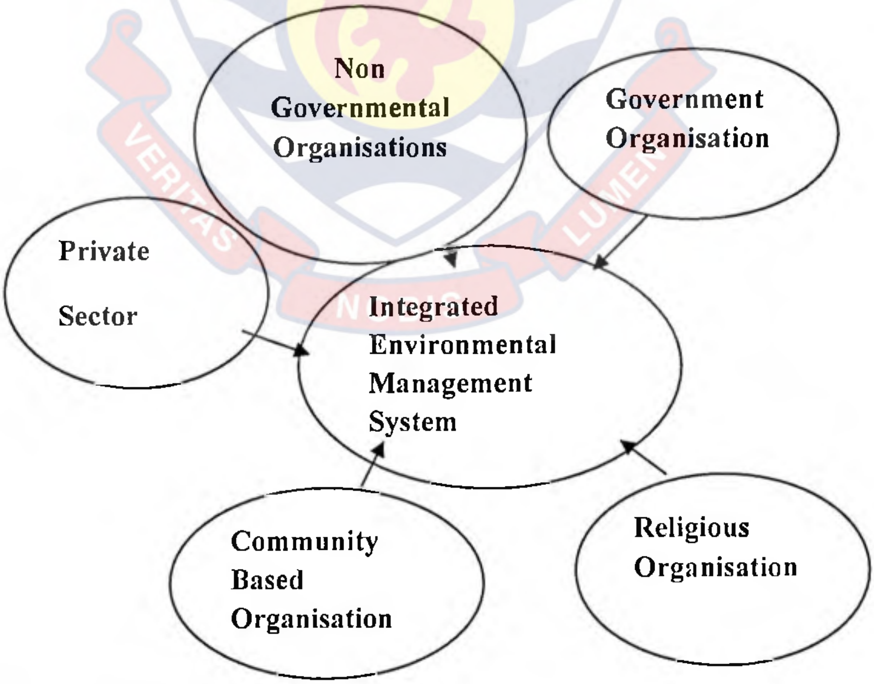

Figure 4: Integrated Environmental Management

Source: Kessler (2003)

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If, after the collaboration, it is realised that two parties can effectively solve the problem, it then becomes co-management. As such, adopting an integrated environmental management approach can lead to the identification of specific issues that can be dealt with in a co-management approach.

Integrated Coastal Zone Management

The definitions of the, integrated coastal zone management (ICM) process vary, but all fundamentally describe ICM as a process that recognizes the distinctive character and value of the coastal area (Sorensen & McCreary, 1990) and hence acknowledges the interrelationships among most coastal and ocean uses and the environments they potentially affect (GESAMP, 1996). Integrated coastal management itself is characterised by a conscious management process (Cicin-Sain & Knecht, 1998) through which rational decisions are made concerning the conservation and sustainable use of coastal and ocean resources (Krishnamurthy, Kannen, Ramanathan, Tinti, Glavovic, Green, Han & Agardy, 2008). ICM as a process is described as being continuous and dynamic and is designed to ensure that all decisions and activities related to or affecting a country's coastal area are consistent. The decisions are also supportive of agreed goals and objectives of the region and the nation at large.

Figure 5 represent the ICM framework that illustrates the relationship between the stakeholders involved in the integrated coastal zone management. The integration is in a form of stakeholder participation, legislation and technical guidelines, capacity building and stakeholder empowerment. The loop begins with the national government, to the district government and local or the coastal

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area. Information is shared among the various stakeholders and this ensures decentralisation of policies.

In a while after the initiation of the national CZM program in the United States in 1972, coastal management efforts began in a number of other countries, many of them developing nations. Often, these programs were encouraged and supported by donor organizations or donor nations in an effort to ensure that development projects reflected good coastal planning and practice. A comprehensive baseline study by Sorensen (2002) showed that in 2002 there were approximately 700 ICM initiatives (including those at the local level) in more than 90 nations around the world. Data collected by Cicin-Sain and Knecht (1998) shows a significant increase in ICM global efforts from 1993 to 2000 although there were substantial differences in the extent of ICM activity in various regions.

Stojanovic and Ballinger (2008) cite approximately 60 non-statutory coastal management initiatives established throughout the United Kingdom (U.K) at the local and regional level since the 1990s.

ICM initiatives exist in all parts of the world, at all levels of governance, in all types of political regimes, in all types of environments and at all levels of national economic development.

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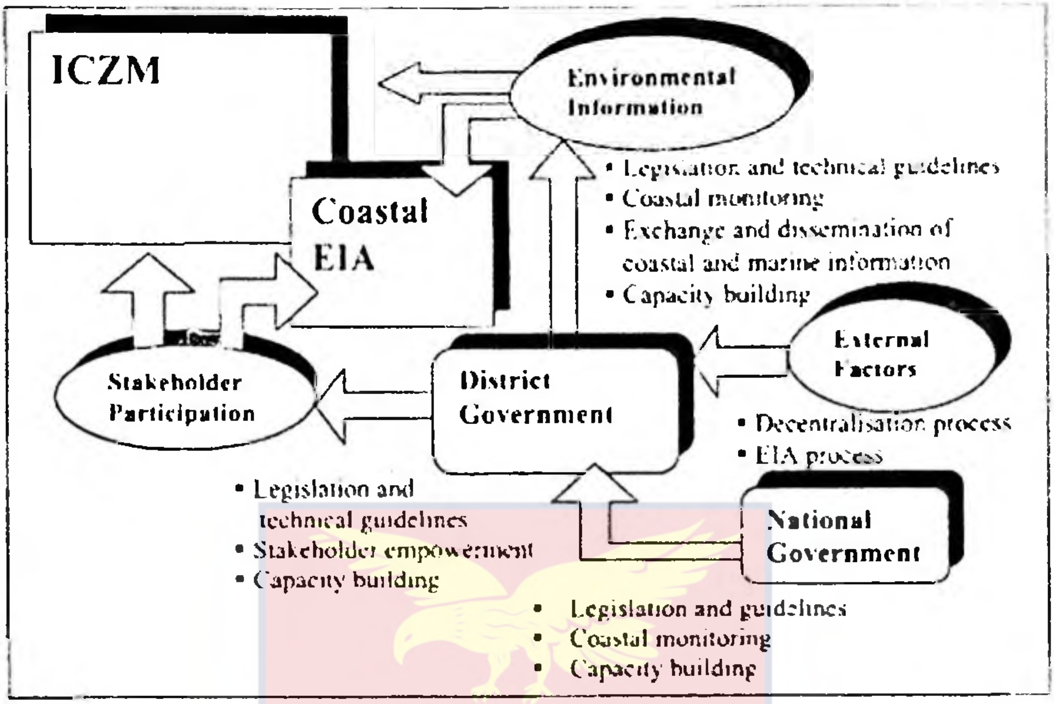

Figure 5: Integrated Coastal Zone Management

Source: Sorensen (2002)

Community-Based Management Theory

CBRM is intended as an integrated approach to area development. It is holistic in the sense that, it aim at resolving conflicts over multiple resource use and attempts to integrate socio-political and economic wellbeing with the biophysical elements of resource management. CBRM emphasizes that environmental problems have both social and technical connotations. Hence, CBRM help people to make their own rules and decisions and enforce them (La Viña, n.d). According to Hegarty (1997), much of the debate has centered on national, pan national and global perspectives. Community-based management developed independent of and even preceded governmental regulations and theory persisted even after formal regulatory norms were established. Years of

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experience in community-based resource management (CBRM) existed in most communities and were beneficial to them. The background of CBRM is traced from forestry to fisheries and shows the common reasons why such approaches are desirable. Batongbacal (1991) summarizes the community based management theory in the context of coastal resource management as follows:

- The communities' dependence on the coastal zone;
- Inadequacy of traditional systems of centralized government management;
- Greater efficiency in planning and implementation;
- Democratization of access to resources;
- More prospects of success; and
- Failure of previous cooperative activities.

CBRM is people centered approach that relies on indigenous knowledge and expertise in the development of management strategies. The aim is to ensure wise and equitable use of resources on a sustainable basis through proper exploitation and protection. It requires maximum participation of coastal communities to ensure that benefits will accrue to the majority of the people.

Community-based approaches to resource management are applicable to not only small-scale coastal resources and traditional artisanal communities, and can at the same time important role as industrialization and urbanization sets in. On the contrary, as society changes rapidly and pressures mount and become more complex, ICM becomes necessary. The community based management theory is gaining grounds because there has been growing concern by local stakeholders to be more actively and meaningfully involved in the traditional

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government decision-making processes. Charles et al. (2010) avers that traditional government initiatives entail some aspect of environmental and economic issues but generally fail to address cultural and social components which serve as the traditional knowledge of the people and hence the missing link prevails all the time.

Coastal Zone Management in Ghana

Ghana has endorsed and ratified a number of environmental related conventions that are binding (Amlalo & Ahiadeke, 2004). These conventions include:

- International Convention for the Prevention of Pollution of the sea by Oil (21st October, 1962).
- Convention on the Africa Migratory Locust (25thMay, 1962).
- Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space and Under Water (5th August, 1963).
- International Convention for the Conservation of Atlantic Tunas (4thMay, 1966).
- Africa Convention on the Conservation of Nature and Natural Resources (15thSeptember, 1968).
- International Convention on Civil Liability for Oil Pollution Damage (29thNovember, 1969).
- Convention on Wetlands of International Importance, Especially as Waterfowl Habitats (2ndFebruary, 1971).

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- Treaty on Prohibition of the Emplacement of Nuclear Weapons of Mass Destruction on the Seabed and the Ocean Floor and in the Subsoil Thereof (11th January, 1971).
- International Convention on the Establishment of an International Fund for Compensation of Oil Pollution Damage (18th December, 1971).
- Convention Concerning the Protection of World Cultural and Natural Heritage (16th November, 1972).
- Convention on International Trade on Endangered Species of Wild Fauna and Flora (3rd March, 1973).
- Convention on Military or Any other Hostile Use of Environmental Modification Techniques (10th December, 1976).
- Convention on the Conservation of Migratory Species of Wild Animals (23rd June, 1979).
- Convention for the Cooperation in the Protection and Development of Marine and Coastal Environment of the West and Central African Region, (1981) (Abidjan Convention).
- United Nation Convention on the Law of the Sea (10th December, 1982).
- Montreal Protocol on Substances that Deplete the Ozone Layer: 24th July, 1989).
- Framework Convention on Climate Change (June, 1992).
- Convention on Biological Diversity (1992).
- Ramsar Convention (1971).

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Policies on the Environment

A variety of environmental related policies exist in Ghana, however there is no specific policy on the coastal zone. The underlying factors and course of national policies on the protection, management and development of marine and coastal environment is rooted in the following three major areas: integrated coastal zone management and sustainable development; marine environmental protection, both from land-based and sea-based activities; and sustainable use and conservation of marine animals.

Figure 6 is an exposition of the lagoon management organisational model that seeks to explain the interaction among three policy guidelines on coastal zone management. It discusses anthropogenic impacts such as tourism, urbanisation, fishing on coastal resources and how these affect the ecological status of lagoons. Scientific research and monitoring is also observed; the role of scientists including the setting up of ecological indicators and ecosystem health status, are evaluated. Conservation practices are also included in the model. The model in effect is an integrated in nature and bring all stakeholders involved in coastal zone management together for effective collaboration and dialogue. The ecosystem functioning of the lagoon is most often the cardinal issue for discussions. Ecological indicators are established to evaluate and assess the water quality status of the lagoons in the catchment areas. The anthropogenic impacts on the lagoons are address at the various meetings to ensure the ecological health of the lagoons.

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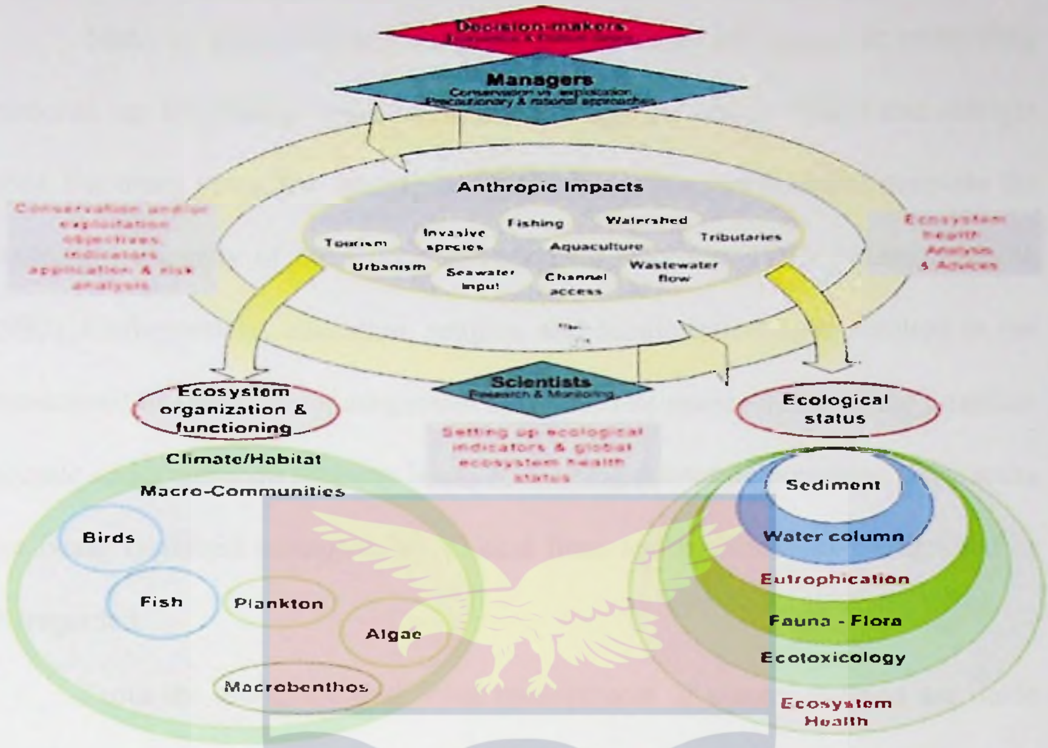

Figure 6: Scheme of the Shallow Water Lagoon Management Organizational model

Source: Patrice et al, (2011)

Traditional Management Approaches of Coastal Lagoons in Ghana

Traditionally coastal lagoon management has been vested in the owners of the lagoons. The owners are usually local clans, fetishes or stools. The organisational framework of these societies is the kinship or family systems lineages and clans. At the various levels of the framework, specific rights and obligations dealing with issues like authority, control, adjudication of conflicts, inheritance, and succession and land ownership are vested in the members. At each of the organisational levels within the framework, there is be a chief, usually hereditary in lineage who functions as the custodian of resources or caretaker.

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Many of the traditional management strategies are geared at controlling resource use by placing limits on access, through the use of taboos and outright bans. For many years, this traditional approach has been sufficient to maintain the ecological integrity of the lagoon environment (Gordon, 1992; Ntiamoa-Baidu, 1992). Unfortunately, education, religion and acculturation have resulted in the breakdown of traditional management systems. The management of the coastline operate under common property laws. With rising economic pressures, these areas are being exploited unsustainably. Local fines and punishments are ignored or disregarded.

From the above the traditional management of coastal lagoons are made up of people whose lifestyles are interlinked with the coastal wetlands and whose activities directly affect the wetland ecosystem. Protection of the wetlands should therefore be for the people and not against them. Every effort has been made to secure the people's participation and involvement and to integrate their needs with the management processes. Apart from the general community, groups whose involvement was to be specifically sought included the traditional administrators (Chiefs, elders, etc.), the town development committees, local political groups such as District Assemblies and NGOs such as the 31st December Women's Movement.

Systems Theory in Geomorphology

Significant advances have been made towards the understanding of the dynamics of geomorphic systems through the development of concepts. During the past decade several attempts have been made, notably by Strahler (1952a),

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Culling (1957), Hack (1960) and by Hack& Goodlett (1960), to apply general systems theory to the study of geomorphology. The intent of this was to examine in detail the fundamental basis of the subject, its aims and its methods. Hall and Fagan (1956, p. 18) have defined a system “as a set of objects together with relationships between the objects and between their attributes." In the light of this definition, it is very significant that one of the fundamental purposes of (Davis'& Hayes, 1984) approach to landform development was to study them as an assemblage, in which various parts of the landform might be related in an aerial and a time sense, such that different systems might be compared, and the same system followed through its sequence of time changes.

Von Bertalanffy (1960) categorised systems into two types; the closed system and the open system. Closed systems are those which possess clearly defined closed boundaries, across which no import or export of materials or energy can take place (Von Bertalanffy, 1960). One of the characteristic of closed systems is that, with a given amount of initial free, or potential, energy within the system, they develop toward states of maximum"entropy" (Von Bertalanffy, 1960). Entropy is an expression for the degree to which energy has become unable to perform work. The increase of entropy implies a trend toward minimum free energy (Von Bertalanffy, 1960, p. 3). Also, in closed systems there is the inherent characteristic thatare sufficient to determine its ultimate equilibrium condition. This inevitability of closed-system thinking is very much associated with the view of geomorphic change held by (Davis & Hayes, 1984).

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Open systems contrast quite strikingly with closed systems. An open system needs an energy supply for its maintenance and preservation (Reiner & Spiegelman, 1945), and is in effect maintained by constant supply and removal of material and energy (Von Bertalanffy, 1960).

In the same way direct analogies exist between classic open systems and drainage basins, slope elements, stream segments and all the other form of assemblages of a landscape. An open system manifests one important property which is denied to the closed system. It may attain a "steady state" (Von Bertalanffy, 1960), wherein the import and export of energy and material are equated by means of an adjustment of the form, or geometry, of the system itself. Open systems allow more substantial changes of form with time, so as to include the possibility of no significant or non-progressive changes of certain aspects of landscape form through time.

Finally in as much as geomorphic systems exchange mass and energy with the surrounding, they are considered open systems (Chorley, 1962). Based on these characteristics of an open system, the present study is theoretically grounded in the open system because lagoons need energy supply for their maintenance and preservation. The Fosu and Essei Lagoons receive from the upstream wastes carried from heavily polluted catchments and freshwaters rich in organic and mineral nutrients. Hence when the inflow is increased, water level in the lagoons also rises, the head of water above the outflow increases, and the outflow discharge also increases until it balances the increased inflow. Changes in the

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supply of mass and energy from the outside lead to self-adjustment of the system to accommodate the changes for the lagoon to be become steady.

Conceptual Framework for the Study

Figure 7 shows the principal components involved in coastal morphodynamics. It shows an integrated causes and effect type of synergy that exist between processes forms and their effects on coastal lagoons. Land-ocean interaction can be considered in terms of flow of water and/or sediment from a river basin, through an estuary, to the coast and near-shore zone. It may be dispersed across a wider area of the inner and outer continental shelf to the shelf edge and deep ocean. In many circumstances, there may be important return flows of water and sediment from the continental shelf to the coastal zone and into estuaries (Pye & Blott, 2009). The figure explains by discussing the linkages between the various processes. It is explained in this form: the environmental context is on the influence of background geological factors that affect coastal lagoons (tectonic movements, geological structure, lithology and relief framework), climatic factors and oceanographic factors, which in this case are related to temperature, precipitation, humidity. These, in turn, affect coastal processes such as patterns of sediment erosion, transportation and deposition, and ultimately coastal morphology.

Anthropogenic activities play significant role in the changes that occur in most coastal lagoons and other coastal environments. Human activities such as excessive fishing, deposition of waste, excessive extraction of water, bottom destruction by dredging, result in pressure on marine ecosystems. In a sense, these

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activities impose pressure on lagoons. Another important subject worth discussing is the coastal morphology. In this case, the impacts of both anthropogenic and climatic factors on coastal resources are necessary to be mentioned and recognised. Sea level rise will have notable impacts on the behaviour of coastal lagoon entrances, which will potentially affect the fundamental structure of the lagoon ecosystem (Rahmstorf, 2007).

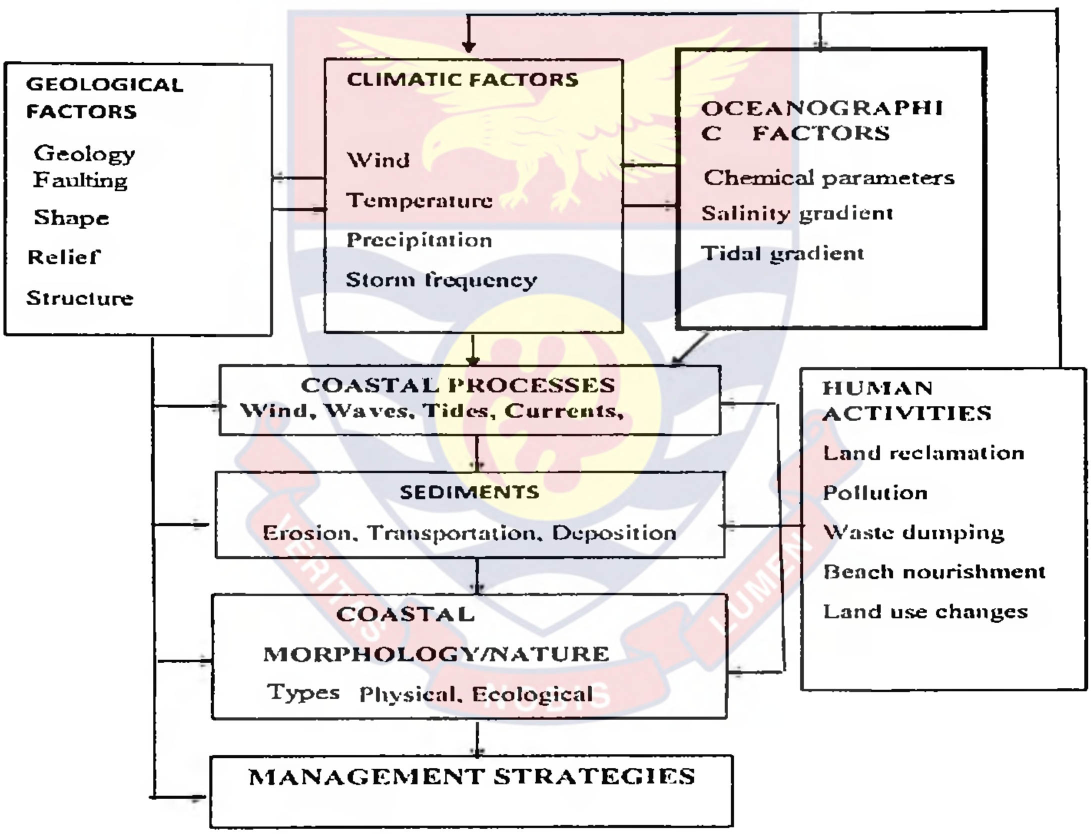

Figure 7: Principal Components Involved in Coastal Morphodynamics

Source: Adapted from Pye and Blott, (2009)

This means that the effects of the natural and anthropogenic processes will have an adverse impact on coastal lagoons. As a result of these changes, there is a need for the development and implementation of coastal management plans and

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strategies. The presence of feedbacks going from the responses to the other steps of conceptualisation highlights that the management of marine ecosystems is necessarily an adaptive process, where efficient solutions must be iteratively searched for.

It is as a result of these contrasting issues that policy makers must solve, the inherent variability of ecosystem dynamics and the incomplete empirical and theoretical knowledge we have about the functioning of marine ecosystems. Again, a lot of missing links persist in the overall management and monitoring of coastal lagoons in Ghana. The missing link is as a result of the problem with ownership regime as the communities surrounding most of the lagoons seem to claim possession of the resource as a common property and the perceived vital role played by governments and their traditional top-down approach to the management of these coastal resources. This has necessitated the review of a number of coastal management strategies and plans in order to formulate or propose a model or strategy for coastal lagoon's management.

Summary

This chapter concerned the review of related literature on the changing dynamics of coastal lagoons which is the main thrust of this study. The review was devoted to the factors causing the changing physical features of coastal lagoons around the world in terms of the physical and the ecological characteristics. The chapter also highlighted the effects of climate change and the anthropogenic impacts on coastal lagoons. It became clear that climate change and the activities of man have significantly contributed to the changes taking

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place in the environments of most lagoons in the world. It also described the management options available for coastal lagoons management. An attempt was made to review numerous coastal zone management approaches and plans employed in the management of coastal resources in both onshore and offshore worldwide. It is expected that the review will help streamline the possibility of selecting the appropriate coastal lagoon management system to ensure the sustainability of coastal lagoons in Ghana. It is clear from the review that, though Ghana has ratified most of the conventions on coastal zone management, the government and community members as well as community-based organisations and other non-governmental organisations are still grappling with lack of commitment in championing the crusade for the better management of water resources.

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CHAPTER THREE

RESEARCH METHODS

Introduction

This chapter describes the methods adopted for the research. Topics covered are the study area, the study design, sampling techniques, the research instrument, data processing and analysis, and the ethical issues involved. Others include the challenges and lessons learnt during data collection process.

Study Area

Ghana lies between longitudes 3° 15' W and 1° 12' E, and latitudes 4° 44'and 11° 15' N (Fig. 8a). The total land area of Ghana is 238,533 km^2 with a coastline of 550km^2. Ghana's coast is mainly high-energy type and has some lowlands, which are prone to flooding (Boateng, 2009). The country is bordered on the east by the Republic of Togo, the west by Cote d'Ivoire, the north by Burkina Faso and the south by the Gulf of Guinea. In addition to country's total land area is an Exclusive Economic Zone (EEZ) of 110,000 km^2 of the sea. About 7% of the land area is home to 25% of the nation's total population of about 24 million (Ghana Statistical Service, 2010) and a place where about 70% of its industries and businesses are located (Armah & Amlalo, 1998).

The country has the tropical humid climatic conditions, and it experiences two major seasons, that are the rainy season and the dry season.

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Geomorphological Setting of the Study Areas

The coast of Ghana has been divided into three, based on geomorphologic characteristics (Dickson & Benneh 1995; Boateng 2009). They are the Eastern, Central and Western coasts (Figure 8a). The central coastline which has the Fosu and Essei Lagoons extends from the Laloi lagoon near Prampram to Ankobra in the Western Region of Ghana. The study areas selected are the Fosu and Essei Lagoons (Figs. 8b and 8c).

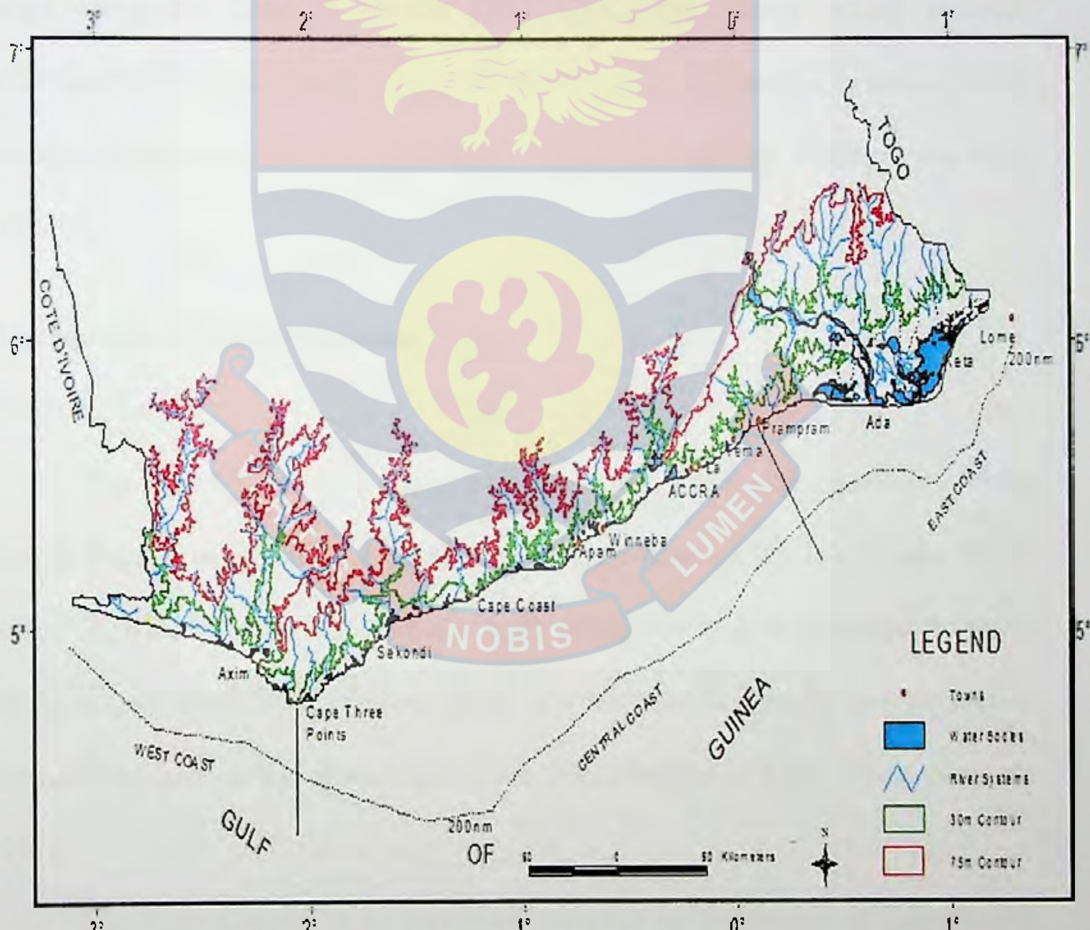

Figure 8a: The Coastal Zone, after Ly (1980)

Sources: (Boateng, 2009; Dickson and Benneh, 1995)

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Climate of the Study Areas

The climate along the coast is described as tropical with significant variation in spatial distribution in precipitation (EPA, 2000). Mean annual rainfall is highest in the coastal west (2083 mm) and lowest in the east. Areas around Keta in the eastern portion receive a mean annual rainfall of about 774mm. Rainfall variability is also lowest in the west (about 26%) and highest in the central portion (40%), and 30% in the east. The mean annual temperature range along the coast is narrow (26°C–28°C) but shows strong seasonal differences (21°C –22°C in August and 24 °C –28 °C in April). The mean annual evapotranspiration rate is low in southern Ghana (80mm) and higher in the north (190mm).

Description of the Selected Study Sites

The Fosu Lagoon

The Fosu Lagoon (Fig.8b) is located in Cape Coast, the capital city of the Central Region of Ghana. The geographical coordinates of the lagoon are 5 °7'N and 1 °16'W. The lagoon is a shallow body of water which is separated from the sea by a sand bar (closed lagoon) which is sometimes broken by heavy rains or manually as part of the rituals during the Fetu Festival in Cape Coast (Armah, 1991).

The Fosu Lagoon is an important resource to the people of Cape Coast because it provides both economic and cultural benefits. The amount of fish that live in the lagoon provides fishermen with some income and the people with protein. The mechanic shops along the lagoon are also used by the artisans as

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their livelihood. The lagoon also forms part of the Fetu festival celebrated by the people of Cape Coast. Two months to the commencement of the festival, all fishing activities in the lagoon are banned and, just before the festival is started, the ban is lifted after which the first fishing net is cast by the paramount chief to mark the beginning of the festival. Apart from these, the lagoon also serves as a tourist attraction which benefits the country as a whole (Armah, 1991).

Armah (1991) observed that, physiochemical and bacteriological parameters of the lagoon were highly above the World Health Organizations (WHO) guidelines for swimming and fishing. Also the total coliforms recorded from the samples showed that the lagoon also contained a high amount of faecal matter. The EPA, in an attempt to salvage the lagoon, advised that portions of the sand bar that separates the lagoon from the sea should be breached to allow the sea to flow into the lagoon and dilute the lagoon water. However, this exercise was highly criticized by the fishermen who claimed that the sea water would kill the fishes in the lagoon and also cause the lagoon to dry up. The Fosu Lagoon is a source of livelihood for some indigenes of Cape Coast and hence, has been subjected to various forms of degradation resulting in the need to restore it. According to the Cape Coast Metropolitan Information Office, the dredging of the lagoon was in the pipeline with sponsorship from Bonn, Germany. He noted, part of a five hundred thousand Euro (€ 500, 000) grant from Bonn will be used for the dredging project.

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Figure 8b: Map of Fosu Lagoon

Source: Field Data (2014)

The Essei Lagoon

The Essei Lagoon maintains a permanent opening into the sea as a result of human interference and that makes it a man-made open lagoon. The geographical coordinates of the lagoon are 4^0 54'N and 1^0 44'W as shown in (Fig. 8c). The lagoon is located in Sekondi in the Western Region of Ghana and is bordered to the north by the Secondi Takoradi Metropolitan Assembly (STMA) road, east by the Bakaakyir road and west by the Bakaano road. The wetland occurring around the lagoon areas is described as low-lying. Fishing in the lagoon is carried out by about twenty resident fishermen; hence no effective fishing activity takes place within the lagoon (Aheto et.al, 2010).

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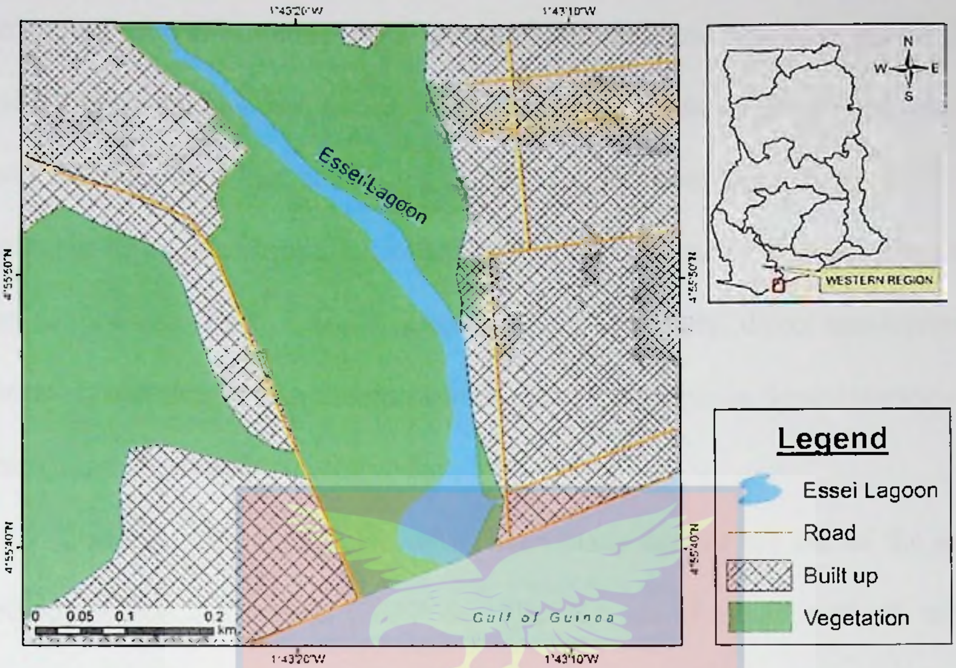

Figure 8c: Map of Essei Lagoon

Source: Field Data (2014)

In addition, salt (sodium chloride) deposits of limestone, silica, gypsum, feldspar and other minerals have been identified within the study area. The Takoradi harbour, which is closer to the study area, handles most of Ghana's imports and exports (GSS, 2010).

Research Design

This thesis employs the exploratory study design. The mixed method approach that involves both qualitative and quantitative methods was used to collect data. According to Tashakkori and Teddie (2003) and Creswell (2003), the mixed method approach has assumed an increasing popularity as a legitimate research design. Mertens (2003) and Punch (1998) stated that the mixed method helps in having a better understanding of the research problem because it covers

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converging numeric trends from quantitative data and specific details from qualitative data. Neuman (2003) recommended the use of the mixed methods when he contended that combining different approaches in a study is the best method to be adopted because it is better to look at a situation from several angles than to look at it from a single perspective. In this study, direct measurements, laboratory analysis of water samples from the two lagoons, in-depth interview and observation were used to generate data from the field.

Some criticisms have, however, been made against the use of the mixed methods approach. Creswell (2003) describes the use of mixed methods as time consuming, while Sarantakos (2005) opined that the mixed method approach is difficult to replicate, and hence advised that any single method produces more suitable, useful and meaningful answers to questions.

Notwithstanding the above criticism, several authors support the use of the mixed method because it offers many advantages which outweigh the disadvantages. Decrop (1999) for example, has observe that the method opens the way for richer and potentially more valid interpretations of observations. Moreover, it helps the researcher to gain better understanding of the phenomenon being studied. Furthermore it complements the strength of qualitative and quantitative methods. Depoy and Gitlin (2005) and Henderson (1991), similarly argued that the mixed method approach helps to reduce bias, because it enables researchers to "guard against the accusation that a study's finding are simply the artefact of a single method and a distinct data source" (p.12).

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Data and Sources

The study involved field-work, observation, remote sensing and Geographic Information System (GIS) application, and interviews. The thesis made use of primary and secondary set data sources. Secondary data were obtained from books, journals, reports and documentary.

Primary data, was sourced from relevant agencies and institutions such as the Water Research Institute (WRI) of the Centre for Scientific and Industrial Research (CSIR) Accra, Ghana, the Meteorological Service Agency Accra, Ghana; Department of Geography and Regional Planning, University of Cape Coast (UCC), Department of Fisheries and Aquatic Sciences, University of Cape Coast (UCC), Traditional Council (Cape Coast and Sekondi-Takoradi), the Environmental Protection Agency(Cape Coast), Friends of Nation Sekondi-Takoradi), and Fishing Communities in Cape Coast and Sekondi. The secondary data were Landsat TM images, aerial photograph, geological, rainfall and temperature data. Landsat images were sourced from Earthexplorer which has a data depository of satellite images of United States Geological Survey (USGS) of Ghana. The 1973 topographical map served as the base year map and the 1996 and 2005 aerial photos were sourced, while the 2014 image was a Landsat TM. Downloaded images went through spatial and spectral processing before they were classified to generate the land- use- maps for analysis.

Aerial photograph, topological maps and hydrological data were sourced from the Ghana Survey Department in Accra. Lagoon extent and other adjoining estuaries were digitized from the topographic sheets after they had been scanned

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and georeferenced in ArcMap 10.0 software. Also these same information were captured from the aerial photo which is a 2005 photo and land use map.

Information on the underlying geology of the lagoons was sourced from the Ghana Geological Survey Department. Field observation of land use and cover were undertaken to validate the classified satellite image and aerial photograph. Lagoonal processes of the study sites were observed and documented by the researcher. Data were collected from the Department of Oceanography and Fisheries, University of Ghana, based on the available geographic datasets and projects conducted on coastal zones of Ghana. The Geographic Information System (GIS) data collected from the various agencies went through data interoperability, thus, converted from their respective geographic data formats into a single Esri Geographic database.

Water temperature, salinity and the pH of the two lagoons and in their entrance channels were recorded and analysed to assess the water quality of the lagoons on regular basis throughout the period of the study. The location of the entry channels and water sampling sites were mapped directly from the field surveys using GPS. A Global Positioning Systems (GPS) receiver, Trimble Juno SD was used for taking sample coordinate points for mapping purposes.

Justification for Sampling Locations and Protocols

The coastal zone of Ghana which is 540km has been divided into three based on geomorphological characteristics (Boateng, 2006; Dickson and Benneh, 1995; and Ly, 1980).The three zones are the western, eastern and central zones (Figure, 8a). Purposive sampling technique was used to select the two lagoons

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within the central coastline. The selected study sites are shown on Figure (8b and 8c). Samples were collected from eighteen (18) different points in the wet and dry seasons in the Fosu lagoon, and six (6) sample locations for each season in the Essei Lagoon. Wet season samples were collected in the month of June, 2014 and that of the dry season were collected in January, 2015.

The reason for the wet and dry season data collections was to analyse the short-term and episodic changes in the lagoons as was espoused by (Gibeaut, Hepner, Waldinger, Andrews, Guiterrez, Tremblay & Smyth, 2001). This is because in the rainy season there is high tide while low tides occur during the dry season. Apart from that, climatic differentiation occurs during the various seasons and therefore account for the differences that exist among the seasons. A map showing sampling points are represented in (Fig. 8c for Essei and 8b for Fosu lagoons). The choice of sampling points for the Fosu Lagoon was influenced by the following protocols and reasons. The Fosu Lagoon is circular in shape, whilst the Essei Lagoon is linear and elongated. The Fosu and the Essei Lagoons are fed by stream from different angles and hence required that samples are taken from different points to ensure uniformity.

Sampling points located at the area where the lagoon enters the sea is called Bakaano. The point located in the middle part of the lagoon just behind the Cape Coast stadium at an area called Siwdu, and finally points located at the portion of the lagoon which is just behind the garages close to Adisadel village. In the case of the Essei Lagoon, the curvilinear nature of the lagoon and the problem of accessibility to the lagoon influenced the selection of the sample

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points for water quality analysis. In all these cases the use of GPS in picking the sample points in the wet and dry seasons ensured that data were collected at the same area in the lagoon. In order words, the samples for the dry season were collected from the same points as was collected in the wet season. This is shown on Figures 8b and 8c, with red points indicating the sampling points.

Sampling Procedure

The purposive sampling technique was used to select the ideal sites for the water sample collection which was based on the interest of the researcher and on background knowledge from literature; hence no sampling frame was needed. The sampling method was purely for convenience and did not demand proportionate representation (of samples). It allowed observation and measurement of cases in any unit of analysis that was judged important in the study (Shaw & Wheeler, 1985). Regardless of its advantages, purposive sampling techniques made generalisation from selected sampled sites problematic (de Vaus, 1993). The sampling method was used to ensure that maximum attention is paid to the selected sites. The problem of accessibility required a purposive sampling technique. The main goal of purposive sampling is to focus on particular characteristics of a population that are of interest, which will best enable one to answer the research questions. The sample being studied is not representative of the population, but for researchers pursuing qualitative or mixed methods research designs, this is not considered to be a weakness. Alternatively, purposive sampling method proved to be effective when only limited numbers of people can

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serve as primary data sources due to the nature of research design and aims and objectives.

Figure 9: Essei Lagoon Sampling Points

Source: Field Data (2014-2015)

Water Sampling

Polyethylene gloves were used on the hand during the collection of water samples from the lagoons. One litre polyethylene bottles were washed with 5% nitric acid (distilled) water and then dried in an oven before being used for the collection of the water samples. At each sampling point, the bottles were rinsed three times with the lagoon water before collection of the sample. Each bottle was

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immersed to about 8 cm below the water surface. The collected water samples were acidified before being transported to the laboratory for analysis. The physico-chemical parameters sampled were made up of salinity, dissolved oxygen (DO), pH, electrical conductivity; temperature and (TDO) were measured with a Multi-Parameter in-situ Water Quality Checker. The collected water samples were sent to the Water Research Institute (WRI) of the Centre for Scientific and Industrial Research (CSIR) in Accra, Ghana to evaluate the metal content in the water for interpretation and analysis. The samples were taken from the surface, at the middle point and finally at the bottom of the lagoons using the gauge sticks.

Social Survey

The subject matter of the study is purely natural and as such onsite information was needed. Personal interviews and case histories were used to supplement onsite information. This personal interview and case histories were used to solicit for information on human activities that affect the Fosu and Essei Lagoons. Purposive sampling technique was used to select 15 stakeholders who had knowledge on the Fosu and Essei Lagoons as shown in Table 1. They were purposively selected since they were in the position to give information about the challenges and management practices on the lagoons Table 1 shows the various stakeholders involved in the lagoon managements.

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Table 1: Stakeholders Involved in the Management of Fosu and Essei Lagoons

Stakeholders	Sample
Environmental Protection Agency	4
Traditional Council	2
Forestry Commission	2
District Assembly	2
Fisher folks	2
Non-Governmental Organisations	2
Coastal Zone Researcher	1
Total	15

Source: Field Data, (2015)

Figure 10: Water and Heavy Metals Sampling Points on the Fosu Lagoon

Source: Field Data (2014-2015)

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Table 2: Nature/Types of Selected Lagoons

Name of Lagoon	Zone	Type/Nature
Essei	Central	Open
Fosu	Central	Closed

Source: Author's Construct (2014)

Data Collection Instruments

In-depth interview guide (IDG) was used to solicit information from 15 key informants or stakeholders. This was for the purpose of understanding the local, technical and expert knowledge on available management options and practices within each of the coastal lagoons selected for the study. This later help in developing an integrated and acceptable coastal zone management plan for the whole coastal zone of Ghana. The interview guide concentrated on the following topics: traditional management approaches, the ecosystem approach to coastal zone management, the driver-pressure-state-impact-response framework, integrated environmental management, integrated coastal zone management, spatial planning, and marine and coastal nature protection framework. As such, the instruments for the data on the management of coastal lagoons were purely interviews which solicited for stakeholder's knowledge. On the other hand, the instruments used for non-human survey were the Global Positioning System (GPS), digital camera, tape measure, and a Multiple-Parameter in-situ water quality checker.

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Training of Research Assistant and Fieldwork

A total of 6 field assistants were involved in a three-day survey training that took place from 10th to13thMay, 2014. All participants were trained in interviewing techniques and the translation of the contents of the interview guide into local language (Fante), the use of GPS and the Multi-Parameter In-situ Water Quality Checker. The procedure for selection of the field assistants was in the form of class presentation and mock interviews using classmates. Four participants were finally selected to constitute a team for the data collection. The selection was based on in-class participation, performance in the field practices and fluency in the local language. The field assistants were taken through in the use of the GPS to assist in the sampling of water. Data collection at the study area was conducted for one year so as to understand and validate the seasonal changes occurring in the lagoons. The data collection spanned from June 2014 to March 2015.

Data Collection Procedures

Data was collected through an in-depth interview with the stakeholders who were involved in the environmental management. The acquisition of available databases on the selected sites was also done through field measurements with stick or gauge measurement using an outboard motor. In the case of the Fosu lagoon, the stick gauge was calibrated with tape measure in order to provide accurate data. In the case of Essei Lagoon the researcher traversed and walked around the lagoon with a graduated sticks taking the sample and

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conducting the measurements. The factors causing the dynamic changing physical features of the lagoons were derived based on some driving forces analysis techniques including literature review, formal and informal interviews, observation and analysis of land use patterns.

The driver pressure state impact response (DPSIR) technique was applied by first assessing the changes that occurred at the study area during the data collection period using quantitative and spatial techniques such as the application of remote sensing and GIS (Yiran, Kusimi & Kufogbe, 2011). Secondly, preliminary identification of driving forces by researcher form the stakeholders was done using interview guide. Interviews schedules were conducted for the stakeholders such as traditional council members, academics, NGO's, a local conservationist group (Friends of the Nation) and EPA staffs. Data on the various physico-chemical parameters were collected in both the wet and dry seasons of 2014 to 2015 to establish the changing seasonal character of the Fosu and the Essei Lagoons.

Data Processing and Analysis

The study employed visual image interpretation to extract information from the images. This method was employed due to the limitation of the data to provide information in other spectral wavelength outside the visible range. The image interpretation method was based on relating colours and patterns to real world features (Kusimi, 2015). It was used to determine the current area extent of the lagoons, and to establish the changes that had occurred. The GIS software was used to present site-specific geomorphological analysis on the two lagoons; this

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helped to determine the nature and extent of the lagoons. Land-use land-cover (LULC) analyses were done for the study areas. The analyses were done for the period between 1973-2014 using the 1973 (topographical map) as a base year (map). The method adopted consisted of three phases. Phase one was for the acquisition and pre-processing of the data.

The second phase was for extracting and validating land-use land-cover information for the two study areas, while the third phase was devoted to the assessment and examination of the land-use and cover changes of the area. Aerial photographs and topographic maps were obtained from the Survey Department of Ghana in Accra. Each photograph was registered to a map (geo-referenced) to bring it to the same scale and frame of reference as the other data sets. Images were then projected from the Accra Ghana Grid to the Ghana Meter Grid. Using on-screen digitizing in ESRI ArcGIS 10.1 of aerial photographs, a classification scheme was formulated to identify four specific land use/cover classifications as shown in Table 3.

Table 3: Land Use Classification for the Study

Category	Description
Vegetation	Area with natural undisturbed vegetation
Built-up	An area densely covered by houses or buildings
Industrial area	Areas where mechanic shops are found
Water	Water bodies in the study area

Source: Field Data, (2014)

The digitized vector maps were converted to raster models and the areas of all land use/cover categories in both years were extracted. The change in land-

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use-cover was calculated by subtracting the areas of land uses in 2005 from that of 2014. The analysis and results were presented in the form of maps, tables, charts and graphs, plates and percentages.

The study also involved laboratory analyses. Both the descriptive and statistical techniques were employed. The laboratory procedures used to detect heavy metals and water analysis are outlined below. The laboratory analysis was performed at the WRI of the CSIR in Accra, Ghana. The content of heavy metal in the water samples were measured with the Analyst 400 Perkin-Elmer Atomic Absorption Spectrophotometer (AAS). The water sample was first filtered with Whatman No. 0.45 filter paper, after which 50ml of the filtrate was acidified with 50% nitric acid to give a pH of 1. The AAS was calibrated with standard solutions, and then de-ionized with water before heavy metal concentrations in water samples were measured. The detection of heavy metals was done following procedures developed by (Eshun, 2011). The Perkin-Elmer flame Atomic Absorption Spectrophotometer (AAS) was used to measure the heavy metals in the samples. All the chemicals used in the laboratory analysis are listed below:

60% $HClO_3$ (BDH)

97% H_2SO_4 (BDH)

NH_3 (Reagent grade)

Sodium hexametaphosphate (MW: 611.79)

99.7% Ascorbic Acid (BDH)

69 – 79% HNO_3 (BDH)

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Various interrelationships among elemental concentrations in water samples obtained at individual sampling points and between different parameters were presented using the Kriging method. Kriging is a geo statistical tool that allows dispersed or scattered data points to be brought together for interpretation. Kriging was used in interpolating the sampled heavy metal concentration parameters in the Fosu lagoon. This gave spatial distribution of the sampled points in the lagoon. It also helped the present researcher to understand the spatial distribution and its relationship with the objects or features located along the lagoon. Areas closer to specific features received inflows from these features. The IDIs, were however, analysed manually. The data from the IDI's were transcribed and categorised under specific themes and were used for the further analysis. The results were presented in a table (in percentages and frequencies) and in pictorial forms.

Ethical Considerations

Access to confidence of the communities were gained through written permissions from the Department of Geography and Regional Planning, University of Cape Coast, Ghana (UCC) and sent to the District Assemblies and the experts whose knowledge and information were sought for the study. The chiefs of the selected communities were contacted to solicit for their knowledge on traditional practices and lagoon management. In each community, the first point of call was the Unit Committee chairman who then introduced the researcher to the chief. The idea was to seek the consent and support of the key personalities in the community. Letters were collected from the Department of

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Geography and Regional Planning, UCC and distributed to the various agencies and departments who were in charge of the two study sites.

Summary

This chapter focused on the research methods, the procedures that were followed to collect data, the statistical tools employed for the analysis, and the presentation of the data. The next chapter presents the changing physical features of the Fosu and Essei Lagoons.

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CHAPTER FOUR

CHANGING PHYSICAL FEATURES OF THE FOSU AND THE ESSEI LAGOONS

Introduction

This chapter describes the changing physical features of the Fosu and the Essei Lagoons. The land-use-land cover changes, changes in the extent of the two lagoons, salinity of the lagoons, bathymetry, structure of the lagoons and rainfall and temperature distribution over the lagoons are discussed in this chapter. According to the Joint Nature Conservation Committee and their Common Standards Monitoring Guidance for Lagoons (2004), the changing physical features of a lagoon could be analysed according to its characteristics such as ecological and physical nature. Other characteristics considered in this study were terraces (that shows lagoon coastline changes) bathymetric analysis depicting the underwater configuration, structural nature of the lagoon and the analysis of rainfall and temperature distribution.

Area Extent of the Fosu and the Essei Lagoons

Lagoons are ephemeral and their extent is an essential structural component of their formation. According to Bamber, Gilliland and Shardlow (2001), the extent and salinity of lagoons vary in the short-term (tidal cycle) and in the medium term (in direct response to seasonal rainfall). In the long term, the lagoon may evolve, infill, shrink, and in some cases disappear in response to seasonal rainfall and drought conditions. Dei (1972) states that the areal extent of

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lagoons vary with seasons and that evidence of former lagoon beaches indicate earlier wetter conditions or earlier periods of more intensive fluvial action.

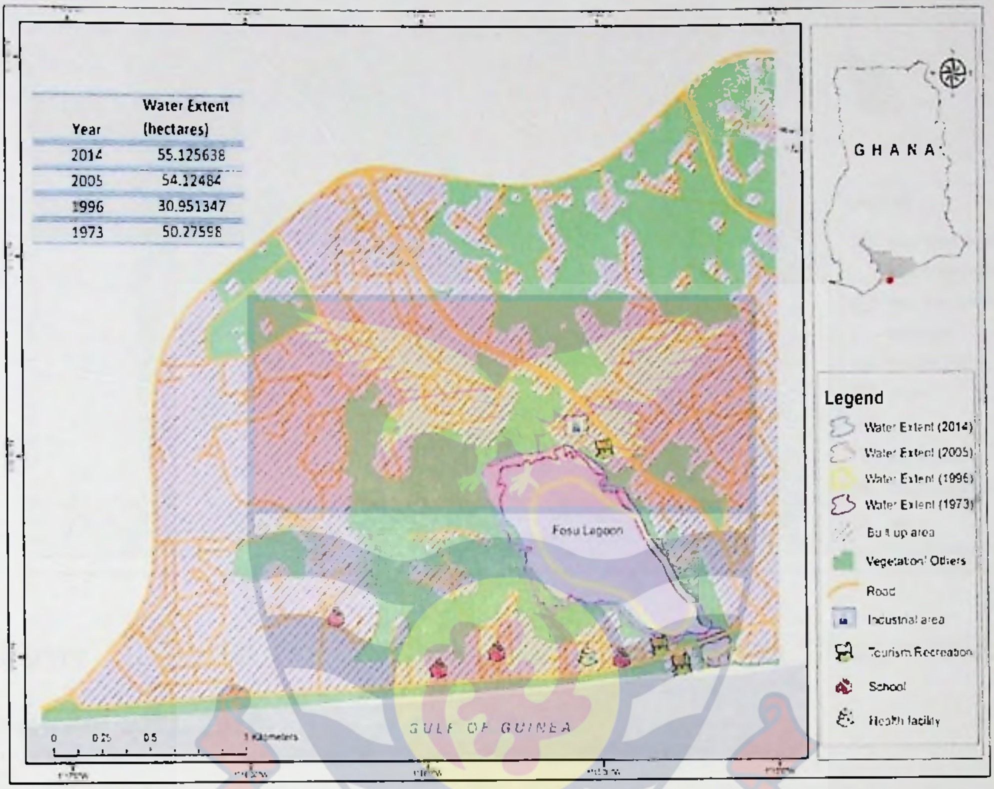

Figure 11: Spatial Extent of the Fosu Lagoon Showing Changes in Area between 1973- 2014.

Source: Field Data (2014)

The areal extent of the Fosu Lagoon in 2014 was 55.2 hectares whilst the Essei Lagoon covered an area of 1.8 hectares as shown in Figures 11 and 12.

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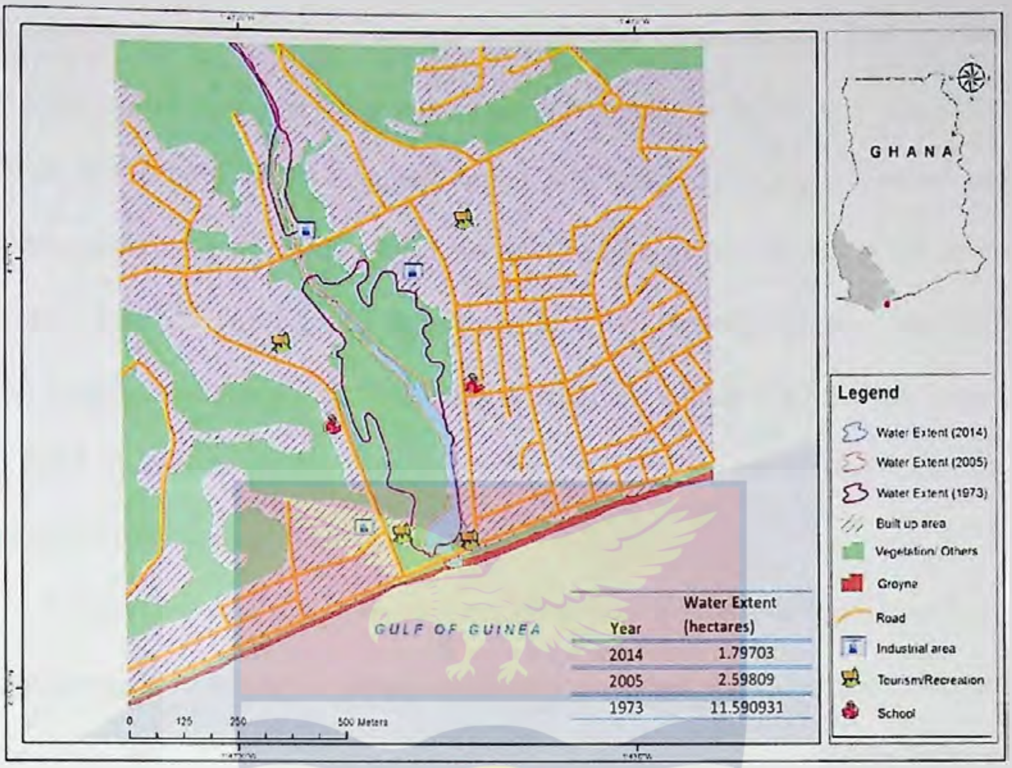

Figure 12: Spatial Extent of the Essei Lagoon Showing Changes in Area between 1973- 2014

Source: Field Data (2014)

The changes in the areal coverage of the water surface of the two lagoons from 1973 to 2014 are shown in Table 4. The results indicate that Essei Lagoon has considerably decreased in surface area between 1973 and 2005 with the total area loss of -77.6 hectares, while between 2005 and 2014; it again lost a total area of -30.8 hectares. On the hand, surface area of the Fosu Lagoon increased by 1.9 hectares between 1973 and 2014. Between 1973 and 1996, the Fosu Lagoon lost an area of -38.5 hectares and between 2005 and 2014, its area increased to 1.9 hectares. The increase in Fosu Lagoon may be attributed to the recent restoration programme engineered under a sister city project with the traditional council and

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the CCMA together with EPA and German aid (Cape Coast Metropolitan Assembly, 2014). On the other hand, satellite images revealed that, the Essei Lagoon has a reduced areal extent and it is mostly attributed to natural and anthropogenic activities within its enclaves. The changes are shown in the aerial photographs of the two lagoons. In terms of land use, the built-up area around the Essei Lagoon amounts to 65. 5% which is relatively higher than that calculated for Fosu which had 60.2%. This information reveals serious consequences for Essei and Fosu in terms of their management.

Many anthropogenic events were observed around the Essei and Fosu lagoons which validate the spatial information derived from the maps. Human activities observed along the lagoons include sand wining, the use of the beaches as places of convenience and disposal of human excreta, use of beaches as car washing bays, disposal of inorganic wastes as well as solid waste materials including polyethene bags, and car tyres (see plate 1 and 2). Flow of liquid waste from domestic drainage systems is also apparent and was observed.

Table 4: Lagoon Extent in 1973 and 2014

Lagoon	Extent (Hectares)) 1973	Extent (Hectares)1996	Percentage change	Extent Hectares) 2005	Percentage change	Extent (Hectares) 2014	Percent change
Essei	11.6	-*	-*	2.6	-77.6	1.8	-30.8
Fosu	50.3	31.0	-38.5	54.1	74.9	55.1	1.9

Source: Field Data (2014)

*Means no data accessed

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Plate 1: Effects of Industrial Activities on the Essei Lagoon

Source: Field Data (2014)

Plate 2: Domestic Waste in the Fosu Lagoon

Source: Field Data (2014)

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Land Use and Land Cover Change of the Fosu and Essei Lagoons

The land use and land cover in the catchments of the two lagoons indicate three main categories (Table 5) which were the built up area, industrial and vegetation. The land use around the Essei Lagoon between 1973 to 2014 was 65.5 percent built up and 32.4 percent vegetation. The remaining land use 1.0 and 1.1 was assigned to industrial use and the water body itself (as shown in Figure. 15). On the other hand, the land cover along the Fosu Lagoon in the 1973-2014 was 60.2 percent Built up, 32.3 percent vegetation, whilst 7.5 percent was allotted to the water body itself and industrial usage. The above analysis shows that, the extent of Fosu is expanding whilst that of Essei is reducing.

Table 5: Land Use and Cover Pattern around the Fosu and Essei Lagoons (1973-2014)

Land Use/Cover	Essei Lagoon		Fosu lagoon	
	Area (hectares)	Percent	Area (hectares)	Percent
Built up	103.3	65.5	474.5	60.2
Industrial	1.6	1.0	3.9	0.5
Vegetation/Other	51.1	32.4	254.3	32.3
Water body	1.8	1.1	55.1	7.0
Total	157.8	100.0	787.8	100.0

Source: Field Data (2014)

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Land use and land cover change are one of the major challenges that affect the natural landscape. It is one of the main causes of global environmental change and central to the sustainable development debate (Lambin, Roosevelt & Geist, 2000). The causes and consequences of land use change on the physical and social environment have been recognised by researchers as alarming. The impact include; impact on water quality, land and air resources, ecosystem processes and function, climate, biodiversity, soil degradation and the ability of natural systems to support life.

Figure 13: Land Use and Land Cover Change around the Essei Lagoon in 2014

Source: Field Data (2014)

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From Figure 13, the Fosu Lagoon recorded built up area as the largest land cover with 60.2% and was followed by vegetation which covered 32.3 percent of the area. A land reclamation project was also observed at the back of the Siwdu sports stadium which might have been spearheaded by the need for a site for a mechanical workshop; that workshop contributes to the industrial chunk of the land use and land cover change (LULCC). Thus, 7.0% of the area is covered by the water body while 0.5% is use for industrial activities. The land use activity as shown by (Fig. 13) is grouped into built up and industrial uses. The land use map shows that chunk of the land is use as built up and is followed by vegetation cover. The industrial activity observed were the tyre repairs, mechanic shops, drinking spots along the lagoon.

Figure 14: Land Use and Land Cover Change around the Fosu Lagoon in 2014

Source: Field Data (2014)

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The Fosu Lagoon has increased in spatial extent by about of 1.9 hectares between 2005 and 2014. This may be attributed to increase in rainfall amount. On the other hand, the Essei Lagoon is decreased by about 77.6% over the period of about 41 years (1973-2014) is shown by the aerial photographs. Habitat damage around the Essei Lagoon must have contributed to the loss in biodiversity to a great extent. In addition, Aheto et al. (2010) observed that habitat disintegration of the Essei Lagoon through the creation of a defence wall in the middle of the wetland to serve as flood control probably aggravated the situation which caused the reduction in the flora and fauna in the area. In the case of the Essei Lagoon, it was observed that at high tides the volume of water in the lagoon increased and reduced at low tides. It was also evident in the dry season in the case of the Essei Lagoon, the non-existence of the lagoon as it was almost dried- up.

Salinity of the Fosu and the Essei Lagoons

The average salinity recorded ranged between 10.66 ‰ for the Essei Lagoon and 1.88 ‰ for the Fosu. The high salinity value measured in the Essei Lagoon largely reflects brackish water conditions that provide moderate condition for brackish and marine species. The result is shown in Figure 15. On the other hand, the Fosu Lagoon has fresh water with a salinity of less than 5‰. According to the Joint Nature Conservation Committee (Common Standard Monitoring Guidance for Lagoons, 2004), if salinity drops below 5ppt, then the hyposaline habitat is effectively freshwater and no longer able to support most lagoonal species. In the case where there are changes in salinity causing severe loss or shift in habitat such that the conservation interest is adversely affected, then this

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should be judged as unfavourable. These changes in most cases may be attributable to:

a. loss or damage to sluice or flow control mechanisms;

b. water abstraction or discharge altering, and

c. anthropogenic alteration to the isolating barrier.

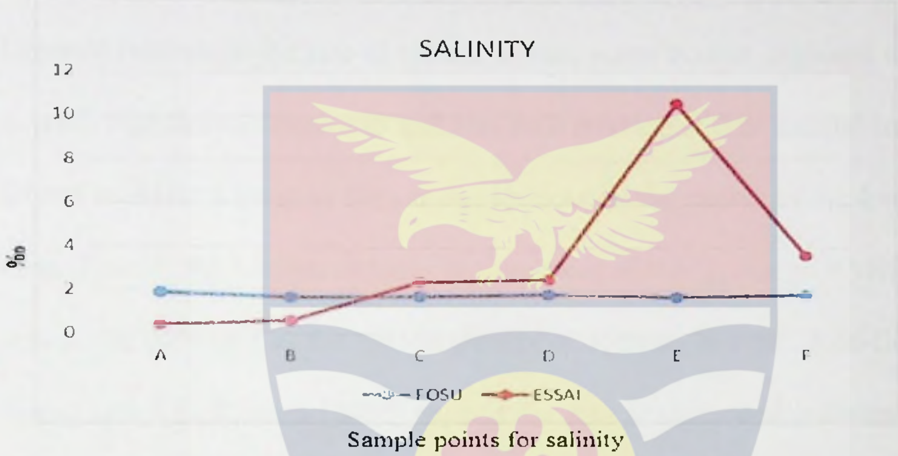

Figure 15: Salinity of the Fosu and the Essei Lagoons

Source: Field Data (2014)

Salinity regime is critical to both the structure and function of a lagoon. It defines the habitat and contributes to the overall diversity within a particular lagoon (Davies et.al, 2001). According to Kjerve (1994), salinity in a restricted coastal lagoon can vary from fresh water to hypersaline. Kjerve (1994) again stated that any change in the prevailing salinity regimes may affect the presence and distribution of species and spawning behaviour. For this reason, it is essential that salinity and tide regimes are always assessed at the same time of the year.

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Terraces of the Essei Lagoon Shoreline/Coastline Changes

The study of the Fosu and the Essei Lagoons shoreline shows a number of terraces and core sediments that have occurred in the past. As can be seen in Plate 3, the terraces show the remnant of the shoreline of the lagoon as a result of rainfall seasonal changes and human induced impacts. The terraces were formed as result of the changes in the lagoon level. Given the smaller size of the Essei Lagoons relative to the size of typical marine water bodies, lagoonal terraces are, overall, significantly narrower and less well developed than marine terraces. The arrows on Plate 3 point to the various terraces on the shores of the Essei Lagoon. From Plate 3, the various changes to the extent of the lagoon as it varies with the season are indicated as the lagoon shrinks or reduces in area. Adu-Boahen, Dei, Antwi and Adu-Boahen (2015) studied the lake terraces and sediment cores and found that Lake Bosomtwe had reduced significantly and this has affected the morphological characteristics of the lake and its surrounding resources. A similar scenario was also revealed at Essei as depicted by plate 3.

Plate 3: The Terraces of Essei Lagoon

Source: Field Data 2014

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Measurement of the Depth of the Fosu and the Essei Lagoons

Water depth is a site-specific attribute used to establish differences when assessing the overall conservation value of the site. According to Bamber et. al. (2001), lagoons are depositional environments where fine sediments, arriving fresh water, and marine inputs accumulate. There is therefore relatively little that can be done to control the composition of the substratum or rate of deposition of materials. The study shows that the Fosu and Essei Lagoons are relatively shallow in depth and most of the sample points had depths of less than one (1) metre.

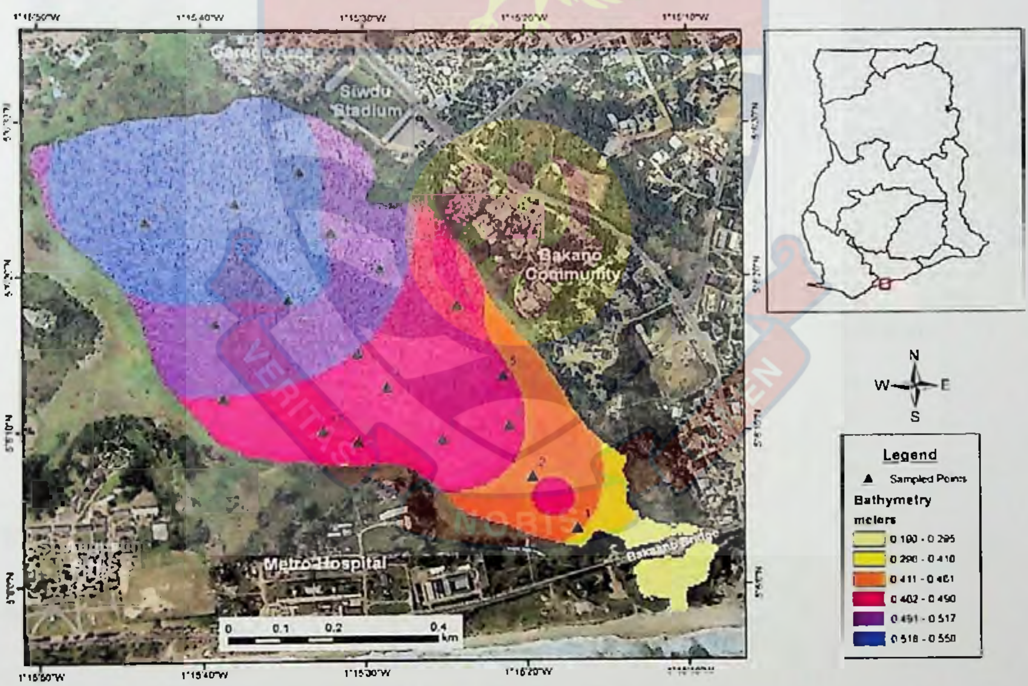

Figure 16: Measurement of Fosu Lagoon Depth

Source: Field Data (2014)

The depth of the Fosu Lagoon is shallow at the mouth (1 metre) and gets deeper (1.5 metres) towards the point directly adjacent the Siwdu Sports Stadium

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as shown by the sample points. As illustrated in Figure 16 below. In the case of Essei Lagoon, the depth was not encouraging at all as it was very shallow. The shallow nature is attributed to deposition by longshore drift and the construction of the sea defence wall as a policy to reduce sea erosion at the area. The depth was averagely around 47 cm at point A, the deepest recorded and the lowest point at the mouth of the lagoon recorded 17 cm.

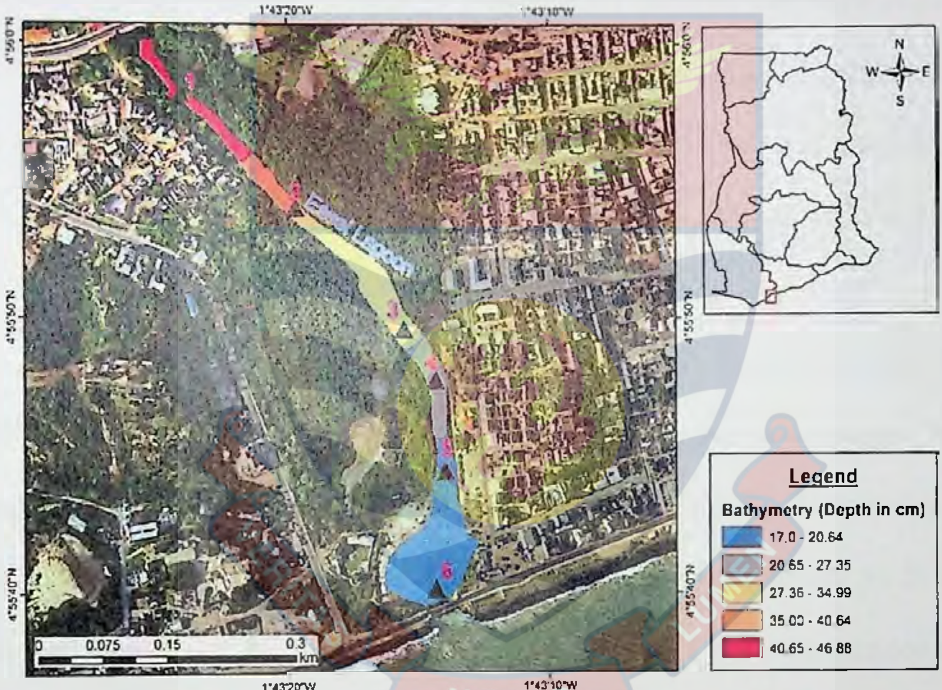

Figure 17: Measurement of Essei Lagoon Depth

Source: Field Data (2014)

Rainfall and Temperature Distribution of Fosu and Essei Lagoons

The result of rainfall and temperature distribution over the Fosu and the Essei Lagoons are presented in this section. The data analysed is the average rainfall and temperature data of the selected lagoons taken from Cape Coast in the Central region of Ghana and Sekondi in the Western region of Ghana between

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1980-2014. In Sekondi, the driest month was January which recorded 27 mm of average rain. Most precipitation falls in the month of June, with an average of 335 mm as shown in Figure 18. With temperature, March was the warmest month recording a highest average temperature of 27.4 °C. The month of August had the lowest average temperature of 23.8 °C. Rainfall is one of the important factors, which affect the distribution of aquatic organisms. According to Milly, Dunne and Vecchia, (2005) regional changes in precipitation patterns can have important effects on the physical and ecological characteristics of coastal lagoons through the alteration of freshwater inputs and associated changes in salinity and dissolved oxygen concentrations in the lagoons. Rate in intensity, amount and duration of rainfall affects the volume of water in lagoons.

Intense precipitation events increase short-term freshwater inputs and decrease salinity (Paerl et. al, 2006). Similarly, lower precipitation could reduce freshwater inputs and causes higher salinity (Valiela, 1995). By this analysis both rainfall and temperature have effects on lagoons and its resources. As in some cases as depicted by the data no rainfall at all was recorded in the selected study areas in some months of the year. The amount of water flowing from the tributaries into the lagoons has a direct impact on pollution: as rainfall increase river flow, more nutrients and sediment are pushed into the estuary. In other words, precipitation and river flow are factors affecting pollution loads and water quality.

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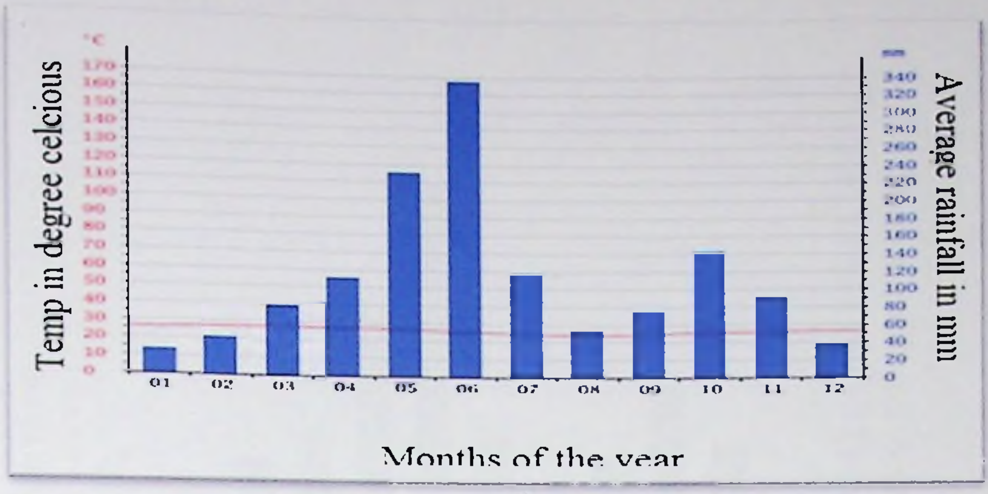

Figure 18: Average Annual Rainfall over Sekondi (1980-2014)

Source: Meteorological Service Agency (2016)

The average rainfall of the Fosu Lagoon from 1980-2014 is shown in Figure 19. Rainfall is very low in January (24mm). June has the highest (327mm) when precipitation reaches its peak. Temperature for Fosu Lagoon was 27.7 °C which is similar to that of Essei Lagoon with 27.4 °C. There was slight difference in terms of temperature and rainfall distribution between the two areas. Both Cape Coast and Sekondi-Takoradi. The two areas should have similar salinity and other chemical conditions.

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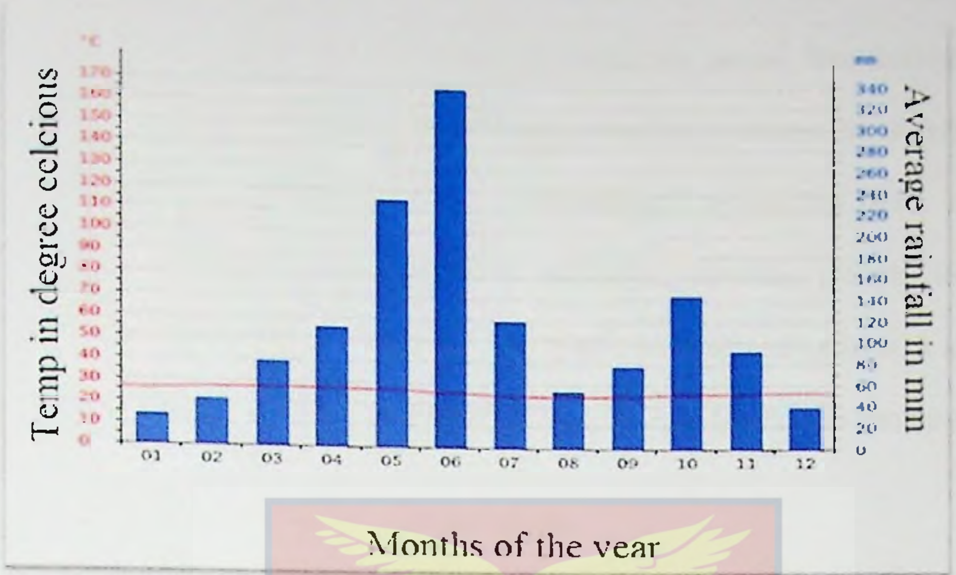

Figure 19: Average Annual Rainfall over Cape Coast (1980-2014)

Source: Meteorological Service Agency (2016)

The variation in Dissolve Oxygen (DO) and salinity is attributed to the type of lagoon. In the sense that Fosu being a closed lagoon does not receives constantly receive sea water, while there is regular interaction of sea with the Essei Lagoon accounting for its high salinity and DO in comparison with the Fosu. Also rainwater is more likely to be retained within the Fosu Lagoon because of its closeness but any fresh water that enters the Essei Lagoon as a result of rainfall drains directly into the sea.

The Fosu and the Essei Lagoon systems are subject to natural changes, related to fluctuations in rainfall amount and intensity as in runoff and temperature. There was an insignificant difference between the Fosu and the Essei Lagoons in terms of rainfall and temperature distribution and its impact on coastal and aquatic resources. In addition there have been changes due to human intervention, including the recent sea defence wall in the case of the Essei

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Lagoon, and breaching of the Fosu Lagoon during the annual Fetu festival. The implication of the result is that rainfall and temperature affects the distribution and abundance of aquatic resources. Temperature is a limiting factor in the aquatic environment because it affects metabolic activities, growth, feeding reproduction distribution and migratory behaviour of aquatic organisms. It affects solubility of gasses in water; gas solubility decrease with increase in temperature.

Structure of the Fosu and the Essei Lagoons

Fosu and Essei Lagoons vary in size and shape in relation to their morphology, the form of the enclosing barrier, and the extent of erosion and deposition. The Fosu Lagoon for instance is almost circular while the Essei Lagoon is elongated. In the case the Fosu and the Essei Lagoons, observations revealed that, the area from which all the freshwater flows (the land to the sea) is heavily affected by human activities (agricultural, industrial and urban areas). The land and sea interaction changes the ratio of land to the sea, and changes to the winds and the tides, and have resulted in a modification to the morphology of the lagoons. The geology of the Fosu and the Essei Lagoons are quite different, and the variations are found in some few places. According to Dei (1975) most of the surface rocks around the Essei Lagoon are ancient rocks belonging to Precambrian metamorphosed schist and sandstones. Between Cape Coast and Takoradi, such sandstones are locally known as Sekondian or Sekondi sandstone Dei (1975). The geological composition of the Fosu Lagoon consists of hard granites, metamorphosed lava, and pyroclastic rock, the hardened nature of the

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rocks influences the buffering capacity of the lagoon as it is able to retain the volume of water in place against the natural and human processes that affect it.

On the other hand, Sekondi sandstones that underlain the Essei Lagoon belong to the sedimentary type of rock which is fragile and loose. The loose nature of the rocks encourage high rate of deposition and sedimentation which causes the shape and size of the lagoon to change and also its aquatic life are degraded. The morphodynamics between the Fosu and the Essei Lagoons are that, the Fosu is increasing while Essei is decreasing in their area extent and aquatic resources. This is shown in Figure 20 and 21. There has been a long time change in the area of the Essei Lagoon as shown by the aerial photograph analysed between 1973-2014.

With sedimentation, the Fosu and Essei Lagoons receive sediments from sources that include runoff, household waste, tidal floods and mechanic shops. The sediments loads depend on precipitation in the catchment area and much of the sediment is deposited in the lagoons during transport. Apart from fluvial inputs, erosion of areas along the lagoons contributes significant amount of sediments into the lagoons. The introduction of suspended sediments from catchments has significant influence on lagoon shallowness and size. High rates of sedimentation lead to lower lagoon depth and size. This has been the case of Fosu and Essei Lagoons as their catchment elevation and adjoining land cover can be used to explain the difference in their shallowness and size.

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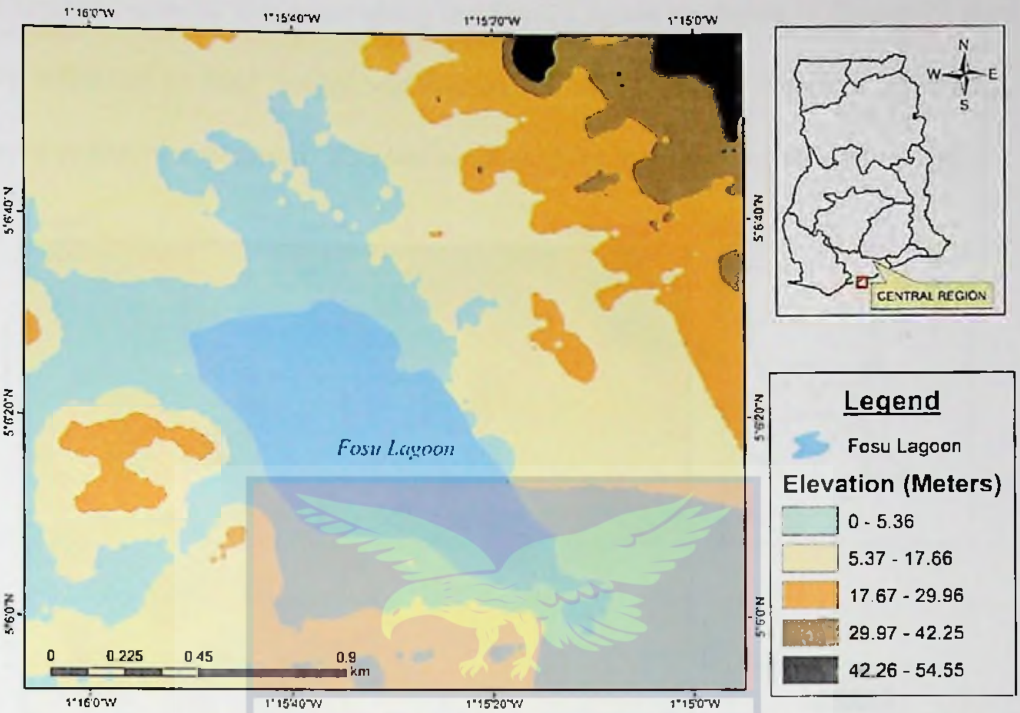

Figure 20: Structure of the Fosu Lagoon

Source: Field Data (2015)

As shown in Figures 20 and 21, deposition into the Fosu Lagoon is low; that can be attributed to its catchment elevation which is 17.67-54.55 meters compared to the Essei Lagoon (Fig.21) which has an elevation of 14.83-70.00 meters. Low elevation reduces erosive ability of rainfall and reduces the rate of sedimentation. Also the existence of saltmarsh and built up or settlement along the lagoon serve as filter to sieves the water to remove the sediment load that are transported and would be deposited into the lagoon. Bromberg-Gedan, Silliman & Bertness, (2009) opined that high elevation with longer distance reduces the rate of sediment load. In the case of Fosu lagoon, high areas within the catchment are well above 1.9 km away but for Essei most of the high land areas are very close (0.34 km) to the lagoon hence deposition of sediment loads into the lagoon

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is large. In spite of low areas along the Essei Lagoon as shown in Figure 21 they are subjected to long lasting and frequent tidal floods and therefore experience more sediment deposition. This has accounted for the declining size and depth.

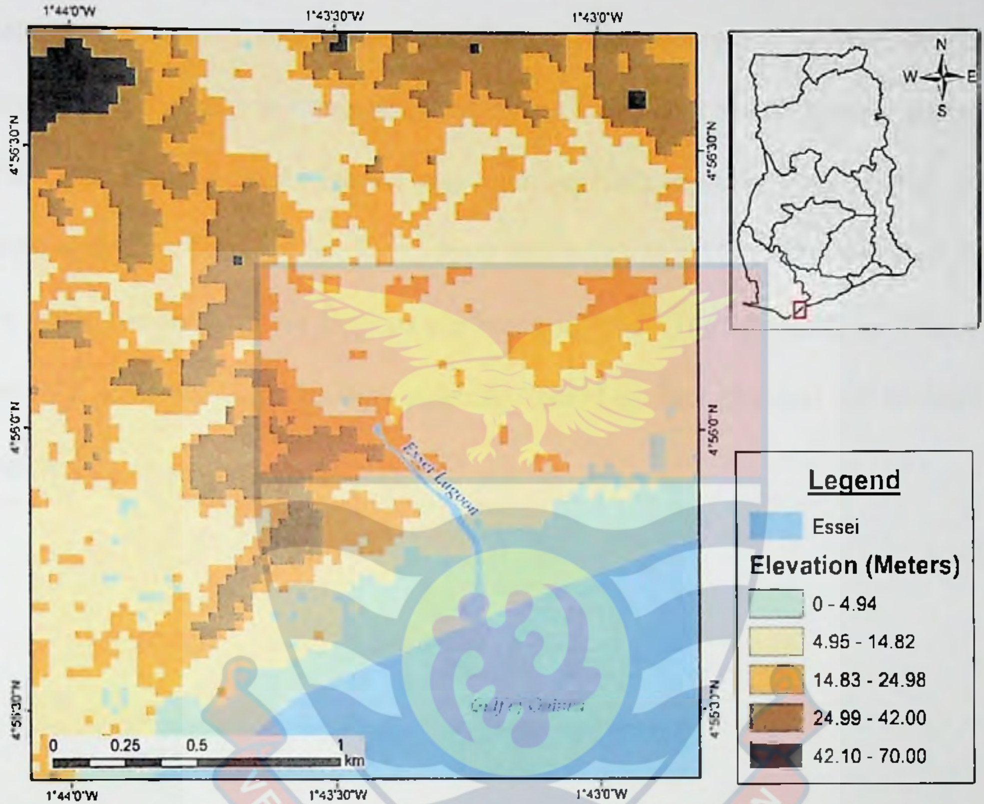

Figure 21: Structure of the Essei Lagoon

Source: Field Data (2015)

The implication from the above is that, much runoff into the Fosu and Essei Lagoons is arises. When this happens, sediment and nutrient loads are deposited into the lagoons which contribute to changes in the area and size of the lagoons. The hydrology, sedimentation and biological production processes in the lagoons are also affected. In view of this, limited or no fishing activities takes place in the Essei Lagoon. These increasing human and natural processes therefore call for an integrated management approach to solve the problems.

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Summary

The chapter was devoted to the changing physical features of the Fosu and the Essei Lagoons. The results revealed that lagoons shows different physical features based on their type. The Fosu a closed lagoon showed different conditions and nature in terms of extent, salinity, and land use land cover changes. Whilst the Essei, an open lagoon was reducing both in extent and land use land cover activities. The land used/land cover analysis was performed to evaluate how the lands surrounding the lagoons are being utilised. The changing dynamics of the Fosu and Essei Lagoons were examined based on their physical and ecological features.

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CHAPTER FIVE

WATER QUALITY STATUS OF THE FOSU AND ESSEI LAGOONS

Introduction

This chapter discusses the water quality status of the Fosu and the Essei Lagoons. The chapter describes the physico-chemical parameters that are temperature, dissolved oxygen (DO), total dissolved oxygen (TDO), salinity, and electric conductivity. Physico-chemical analysis is significant because it provide signals on the changing conditions in the environment and its effect on aquatic flora and fauna in the Fosu and Essei Lagoons.

Physico-Chemical Analysis of the Fosu and the Essei Lagoons

Temperature in the Fosu and Essei Lagoons

According to Delince (1992), temperature contributes significantly to water quality levels as colder water can hold more oxygen than warmer water. There are other factors such as environment that affect the growth and development of fish more than temperature. Figure 22indicate higher temperature in the Fosu Lagoon than in the Essei Lagoon. The mean temperature of the Fosu Lagoon was 29.8°C compared to the Essei which recorded 29.6 °C in the wet season. In the dry season there were changes in the range of 31.2 °C and 28.2 °C respectively for the Essei Lagoon and an average of 33.4°C -31.0°C in the case of the Fosu lagoon. The dry season temperatures changes are due to the seasonal differences exist between the various parameters. It can therefore be inferred that the water temperature recorded during the sampling period in the wet season for the various sites did not differ significantly between the study areas. According to

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Delince (1992), temperature is important for aquatic ecosystem as it affects the organisms, as well as the physical and chemical characteristics of water in which they live. According to Abulude, Fapohunda and Awanlenhen (2006), temperature range of 24 to 30°C temperature is needed by fish to grow well in lagoons. As shown in figure 24 the survival of aquatic life in the Essei Lagoon will be affected and only few aquatic resources will be able to live in the lagoon due to its high temperature.

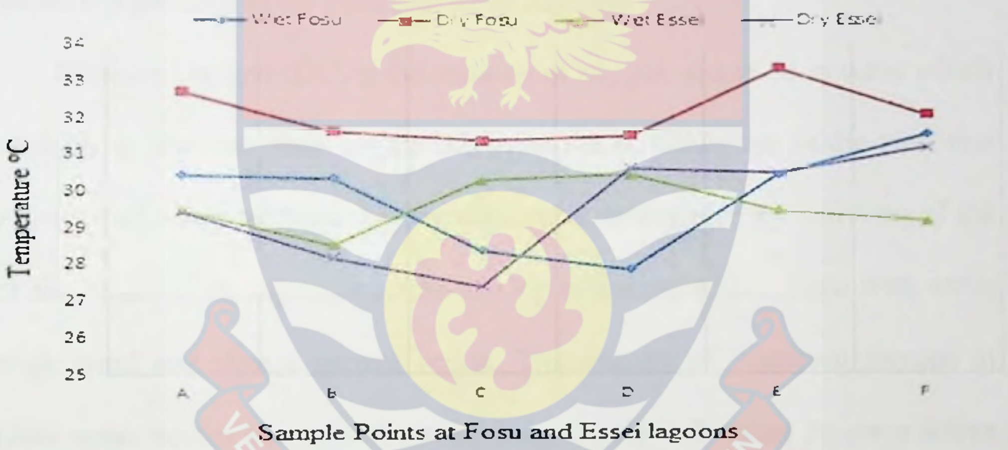

Figure 22: Temperature of the Fosu and Essei Lagoons by Seasons

Source: Field Data (2014, 2015)

Aheto et al. (2010) are of the view that aquatic organisms are dependent on certain temperatures for optimal health and that temperature affects many other parameters that include the amount of dissolved oxygen available, the types of flora and fauna present, and how susceptible the organisms are to parasites, pollution and disease in water. According to Roberts, Waiser, Arts and Evans (2005), biochemical activities such as decomposition double every 10 °C of

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temperature increase. Increase in water temperature is associated with increase in bacterial numbers that are essential for the decomposition of organic matter (Roberts et al., 2005) that accumulates inside the lagoons. Another implication of the results is that, water temperature is also an important inorganic substance to organisms that are highly organic in parameter, because it influences the biota in a water nature. Turbid water is undesirable from aesthetic point of view, there by affecting activities such as behaviour, respiration and metabolism.

Dissolved Oxygen (DO) in the Fosu and Essei Lagoons

Dissolve Oxygen (DO) is the measure of oxygen dissolved in water which is available to fish and other aquatic life. Aheto et al. (2010) are of the view that DO content of water quickens the photosynthetic and respiratory activities of the flora and fauna in the lagoon, and the mixing of atmospheric oxygen with water through wind and stream current action. The amount of dissolved oxygen in shallow water bodies has been observed to be largely influenced by wave action (Brönmark & Hansson, 1999). Dissolved oxygen is considered to be the most critical water quality parameter that can affect fish survival and their distribution in aquatic systems (Agostinho, Pelicice, Petry, Gomes & Júlio, 2007; Rendón-Von Osten, Memije, Ortiz, Soares & Guilhermino, 2006). Figure 23 shows dissolved oxygen profiles of the Fosu and the Essei Lagoons during the wet and dry seasons. From (Fig. 23)7.0 mg/L DO was recorded at the mouth of the Fosu Lagoon and 0.5 mg/L at mouth of Essei Lagoon in the wet season. DO parameters were fairly stable from the mouth to the upper limits of the Fosu Lagoon with an average value of 0.7 mg/L (Figure 23). According to Cunningham and Saigo,

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(1995) when DO is below 2 mg/L, many aquatic organisms perish due to difficulty in biological respiration including those related to decomposition processes which reduce the concentration of DO in water bodies

The mean value of 1.7 mg/L recorded for the Essei Lagoon was not positive for biological productivity of the lagoon hence fishing activities are not encouraged in the Essei Lagoon. In the dry season significant changes were recorded at the study sites with Fosu having its highest at 11.7 mg/L and lowest at 6.6 mg/L respectively whiles Essei recorded an average high of 5.0 mg/L and low of -0.9 mg/L. The highest points were recorded at point A for Fosu and point F at Essei. These points are the mouths of the lagoons and where sea water and fresh water interaction is expected at some point in time. This finding also supports the fact that no meaningful fishing activities are conducted in the Essei Lagoon.

Mostly, oxygen concentration of 5 mg/L is generally required for fish survival and growth (Cunningham & Saigo, 1995). The Oxygen content of the Essei Lagoon was at critically low levels ranging between 0.9-1.7 mg/L, which may be regarded as near deoxygenation. This may have accounted for the very low fisheries content of the lagoon compared to the Fosu lagoon. The water quality status of the Essei Lagoon is generally degrading in effect and could have a significant impact on flora and fauna and this in a way have affected fishing in the lagoon.

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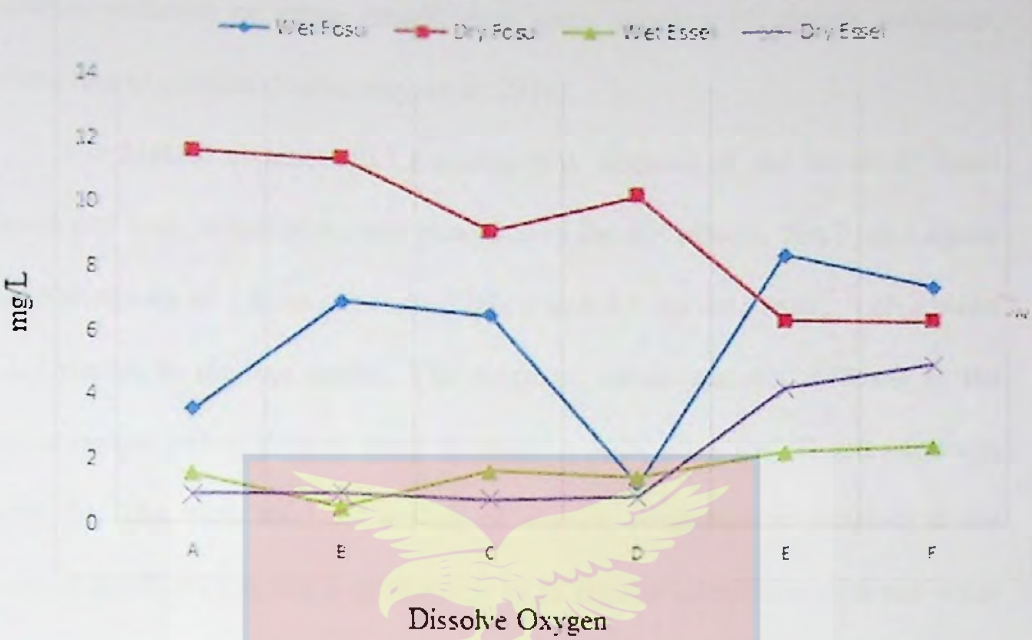

Figure 23: Dissolved Oxygen (DO) in the Fosu and Essei Lagoons by Seasons

Source: Field Data (2014, 2015)

Electric Conductivity in the Fosu and Essei Lagoons

Electric conductivity of water is a measure of positive or negative ions present in a given volume of water. High water temperature increases the movements of ions in the water; and this increases electric conductivity in that water (Dubrovsky, Burow, Clark, Crunberg, Hamilton, Hih & Muller, 2010). According to Aheto et. al. (2010), electric conductivity in water is affected by the presence of inorganic dissolved substances such as chloride, sulphate, sodium and calcium. It is also affected by the geology of the area through which the water flows. According to the authors water bodies that run through granite bedrock have lower electric conductivity, while those that flow through limestone and clay soils have higher conductivity. High conductance readings can also come from

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industrial pollution or urban runoff, thus water running off streets buildings, parking lots or garages (Dubrovsky, et.al. 2010).

The highest conductivity3.4 ms/cm was recorded at the mouth of Essei Lagoon and least of 0.6ms/cm was measured in the wet season. The Fosu Lagoon had conductivity of 1.8 ms/cm as the highest and 1.7 ms/cm lowest, with a mean of 1.7 ms/cm in the wet season. The range of values was not different as the various sample points showed some characteristics of closeness. This is shown in Figure 24. The high level 3.4 ms/cm of electric conductance recorded at the mouth of the Essei Lagoon is attributable to its regular interaction with sea water during both high and low tides. With regards to the dry saeson, high electric conductance level was recorded at Essei 16.7 ms/cm though low of (2.3 ms/cm) was recorded at sample point A which was the farthest point from the south. The Fosu Lagoon recorded conductivity of 2.3 ms/cm as the highest and 1.9 ms/cm as the lowest. The results give an indication of differences between the dry and wet seasons. This high electric conductivity results will have a negative implication on the aquatic habitat with regards to their survival, hence limited aquatic life exists in the Essei Lagoon.

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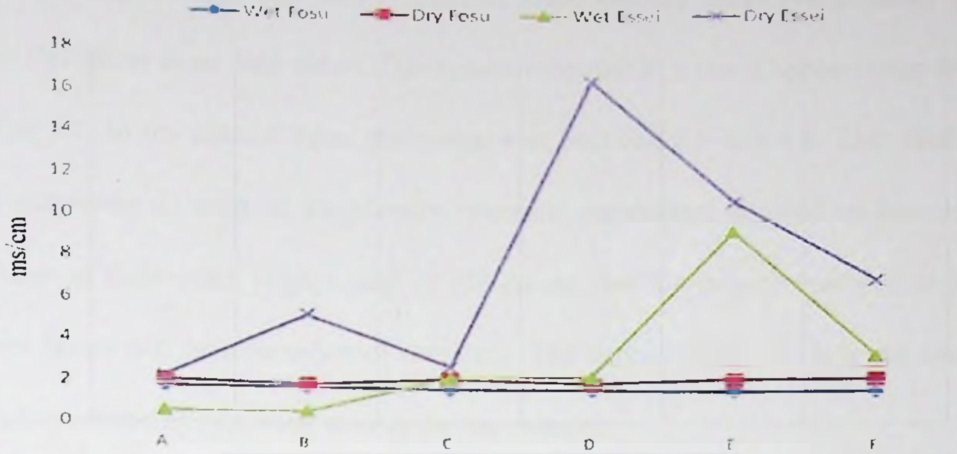

Figure 24: Electric Conductivity of the Fosu and the Essei Lagoons by Seasons

Source: Field Data (2014, 2015)

pH of the Fosu and the Essei Lagoons

pH of water bodies depends on the type of bed-rock or the sources of the rivers and to some extent on temperature. According to the USEPA (2010), a normal pH of surface water should lie between 4.5–9.0.It is the amount of relative acid or alkaline in a sample. Figure 25 shows amount of alkaline and acid in the Fosu and the Essei Lagoons. The Fosu Lagoon recorded a high alkaline value of 7.7 and a low value of 6.6. On the other hand, the Essei Lagoon recorded the high alkalinity of 7.3 and a low of 6.9. It can therefore be inferred that the pH values of the lagoons are acceptable, and pose no threat to aquatic life. The result is in conformity with the previous study by Aheto et al. (2010) that recorded pH values of 7.5-7.8. Based on that result, they concluded that pH values between 7 and 8 shows that, the lagoons have a reasonably good buffer range capacities that are optimally good for supporting a range of aquatic life.

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The pH values recorded in the two areas showed much resemblance and little deviation from each other. The values recorded at Essei Lagoon range from 7.4 to 7.1. In the case of Fosu, the range was between 8.9 and 8.4. The result is not surprising as most of the physico-chemical parameters showed an increased volume of their units. High values of pH during the dry season were due to low water levels and concentration of nutrients. The decrease pH values were due to dilution caused by rainwater during the wet season.

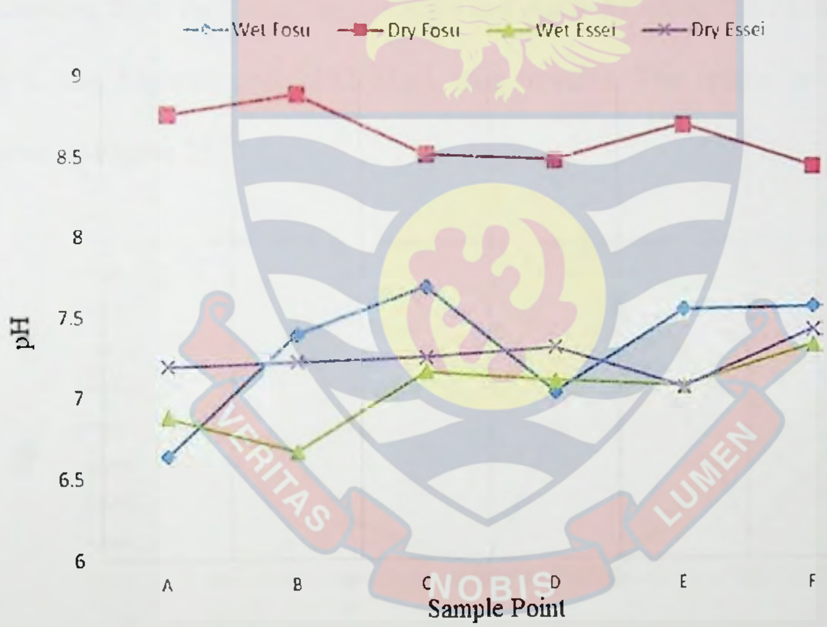

Figure 25: pH of the Fosu and the Essei Lagoons by Seasons

Source: Field Data (2014, 2015)

Total Dissolved Solids (TDS) in the Fosu and Essei Lagoons

Total dissolved oxygen (TDS) is an index of the amount of dissolved solids in water, which determines the degree of salinity. TDS concentrations were

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monitored in the Fosu and Essei Lagoons. The highest TDS 9406.7 Mg/L was recorded in the Essei Lagoon at point E which is the mouth of the lagoon and the lowest value 572.3 Mg/L was recorded at sample point B. There is currently no official guideline as to what is considered a safe level for conductivity (Karikari, Asante & Biney, 2007b).

The results of the dry season were not different from the wet season as the TDS values were also affected by the changing season. The values recorded in the Fosu Lagoon were 2383 Mg/L (the highest) and 2056 Mg/L (the lowest). Recording from the Essei Lagoon were not much different; the values were 16986 Mg/L (the highest) and 2232 Mg/L (the lowest). The results as presented are shown in Figure 28.

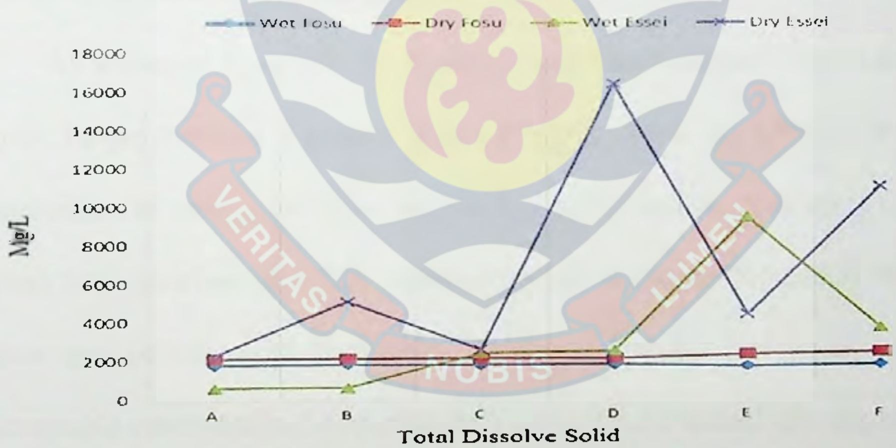

Figure 26: Total Dissolved Solids of the Fosu and Essei Lagoons by Seasons

Source: Field Data (2014, 2015)

Concentration of Heavy Metals in the Fosu Lagoon

Chemical pollution which is directly associated with heavy trace metal pollution may adversely affect the physical, chemical and biological properties of

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water. Values of trace heavy metals in the Fosu Lagoon were obtained using the spatial distribution software in GIS. The four metals that were found were lead, copper, magnesium and cadmium. All these were sampled in three parts between the years of 2014-2015. Heavy metal samplings were not done in Essei Lagoon because little or no fishing activities were done in it. Aheto et al. (2010) made the same observation when they conducted their studies on Butuah, Essei and Anankwari lagoons in the Western Region of Ghana. The concentrations of heavy metal levels were done in order to advice policy makers on the way forward and to determine the water quality status of the Fosu and the Essei Lagoons for both human and aquatic lives.

Lead Concentration in the Fosu Lagoon

As shown in Figure 27, the average mean lead concentrations in the Fosu Lagoon ranges between 1.3mg/kg and 2.6 mg/kg while the USEPA threshold concentration of lead in surface water was 3.0 mg/kg. Hence, comparing the Fosu Lagoon concentrations to USEPA concentrations, it can be concluded that Fosu Lagoon gets polluted with lead during the wet season and is even closer to the unacceptable concentration. According to Young (2005), leaded fuel deposited on roads by automobiles can be transported by runoffs into water bodies to cause an increase in lead in concentration. This can explain why the highest lead concentrations in the Fosu Lagoon occurred at points very close to the road and garages around the lagoon as well as where sand bar separates the sea from the lagoon. By implication, the Fosu Lagoon could be classified as polluted with lead

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and hence making use of resources from the lagoon can affect both the aquatic life and residents who consume fish and other resources from the lagoon.

During the second trimester, the lead concentration increased. This is shown in Figure 28. The concentrations were recorded at the same points as in the case of the wet season. The results indicated a lead concentration of 1.7 mg/kg to 3.2 mg/kg, slightly above the USEPA recommended threshold average range.

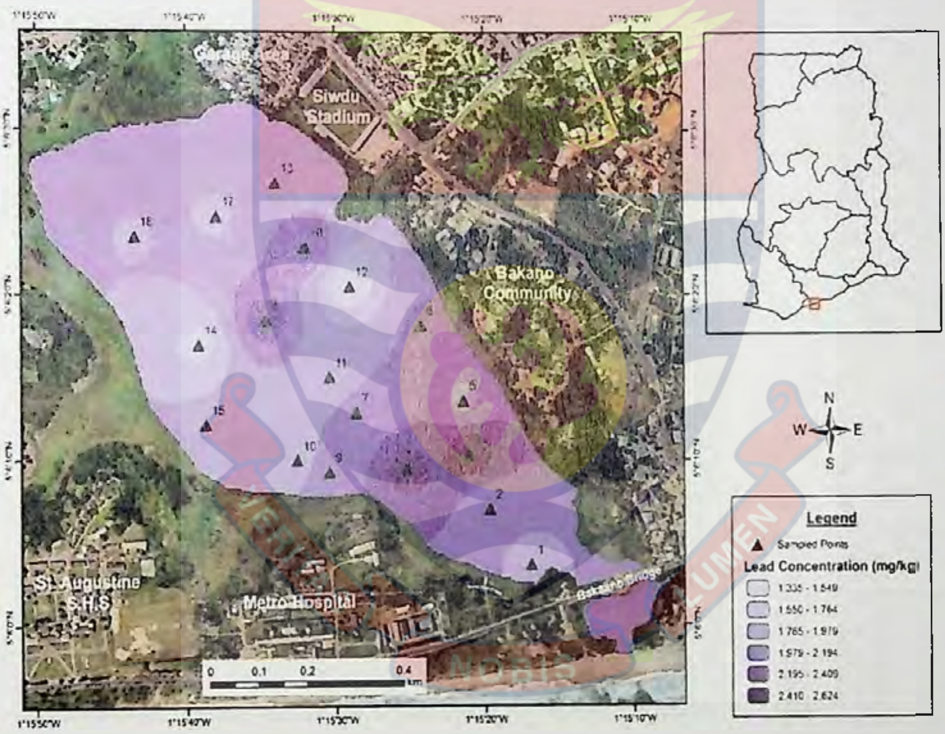

Figure 27: Lead Concentration in the Fosu Lagoon during the first Trimester

Source: Field Data (2014)

During the third trimester result was not different from the first trimester; values were between 1. 4 mg/kg and 2. 9mg/kg. The seasonal differences showed the disparity between the wet and dry season in the values recorded. The average

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lead recorded was not up to the standard threshold of 3.0mg/kg (USEPA. 1986). This result is slightly below the standard threshold. The second trimester value was higher than the last trimester. This probably was due to the dry season during which the second trimester data was collected. The result presented is shown in figure 30. According to Ramadan (2003), lead is an extremely toxic metal to man since it causes brain damage, particularly, to the young and boosts aggressive behaviour. Lead contamination affects man through air respiration (inhalation), water contamination from lead piping and from polluted fish stuff.

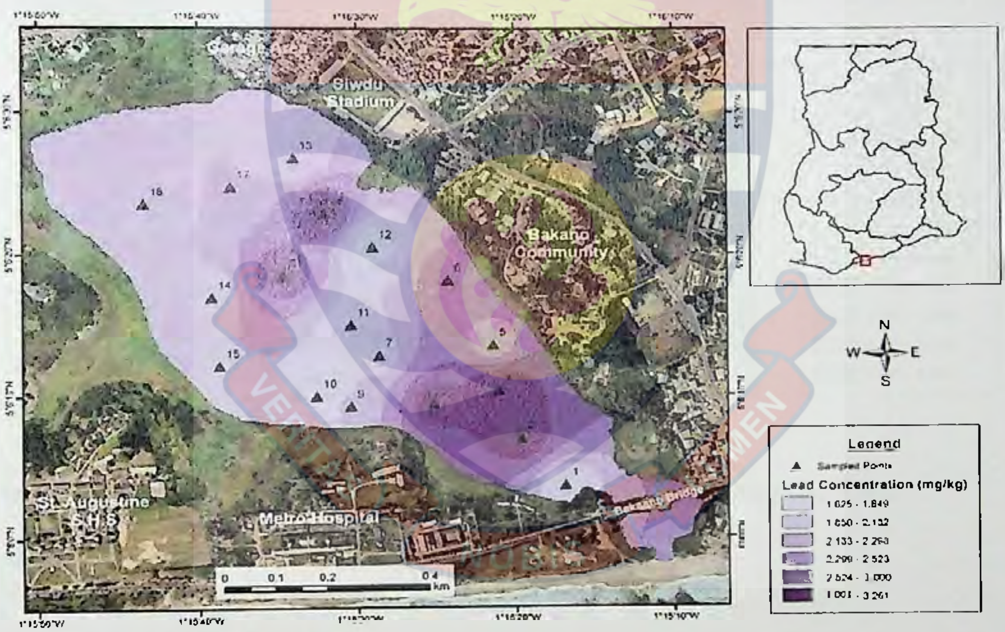

Figure 28: Lead Concentration in the Fosu Lagoon during the Second trimester

Source: Field Data (2014)

The seasonal variations are due to the strong environmental conditions of the lagoon. Seasonal rainfall and temperature variations affect the condition of the lagoon. Changes were observed in the different seasons with regards to the

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physico-chemical parameters and heavy metal concentrations. The high and low metabolic events affect the water quality and the aquatic ecosystem. The heavy metals levels caused the distribution and abundance of flora and fauna in the lagoon.

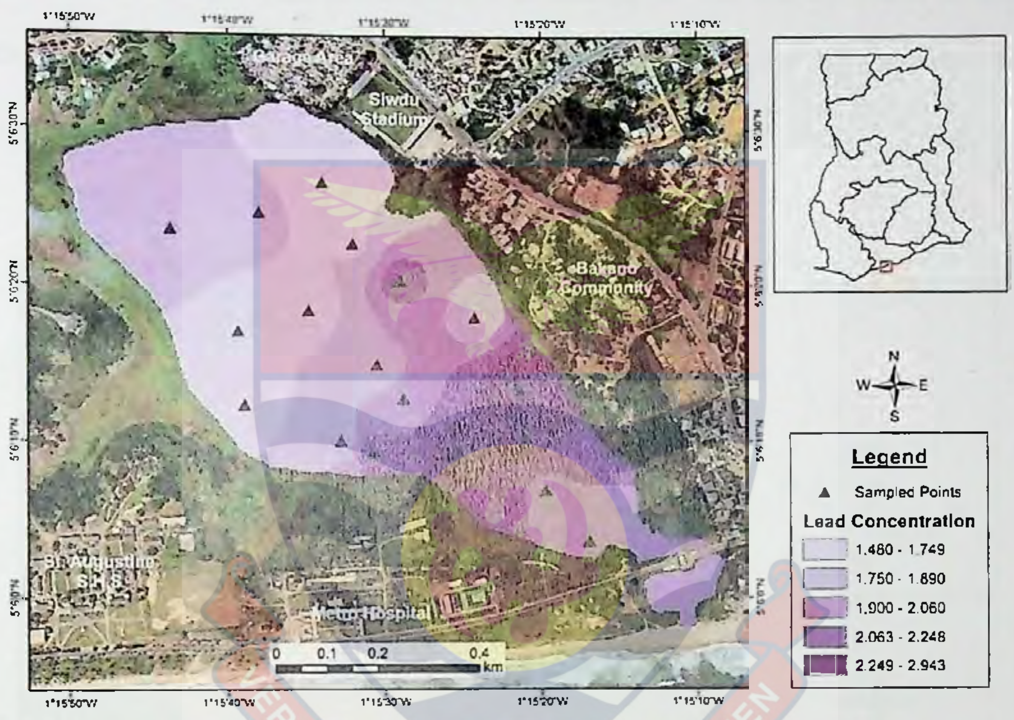

Figure 29: Lead Concentration in the Fosu Lagoon during the Last Trimester

Source: Field Data (2015)

Copper Concentration in the Fosu Lagoon

The sample of copper recorded in the Fosu Lagoon was the lowest concentrations in all samples the heavy metals. It recorded a range of 0. 128-0.397 mg/kg in the wet season. This is very low and poses no threat to human and aquatic life when compared with the USEPA threshold value of 65 mg/kg of

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copper in surface water as shown in Figure 30. The United States Geological Survey (USGS. 2004) avers that major sources of copper in aquatic environment are geological weathering and corrosion of plumbing materials and infrastructure. These low concentrations have no harmful effects on the lagoon and its ecosystem. Though the concentration was limited, it was mostly found at the mouth of the lagoon and that could be due to the seasonal lagoon and sea interaction.

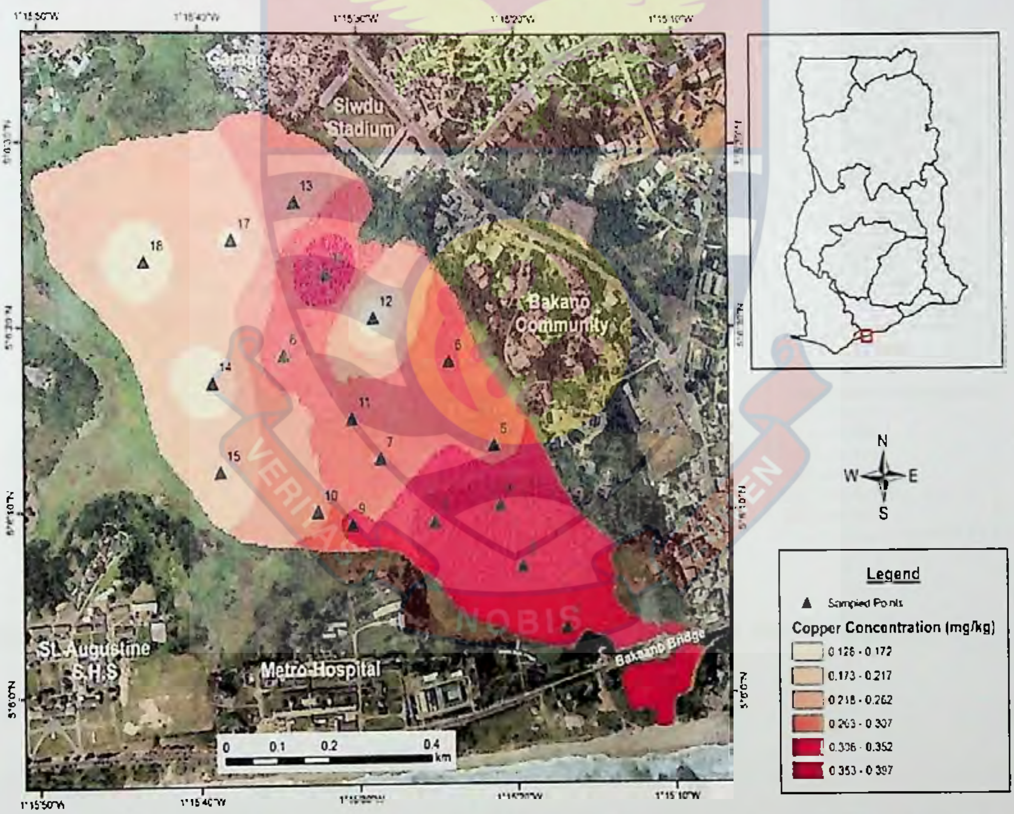

Figure 30: Copper Concentration in the Fosu Lagoon during the First Trimester

Source: Field Data (2014)

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In the second trimester there was an appreciable increase in copper concentration (ranging between the averages of 0.2 mg/kg to 0.5 mg/kg.) which is a little above the wet season range. As indicated earlier in Figure 31, the low concentrations of copper recorded in the samples have no harmful effects on the lagoon and its resources.

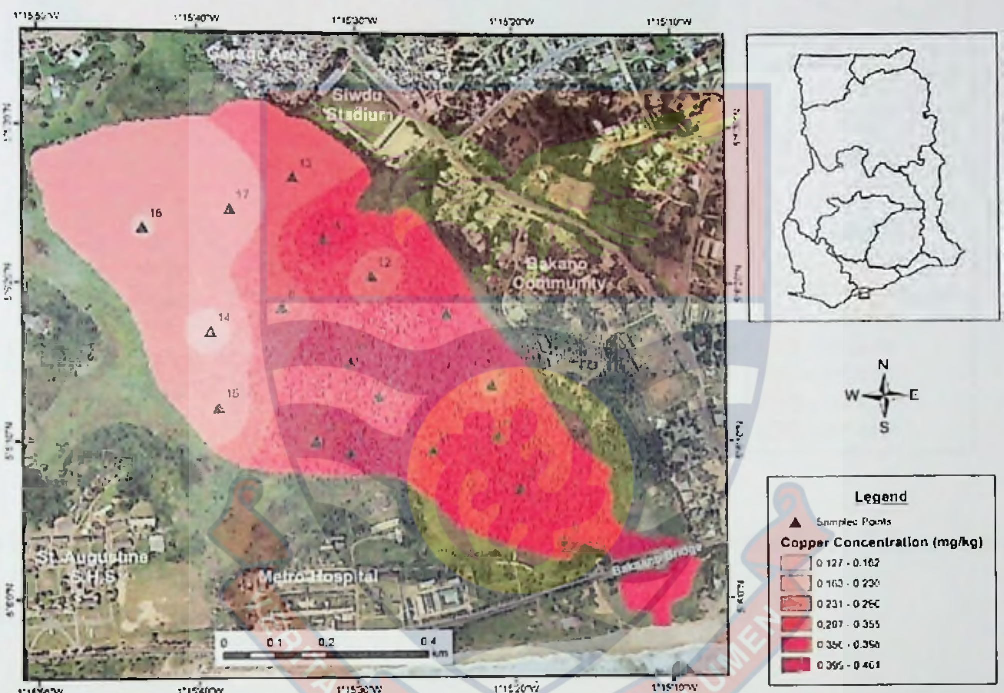

Figure 31: Copper Concentration in the Fosu Lagoon in the Second Trimester

Source: Field Data (2014)

The values of copper concentration recorded in the Fosu Lagoon for the last trimester is shown in Figure 33. Values ranged between 0.1mg/kg low to 0.4 mg/kg high and were slightly below the average of the second trimester. The low

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concentration was probably due to the dilution of the lagoon by rain water received from minor season rains.

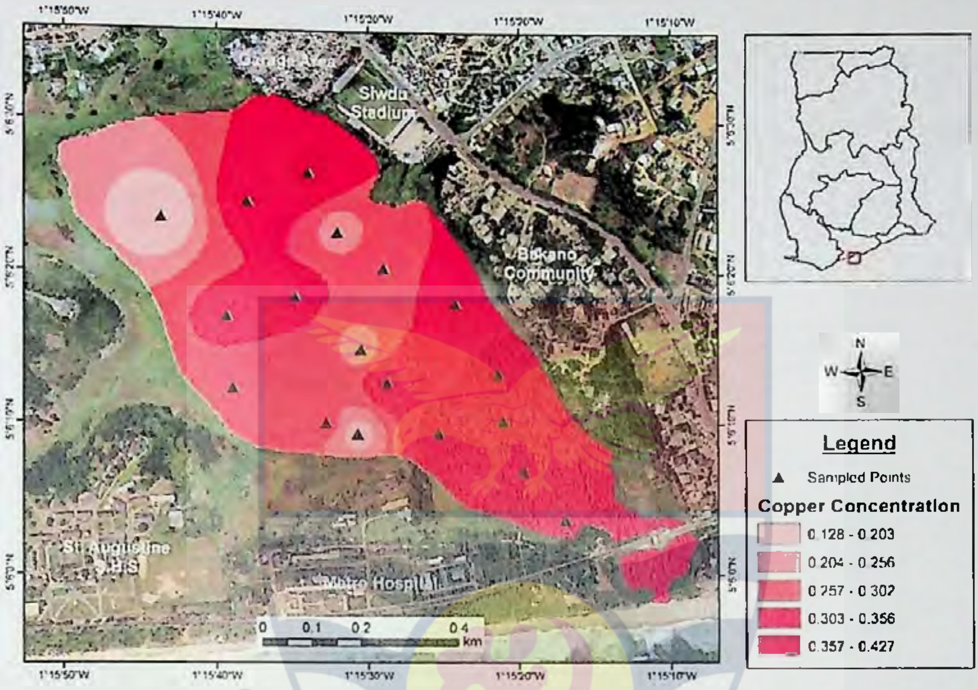

Figure 32: Copper Concentration in the Fosu Lagoon in the Last Trimester

Source: Field Data (2015)

Cadmium Concentration in the Fosu Lagoon

The mean concentration of cadmium (Cd) in the Fosu Lagoon ranged from 0.9 to 1.3 mg/kg as shown on Figure 33. The range obtained for the water is good per the standard0.05 mg/L Maximum Contaminant Level (MCL) (USEPA, 1986) for natural waters. The low concentration of cadmium in the samples poses no threat to the aquatic lives in the lagoon. Apart from natural sources like runoff from agricultural fields where phosphate fertilizer might be in use, other sources may include leachate from Ni-Cd based batteries. Cadmium are deposited into

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lagoons through the dumping of metal waste into; and along the banks of the lagoons, this may pose potential danger to metal toxicity in the lagoon. The Fosu Lagoon is located in an urban area and the industrial activities are gradually adding to the toxins in it. The geographical distribution of the metal is clearly seen behind the Siwdu stadium-end of the lagoon where there is massive deposition of industrial waste.

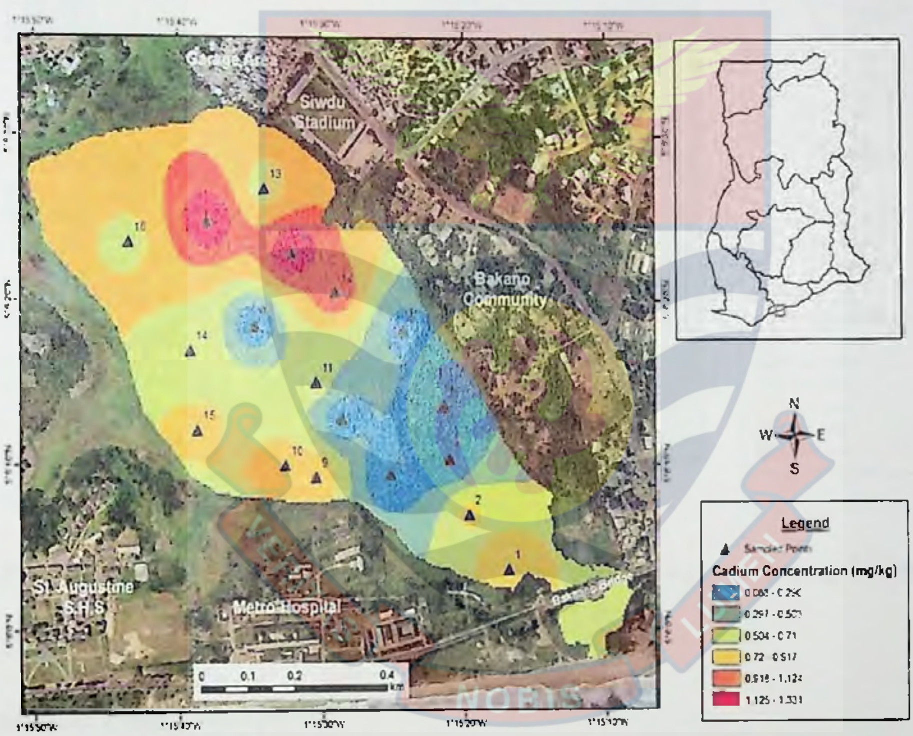

Figure 33: Cadmium Concentration in the Fosu Lagoon in the First Trimester

Source: Field Data (2014)

The corrosion of galvanized pipes on the canoes and other deposits, erosion of household waste such as batteries and paints from the town and nearby surroundings are the main sources of cadmium contamination in the Fosu Lagoon.

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The growth of water hyacinth and algae blooms are observed in the Fosu Lagoon most especially at the eastern portion of the lagoon's mouth.

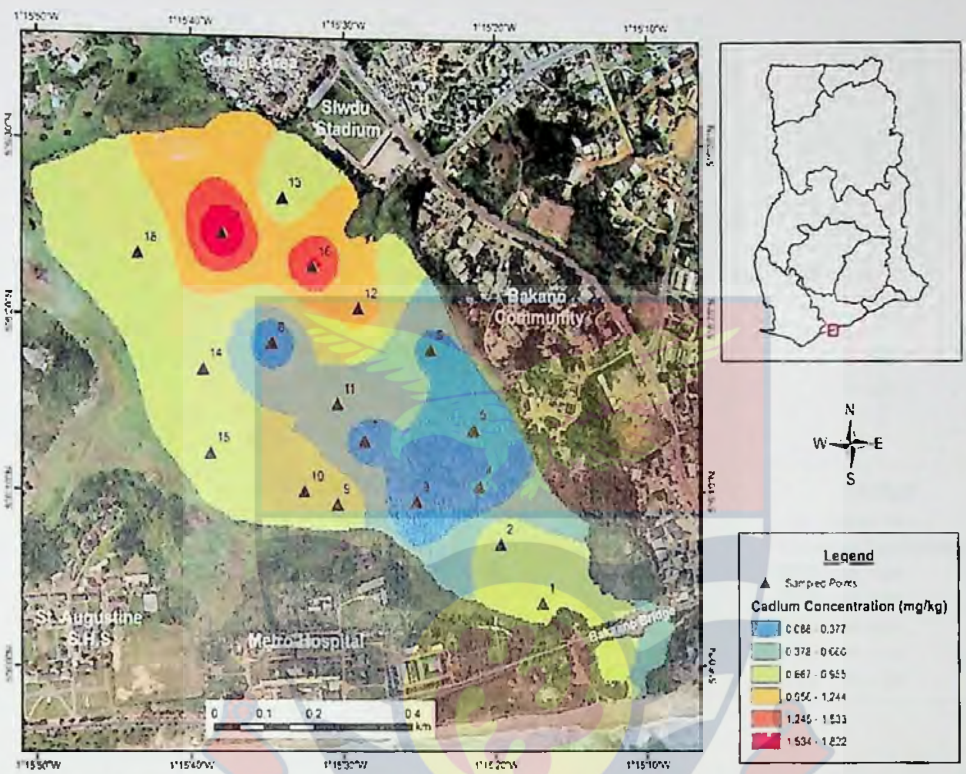

Figure 34: Cadmium Concentration in the Fosu Lagoon during Second Trimester

Source: Field Data (2014)

On the other hand, the values of cadmium concentration recorded for the second trimester showed some significant differences in concentration. The values recorded ranged between 0.1 mg/kg and 1.8 mg/kg which were higher than the EPA standard for cadmium concentration (0.05mg/kg) in lagoon. The high concentration of cadmium in fish from the Fosu Lagoon (1.8 mg/kg) is a possible indication of cadmium pollution in the lagoon as shown on Figure 35. The water

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quality status is generally degrading in effect and could have a significant impact on flora and fauna in the lagoon.

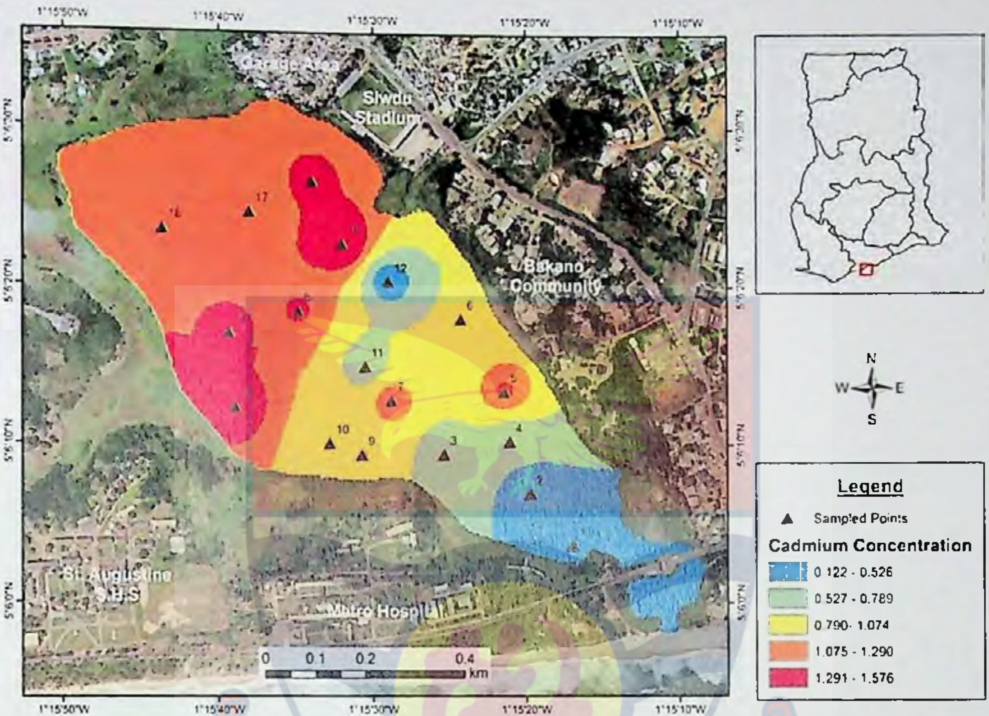

Figure 35: Cadmium Concentration in the Fosu Lagoon during Last Trimester

Source: Field Data (2015)

There was not much deviation of concentration of cadmium in the last trimester result as shown in Figure 35, as 0.1mg/kg - 0.6mg/kg. The dissolution of the metal again happens behind the Siwdu part of the lagoon, where the previous concentrations were recorded. This latest results is a little above the EPA standard cadmium concentration of 0.05mg/kg. This affirms the earlier results on the pollution of the lagoon by cadmium.

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Manganese Concentration in the Fosu Lagoon

Manganese (Mn) concentration value of 0.7mg/kg -0.8 mg/kg in the Fosu Lagoon during the first trimester is shown in Figure 36. The high value of 0.8 mg/kg was recorded in a sample upstream of the lagoon area. However, no known threshold value exists for Mn in surface water. The highest recorded for the seasons could mean that, the activities of the garages close to the lagoon are releasing some metal pollutants including Mn into the lagoon thereby making the lagoon polluted with manganese.

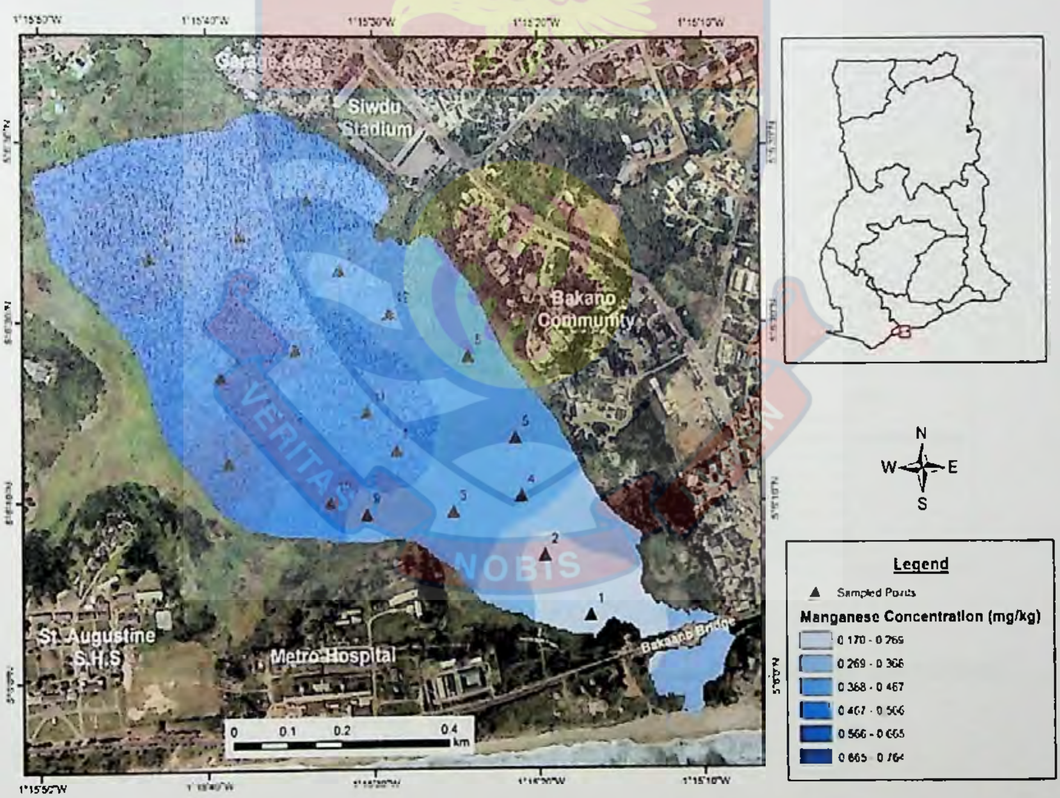

Figure 36: Manganese Concentration in the Fosu Lagoon at the First Trimester

Source: Field Data (2014)

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The lowest concentration recorded was in the range of 0.2mg/kg - 0.3mg/kg along the mouth of the lagoon and this is largely due to the interaction with the sea at the point of annual breaching. The abundance of manganese in the earth can also contribute to the high levels in the samples. Though the results in Figure 37 show an increase in quantity, there is no known tolerance level and hence constitutes low risk to the ecosystem's health.

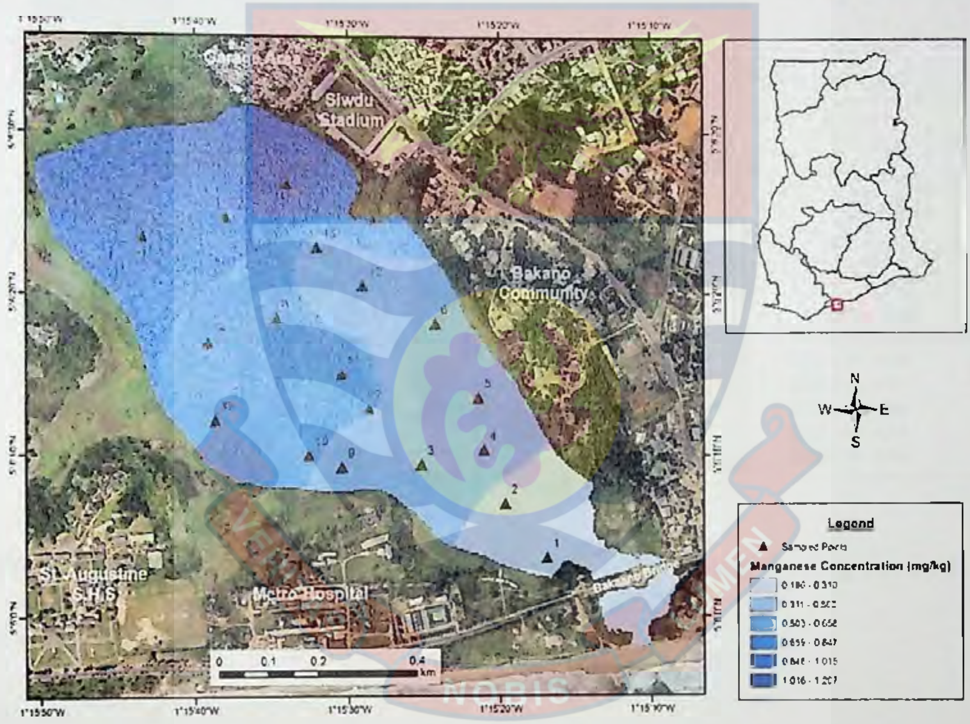

Figure 37: Manganese concentration in the Fosu Lagoon during the second trimester

Source: Field Data (2014)

The average concentration of manganese during the third trimester was between the ranges of 0.2mg/kg -0.9mg/kg. The result is a true reflection of the minor raining season in southern Ghana which seems to support the seasonal

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variability in the distribution of heavy metals. The result is shown in Figure 38. Comparing the first two trimester's result with the last trimester, one can inferred that, the results if the last trimester is lower than the first two trimesters.

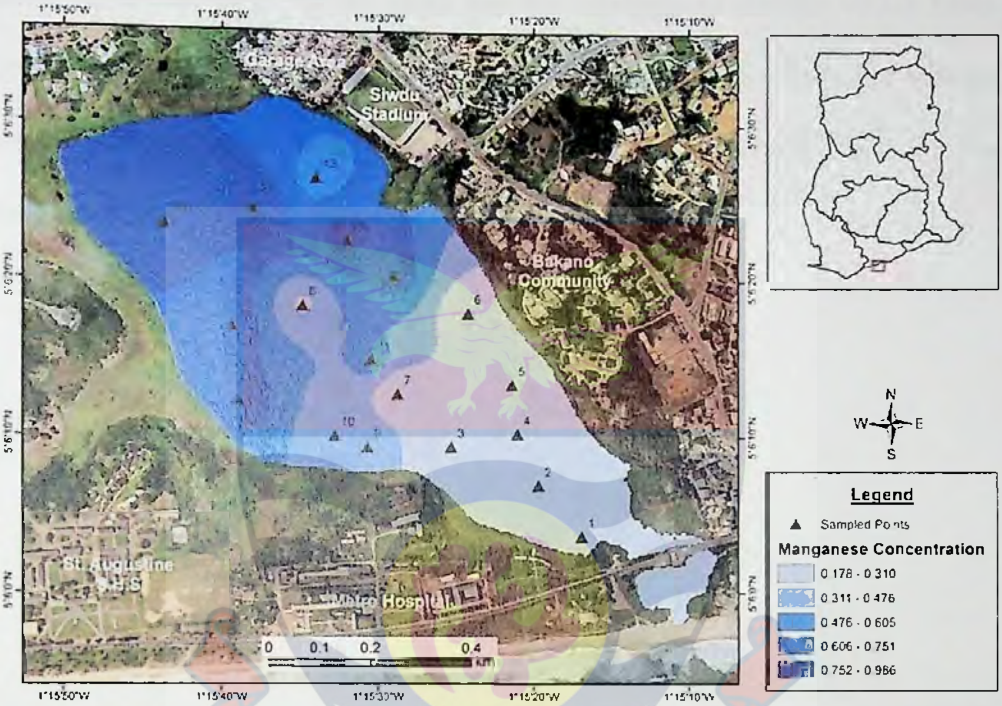

Figure 38: Manganese Concentration in the Fosu Lagoon during the Last Trimester

Source: Field Data (2015)

Summary

This chapter concerns the water quality status of the Fosu and the Essei Lagoons. The application of geographic information system and remote sensing using the Kriging method contributed to the presentation of seasonal variability in the distribution of the various heavy metals in the Fosu lagoon. Though the concentration of the heavy metals were low, the real situation that exists at the

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Lagoonal environment was horrible as human activities continue to impinge on the ecological health of the lagoons. The water quality status of the lagoons was deteriorating due to human and natural activities. In the case of the Fosu lagoon, fishing is still ongoing but the catch per trip continue to decline whilst Essei Lagoon is completely cut off from fishing due to poor or little catch per fishing. The next chapter is solely devoted to the stressors and factors influencing the selected lagoons.

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CHAPTER SIX

FACTORS CAUSING THE CHANGING PHYSICAL FEATURES OF THE FOSU AND THE ESSEI LAGOONS

Introduction

This chapter describes the factors causing the changing physical features of the Fosu and the Essei Lagoons, and the management arrangements or alternatives available. Urbanization, industrial processes and lagoon management issues, including local knowledge and activities of managing institutions and stakeholders are described. The bottom-up approach to coastal lagoon management is proposed for coastal lagoons' management in Ghana.

Changing Physical Features of the Fosu and the Essei Lagoons

Driving forces (are any natural or human-induced) factors that cause a change in an ecosystem (WRI, 2005). The identification of the factors causing the changing physical features helps researchers to estimate the future changes and to understand the causes of past occurrences. Observations, and in-depth interview with respondents by the present researcher revealed that the factors that caused the changing physical features of the Fosu and Essei Lagoons biophysical environment included shoreline morphology modification, loss of vegetation cover, aquifer pollution, groundwater depletion and salinisation, fresh water pollution, river sediments increase, and river discharge increase.

Changes observed in the socioeconomic environment included population increase around the lagoons, salt marshes destruction, infrastructure expansion, increased in areas reserved for dry land cropping; increase in surface left for

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intensive agriculture, decrease in protected areas decrease and decrease in protected heritage. The factors causing the changing physical features observed in the study are discussed below.

Sewage Discharges from Residential and Industrial Areas of the Fosu and Essei Lagoons in Ghana

Many sewage treatment and untreated plants in Ghana discharge waste into coastal lagoons (EPA, 2000). It was observed that domestic and industrial treated or untreated wastes were being discharged from various points into the Fosu and Essei Lagoons. Observations were that raw sewage discharges during heavy rainfall remained a problem in many areas along the Fosu and the Essei Lagoons. Plates 4a and 4b show sewage discharge in the two lagoons. The discharge materials were from houses and from waste treatment systems into the lagoons. The sewage effluent was quite high in organic matter and nutrients and therefore, caused water quality degradation primarily through eutrophication, oxygen depletion and elevated turbidities (Coughanower, 1995). Discharges probably resulted in large growths of algae, which sometimes extended to a few kilometres from the outfall and have led to species loss and reduced diversity in the natural algal communities (Brown, Davies & Synnot, 1990). The presence of algae blooms of cyanobacteria and toxic microalgae probably have also been triggered off by the high nutrient loads which subsequently have contaminated and in extreme cases, caused mortality of shellfish. Plate 4a and 4b below show that communities (Bakano, Siwdu, Bakakyir) living along the lagoons direct waste into the lagoons. An investigation conducted at the Essei Lagoon for

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instance revealed an incident where households around the lagoon discharged faecal matter into the lagoon to be washed by the waves during high tides. That behavioural practice degraded the quality of the water.

Plate 4a: Sewage Discharges around Fosu Lagoon

Plate 4b: Sewage Discharge around Essei Lagoon

Source: Field Data (2015)

Urban Run-Off into the Fosu and Essei Lagoons

According to Armah, Luginaah, Kuitunen and Mkandawire (2012) waste from agricultural and other human activities have changed the conditions in the Fosu and the Essei Lagoons. The mechanic workshops near the Fosu Lagoon are sources of heavy metals, and polycyclic aromatic hydrocarbons. An interview by the present researcher with a mechanic at Siwdu revealed that dirty oil and other

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waste products (both solids and liquids) are intentionally discharged into the lagoon. Similar observations were made around the Essei Lagoon.

One respondent recounted how waste from garages and near-by industries such as the Amin Sangari Soap Factory in Cape Coast are directed into the Fosu Lagoon. Essei Lagoon has a number of household's discharging their human excreta directly into the lagoon. Interviews by the present researcher with the Head of research at Friends of the Nation in Sekondi-Takoradi showed how poorly untreated urban wastes are managed in the areas around the lagoon. The Head indicated that very often when it rained people just dumped the waste they have generated in their houses into the run-off to be emptied into the lagoon.

The impacts on the lagoon from the untreated household waste waters included; nutrient enrichment and eutrophication, bacterial contamination, oxygen depletion, elevated turbidity, siltation, and acute and chronic toxicity (Scott, 1996). Algae growths are accumulated in the beach areas, forms large decomposing drifts, and smothered benthic habitats (Edyvane, 1995). Stormwater discharges have also caused seagrass loss, mangrove and saltmarsh dieback, and increasing frequency of 'red tides' formed by blooms of microalgae (EPA, 1998; Macdonald, 1995). These impacts have probably occurred as a result of reduced light attenuation associated with turbid waters and smothering of seabed and tidal flats by sediments and algae growth. Plastic litter discharged from stormwater outlets have also impacted on biota negatively because debris entering the coastal environment harms fish, marine mammals and seabirds through ingestion and entanglement.

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Urban Agricultural Land Use and Run-off along the Fosu and Essei Lagoon

Several backyard agricultural activities were observed around the Fosu and Essei Lagoons. These urban agricultural practices normally used chemicals in their farms. These urban farmers were involved in the cultivation of crops such as plantain, cassava, sugar cane, coconut and other perishable leguminous crops. There was also land reclamation for agriculture and other rural industries such as charcoal making, for building garages and workshops. Construction of houses was observed to be one of the causes of the increasing catchment run-off. The run-off contained animal waste, fertilisers, pesticides, weedicides that were major sources of elevated sediment and nutrient loadings.

According to Edgar (2001), high levels of dissolved solids and nutrients in agricultural run-off result in degradation of water quality and were connected with the loss of seagrass. Associated nutrient enrichment also caused algae blooms which were very common in parts of the Fosu lagoon. While blooms are natural phenomenon, they appeared to have increased in frequency and extent as a result of increased nutrients from agricultural areas and may cause considerable environmental damage. It was observed during the data collection that a garage owner was attempting to reclaim a portion of the lagoon at the back of the Siwdu sports stadium in Cape Coast for the construction of a mechanic shop. All these activities degraded and impinged on the state of the lagoons.

Altered Water Quality of the Fosu and the Essei Lagoons

Observation by the present researcher show that chemical contaminants, pathogens, nutrients, suspended solids and organic matter that entered the marine

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environment have markedly lowered water quality in many parts of the lagoons. In the case of the Fosu Lagoon, water hyacinth and algae blooms appeared during the dry season, a clear manifestation of the poor water quality of the lagoon. An interview by the present author with the Central Regional EPA Director in Cape Coast revealed that whenever water hyacinth appeared on the lagoon as a result of accumulation of waste, residents reported to them and in most cases the lagoon was breached to allow sea water to mix with the lagoon water. The chief of Bakano in Cape Coast confirmed the answer by the EPA Head when he said that on many occasions they reported the growth of water hyacinth to the EPA but no concrete decision was ever taken on it. One fisher man recounted that such developments are due to the dirty oil discharged into the lagoon by the garages or mechanic shops along the lagoons. The aggregate effect of these inputs into the lagoons are that water quality conditions frequently do not meet recommended criteria for protection of aquatic ecosystems (Coughanower, 1995).

Reclamation and Redevelopment of the Fosu and Essei Lagoons

Observation and in-depth interview by the present researcher with stakeholders showed that land reclamation had occurred around the Fosu and the Essei Lagoons for the purposes of industrial, residential, tourism and recreation developments, and establishment of refuse disposal sites and construction of roads and other public facilities as shown on Plates 5, 6a and 6b. In the case of the Fosu Lagoon a number of tourist centres were found in the catchment area of the lagoon which were not previously there. In the case of the Fosu Lagoon, land reclamation and redevelopment around the lagoon was observed as a number of

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mechanic shops were springing up around the mouth of the Fosu Lagoon and the central portion of the Essei Lagoon from the bridge that leads to Sekondi-Takoradi. A fisherman who works in the Fosu Lagoon reported that due to the quantum of noise being made at the site aquatic resources were disturbed. The construction of the sea defence wall at the Essei Lagoon had its impacts on marine and estuarine habitats. According to Edgar, (2001) habitat and biological productivity are permanently lost by the removal of inter-tidal and nearshore sections of the seabed for harbour and sea defence wall.

Observation by the present researcher along the Essei Lagoon showed that land reclamation was a significant contributory factor to the decline in the lagoon resources, particularly seagrass beds and was one of the causes of mangrove and salt marsh declines along the lagoon. Residents harvest the mangrove for charcoal making.

Plate 5: Portion of the Essei Lagoon Reclaimed as a Football Field

Source: Field Data (2015)

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The Fosu and Essei wetlands are vulnerable to damage and yet have frequently been reclaimed for industrial and agricultural activities, and to be used as waste disposal sites.

Land reclamation and redevelopment have led to loss of habitat for aquatic species, wetland birds and degradation of water quality. The state of the lagoons as a result of land reclamation for mechanic shops, tyre repair centres, residential accommodation and other usages have resulted in reduction and pollution of the lagoon. Plate 6a shows the portion of the Essei Lagoon that have been used as a sea defence wall to prevent flooding of the communities along the lagoon. The plate also shows part of the land that have been used for building house for residential accommodation. Plate 6b on the other hand shows areas along the Fosu Lagoon being used as tyre repairing shop.

Plate 6a: Land Reclamation and Redevelopment along the Essei Lagoon

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Plate 6b: Land Reclamation and Redevelopment along the Fosu Lagoon

Source: Field Data (2015)

Application of the DPSIR Framework to the Fosu and the Essei Lagoons

Table 6 shows the application of the DPSIR framework to the study of the Fosu and Essei Lagoons. The first part of the framework is the drivers (D). Drivers are the direct and indirect factors that affect the lagoons. By the application of the DPSIR framework the drivers observed by the researcher were the establishment of industries along the lagoon, urbanisation and infrastructural developments and climatic changes through increase in temperature and reduction in rainfall around the Fosu and Essei Lagoons catchment areas. The second part of the framework is the pressure. The pressures (P) observed along the lagoons were industrialisation in the form of an increase in the number and magnitude of industrial establishments including tyre repairs, carpentry shops, recreation and tourism facilities etc. along the lagoons.

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The state (S) is the third aspect of the framework and talks about the current conditions of the lagoon. The state of the lagoons at the point of data collection was changes in salinity, contamination by heavy metals, changes in sediment and biogeochemistry of the lagoons. The fourth aspect is the impacts (I) which talks about the changes that have occurred in the lagoons. The impacts observed were altered freshwater or saline water equilibrium, reduced water quality, damage to aquatic and biota resources due to contaminants. The following were the recommended policy response (R) to reduce the impacts. The response was decrease industrial density; increase treatment level for industrial waste water, increase waste water reuse and development of buffer zones around the lagoons.

Table 6 again indicates the effects of urban and infrastructural developments as a driver to change and the following were observed. The pressures discovered by the study were, increase in residents population (GSS, 2010) coupled with wastewater production, water consumption, reclamation for shops and houses. The state of the lagoons was heavy metal contamination in the case of the Fosu lagoon, changes in sediment and composition with both the Essei and Fosu lagoons and biogeochemistry of the lagoons. The impacts on the lagoons were shown as poor freshwater/saline water equilibrium, reduced water quality, damage to aquatic biota due to toxic contaminants. The following were the recommended policy response by the stakeholders; decrease industrial density, increase treatment level for industrial wastewater, increase waste water reuse, develop buffer zones around lagoons.

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Table 6: Application of Driver, Pressure, State, Impact and Recommended Policy Response in the Study Areas

Driver	Pressure	State	Impact	Recommended policy response
Industry	Increase in number and magnitude of industrial establishments: tyre repairs, carpentry shops etc.	Changes in salinity Eutrophication Contamination by heavy Metals, Changes in sediment and composition and biogeochemistry	Altered freshwater/saline Water equilibrium Reduced water quality Damage to aquatic biota due to toxic contaminants	Decrease industrial density; Increase treatment level for industrial wastewater Increase wastewater reuse; Develop buffer zones around lagoons
Urban and Infrastructural development	Increase in resident and seasonal population wastewater production freshwater consumption wetland reclamation for shops and houses	Eutrophication Contamination by heavy Metals, Changes in sediment and composition and biogeochemistry	Altered freshwater/saline water equilibrium Reduced water quality Damage to aquatic biota due to toxic contaminants	Decrease industrial density Increase treatment level for industrial wastewater Increase wastewater reuse Develop buffer zones around lagoons

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Climatic variability	Temperature increase and changes in rainfall patterns (increased frequency of high intensity rainfall events, increased number and duration of dry periods).	Changes in oxygen solubility and budgets, Changes in nutrient budgets Changes in suspended particulate matter, Changes in water budgets due to extreme single event drought/flood	Altered freshwater/saline water equilibrium Sediment erosion and loss of habitats Threats to biodiversity Alteration of biological cycles Biological invasion	Increase the level of land protection measures Riverbed and stream

Source: Adapted from Arthurton, Odada, Salomons and Marshall Crosslandet (2002)

Source: Field Data, (2015)

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In Table 6, the complexity of the interactions between factors causing the changing physical features is shown. This was also confirmed by content analysis and remotely sensed data which depicted that domestic activities and industrial setup were the most impacting driving forces causing the numerous changes that had occurred in the lagoonal environments. Cultural practices had produced little changes on the lagoon as in the case of the Fosu Lagoon and the Oguaa Fetu Afahye as modernisation is shaping the mind-set of residents.

Plate 7: Domestic and Industrial Activities around Fosu and Essei Lagoons

Source: Field Data (2015)

Threats to the Fosu and the Essei Lagoons

The respondents met by the present author were unanimous on the threats that both human-induced and the natural processes have on the lagoons. The threats reported were:

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- Use of small mesh nets in the beach seine fishery and other illegal fishing methods in the lagoons;
- Loss of coastal habitat through establishment of backyard farms;
- Destruction of wetlands for infrastructure development;
- Solid waste disposal into the lagoons;
- Harvest of mangrove forests;
- Beach sand wining; and
- Tourism development along the lagoons.

Inspection of the coast showed that the mangrove cover along the Fosu Lagoon had been lost as a result of human activities. The garages along the Fosu and Essei Lagoons and their activities contributed to the deposition of oil into the lagoons. Increasing population density which could bring about an increase in the rate of exploitation of resources of fragile ecosystems and the high dependence on the coastal resources was also identified by the respondents as a major threat to the lagoons. The weak governance, legislation and institutional framework due to the fragmented nature of environmental legislation and lack of political will to enforce legislation were also mentioned by respondents as threats to the lagoons.

An interview by the current researcher with the Wildlife Manager at Sekondi-Takoradi showed that, the management of Fosu and Essei Lagoons were threatened by power and influence. Power, according to the Wildlife Manager is held by the government and the influence by the local people (in the form of economic, social and political as they are the custodians of the lagoon) and their influence may impinge on the resource in a positive or negative manner. It was

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explained that with respect to power and stakeholders, we look at it from two angles: 'power' and 'influence'. One stakeholder may be quite powerful but the influence may be less, another stakeholder may have a high influence but limited power.

The Wildlife Division, Ghana, according to the person the author interacted with possesses high power, the district assembly are very high power as they represent the government at the local level, but then their influence compared to the local community is low though the local community have the lowest power, their influence is quite high, so if one draws a chart of power and influence one would realised that the local communities are the most influential stakeholders. So when any individual or organisation draws a plan of action in his/her office one needs to have their local community's support to be able to implement it. There is therefore a need for political, social and economic balance in decision making towards the effective management of coastal resources. The wildlife manager mentioned that, they were challenged in the form of logistics, personnel, finance and limited commitment from the government and local communities. This in a way affects the delivery of their mandate as an agency.

The chief of Bakano in Sekondi revealed that the occurrence of densely populated urban communities around the peripheries of Essei Lagoon and the associated dumping of untreated sewage and agricultural waste have tremendously impacted on the lagoon environment in terms of their area extent (encroachment) and the quality of the lagoon. It can therefore be concluded that

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the major cause of these threats are mainly attributed to the increase in human pressure along the lagoon.

Monitoring the Fosu and Essei Lagoons Based on Tenure and Protection Status

The lagoons were monitored based on nature of tenure and their protection status. The respondents who are mostly coastal experts and residents shared their views on the status and tenure of the lagoons. These findings were obtained by the current researcher from interviews with key informants, including fishermen, traditional council members and through observations by the researcher. Table 7 shows the results as reported by the respondents.

Table 7: A Year monitoring of the Fosu and Essei Lagoons based on Protection Status

Attribute	Essei	Fosu
Type of water body	Man-made open lagoon	Classical closed lagoon
Tenure	Public property expected to be managed, protected and held in trust for the people by the District Assembly	Not well defined and may be regarded as mixed tenure between public ownership, customarily owned or Stool lands

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Table 7 contd.

Protection status of water body	Legally protected by law as a Public Good but not gazetted as a nature reserve	Legally protected by law as a Public Good but not gazetted as a nature reserve
Protection measure	Presently no protection measure	No known managed protection for Public lands. Some areas of Public lands are encroached by private people and there is no well-defined protection status for customarily-owned areas.
Land use	Settlements, small-scale business enterprises e.g. provision kiosks, drinking bars, dump sites for scrap metals, car washing places, mechanic shops, agriculture, hotel infrastructure	garages, settlement, fish landing sites, educational institutions, small-scale economic activities and land preparation for industrial establishment, hospital

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Table 7 contd.

Drainage	Several open drains from settlements	Several open drainages exist from nearby settlements into the lagoon.
Access/ fencing	Free access granted, anyone could swim or fish in the lagoon. He/ she may even openly mine sand without being questioned by anyone. No fencing	Free access granted. No fencing

Source: Field Data (2015) and adapted from Aheto et al (2010)

Current Sustainable and Management Thinking on Coastal Lagoons

An interview by the current researcher with the Research Officer at Cape Coast Municipal Assembly (CCMA) which was confirmed by the EPA Director at Cape Coast revealed that, the Wildlife Division under the Forestry Commission Ghana has been mandated to oversee the day- to- day monitoring and management of the lagoons. They are to approve projects, monitor projects, facilitate stakeholder consultation and provide education and sensitisation in consultation with the EPA. Though these policy frameworks exist, there seem to be lack of coordination among the stakeholders involved in monitoring these lagoons. There is limited commitment among them; this is borne out of lack of logistics such as vehicles, equipment,

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conflicting view on approaches and practices, lack of qualified personnel and funds for their activities (as shown on Plate 8).

The dynamic and interactive nature of coastal environment is difficult to manage, especially when standards and frameworks are placed at a national level (Hart & Bryan, 2008). Recognising that local communities are the first to feel the effects of any environmental injustices within their catchment area, (Ekow & Adu-Boahen, 2014), local communities can be very effective in improving the efficiency of any implemented managerial activities. According to Steenson (2010), local knowledge is a vital linkage that seeks to provide feedback between local scale management and the environment. The author applied this philosophy when investigating a Rakaia Hut Community in New Zealand on their management of coastal lagoons.

Plate 8: Poor State of a Vehicle at STMA

Source: Field Data (2015)

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In the case of the Fosu Lagoon, the local people in a way manage the lagoon by breaching the sand bar during the Fetu Afahye and also by clearing the water hyacinth when they developed in the lagoon. Other beliefs and cultural practices governing these lagoons such as avoidance of sand wining, use of small mesh nets, cutting of mangroves are flouted by the fishermen and other users. The evidence from the study shows that the current management at all levels (national, regional, and local) do not promote sustainable coastal lagoon management in the case of the Essei and Fosu Lagoons. An interview with a fisherman at the Fosu Lagoon which was confirmed by the monitoring officer EPA office in Cape Coast revealed that whenever there is any incidence of water hyacinth development, it is reported to the EPA and no practical action is taking after the report.

In the case of the Essei Lagoon, sign boards are being developed by an NGO, Friends of the Nation to educate and sensitise the public about the need to conserve the lagoon for its sustainable use. Although efforts towards integration and holistic thinking are being developed particularly at the regional and local levels, the impact has been minimal. It is a reality that government has a plan for Ramsar sites in Ghana, including Muni, Songhor, Densu, Keta etc but no such plans exists for the other lagoons that do not belong to the Ramsar convention. The study results revealed that an integrated management of the coastal lagoons can only be achieved at the local-scale when there is public involvement in the decision making process. This can be manifested through a bottom-up approach. It shows that applying local knowledge and memory is no doubt the best option available to coastal zone managers. It was established that local people are not very much

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involved in the management of the lagoons under study. The local knowledge and values and memory in this facet is not treated as valuable resource. The values and interest of the local people are not given the premium or opportunity for the management of the lagoons.

The interview with the respondents revealed that, the most important factor that that caused the continued pressure on the Fosu and the Essei Lagoons is the notion that they are common property resource. Although the resource serves common ecological functions and benefits the communities at large, no individual takes responsibility or is accountable for health of the lagoons. A resource with such characteristics cannot be managed merely by enacting laws and regulations. Awareness and participation of key stakeholders in its management are central to their sustainability. On-going initiatives such as the development of master plans, management plans and policy statements are noteworthy but are not able to sustainably maintain the health and the integrity of the lagoons. The result of the narrations show revealed that, the ecological health of the lagoons are being compromised and hence degraded.

Suggested Management Plans by Respondents

The respondents made considerable suggestions on managing the Fosu and the Essei Lagoons and by extension lagoons in Ghana. Some of the suggestions are discussed below.

Education and Sensitization

The respondents were of the view that to ensure the sustainable management of lagoons, there is a need for education or sensitization and

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dialogue to make local people feel belonged and value the lagoons as basis of their livelihood and survival. The respondents envisaged that in order for people to show ownership of the Fosu and the Essei Lagoons and manage them well, government, civil society based organisations, academics and other national and international level stakeholders should begin to think like the local people. This could be an appropriate time to address the situation holistically and the people are likely to show ownership of the resource at their disposal. According to Steenson (2010), local residents have wealth of knowledge about their environment and they also depend on it for their livelihood, hence their values, interests, and concerns should be the basis of local management and should be an integral part of the decision making process. This fact was also supported by the Wildlife Manager at the Second Metropolitan Assembly.

Empowering the Traditional and the Local Authorities

Coastal lagoon management in the case of the Fosu and Essei Lagoons is based on the traditional management approach where there is a chief, usually hereditary in lineage, who functions as a custodian or caretaker and the lagoon is controlled, managed, regulated and monitored by taboos and outright bans and, in some cases, customary laws and practices. The present study indicated that education, religion and modernisation as well as economic conditions have changed the paradigm on which this traditional management approach operated. The chiefs and the traditional leaders do not have power again as every individual sees the lagoons as a common property. Hardin (1968) argued that natural resources held in common are subject to massive degradation because they are

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exploited as if there was no limit. This proposition by Hardin (1968) is evident in the study areas, as every individual in a way claim possession or ownership of the lagoons and decides on its usage in his or her own will and interest. This in a way has degraded and polluted the Fosu and the Essei Lagoons.

The degradation of the Lagoons are due to lack of regulation on access to resources held as open. The tragedy in many cases occurred only after existing communal land or water resources had been transformed, weakened or destroyed as a result of processes following culture contact. Hardin (1968) argues that users of a commons are caught in an inevitable process that leads to the destruction of the resources on which they depend. According to Berkes (1989); Feeny, Berkes, McCay and Acheson, (1990) the common property (common pool) resources share two characteristics: (a) exclusion or the control of access of potential users was difficult and (b) each user was capable of subtracting from the welfare of all other users These two universal characteristics of commons are referred to as the exclusion problem the ability to exclude people other than the members of a defined group and the subtractability problem (refers to the ability of social groups to design a variety of mechanisms to regulate resource use among members). Ostrom, Dietz, Dolsak, Stern, Stonich and Weber (2002) define common-pool (or common-property) resources as those in which (i) exclusion of beneficiaries through physical and institutional means is especially costly and (ii) exploitation by one user reduces resource availability for others.

Common property or common-pool resources may be held in one of four basic property rights regimes:

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- Open-access is the absence of well-defined property rights. Access is free and open to all;
- Private property refers to the situation in which an individual or corporation has the right to exclude others and to regulate the use of a resource;
- State property or state governance means that rights to the resource are vested exclusively in government to control access and regulate use;
- In communal-property (or simply common-property) regimes, the resource is held by an identifiable community of users who can exclude others and regulate use; and

The current study fits very well in the open-access regime where access to both the Fosu and the Essei Lagoons are free without any restrictions. The residents and other users determine when and how to use the Lagoons for their own benefits.

It should be recognised that these four regimes are ideal, analytical types. In practice, resources are usually held in mixed combinations of property rights regimes. The current research on the status of the Lagoons revealed a missing link in the sense that, the protection of the Lagoons is shrouded in the commons philosophy, thus the open regime and every individual claim ownership, making the management of the lagoons problematic. However, according to Feeny et al. (1990), there is a general consensus that long-term sustainability is not possible under the open access regime and hence resources are depleted under such regimes. The issue of commons tragedy pertains in the Fosu and the Essei Lagoons in Ghana.

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The commons regime become highly visible in the sense that the ownership of the Fosu and the Essei Lagoons are always contested by various stakeholders.. The study revealed that, management institutions such as Ministry of Works and Housing, Water Resources Commission, EPA, Forestry Commission, Traditional Council, CCMA and STMA, as well as NGOs performed poorly due to several challenges relating to capacity for operation. Financial and technical capacities as well as logistical constraints are the common challenges.

The study revealed that national plans and conventions are ineffective to protect resources that are local in scale. The mangrove area and coastal resources are used as local commons by several people. The study discovered challenges of ignorance and mismatch on the management of the lagoons as identified by Cash, (Adger, Berkes, Garden, Lebel, Olsson, Pritchard and Young, 2006). The critical task in this case seems to be the inability of the community to impose its rules on the end users of the lagoons.

There is inadequate enforcement of restrictive regulations; the lack of state recognition, commitment and mechanisms for cross-level coordination has limited the ability of the various stakeholders to contribute to management at the local level. There is also lack of funding, commitment and logistics at the regional level management within the catchment area of the lagoons. It is vital to recognise that the community level is also important as the starting point for the solution of the tragedy of the commons (Ostrom et al. 2002). However, higher levels of

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organisation are also important in providing monitoring, assessment, enforcement, and fostering local management.

Environmental Management

The issue of environmental management was given prominence in the in-depth interview with respondents. Most of the respondents were of the view that the changing physical features and conditions along the lagoons need to be monitored and regulated. They reiterated the need to introduce prosecution into the environmental management system because education has gone down a lot and yet people are reluctant to change their attitudes and behaviour towards the environment. In the case of the Essei Lagoon, the Programmes Coordinator of an NGO the Friends of the Nation (FON), attested to the fact that his outfit has been involved in a number of restoration programmes such as; erection of sign boards and employment of coastal guards to alert, educate and arrest offenders. With regards to the Fosu Lagoon, there is a tripartite committee which is seeking to monitor and manage the lagoon. The committee comprises the EPA, CCMA and traditional council on one hand and the local government of Bonn (Germany). The committee under the sister city project is seeking funding to rejuvenate or restore the Fosu Lagoon to become ecologically healthy.

This effort has not yet yielded the desired results as expected and hence, there is an outcry by residents for offenders to be brought to book as part of the measures to restore the lagoon.

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Legislation and Commitment of Stakeholders

The current research revealed that, current management systems are inefficient to support the protection and management of coastal lagoons in Ghana as there are lack of funds, logistics and personnel to enforce the policies. There is lack of interest and poor attitude on the part of the government and other stakeholders. Legislations and regulations are flouted by the local people and they are not punished by any organisation or institution. The Head of the Forestry Commission in Cape Coast noted that the institution never received monies from the Watershed Management Fund that was established in 1996. The following remarks tend to support the situation:

> *We have always been blamed for non-performance. However, we do not get the needed financial support from government. The quarterly funds that we need for routine repair of our vehicles, payment of casual workers, etc. do not come. For nearly two years, all the state institutions have not received any government subvention or funds.*

The narration supports the case of inadequate resources in the form of human, financial and logistics. There is therefore the need to bring all stakeholders on board in a participatory manner, under the leadership of the local residents to facilitate restoration plan of the Fosu and the Essei Lagoons. Again, national, regional and international environmental pressure groups should join in the call for the restoration of all polluted lagoons in Ghana. Offenders who pollute

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the environment through indiscriminate defecation, dumping of refuse and other industrial waste should be arrested and prosecuted to serve as deterrent to others. The Head of EPA also had this to say about the state of affairs:

> *We struggle hard to get financial support from external bodies. We wait for so many months, sometimes nearly a year, before getting approval from the WRC to use the little monies that we have solicited. Most at times, we are not able to complete our projects because the District Assemblies have failed to support us in terms of revenue generation.*

There is also the need to empower the local residents to lead the crusade for the restoration of the lagoons, thereby making the residents serve with commitment and zeal as local champions. The legislation should be able to ensure the existing local rules and regulations are duly enforced.

Possible Sustainable Management Plans for the Fosu and the Essei Lagoons: A Bottom-Up Approach

Upon a careful evaluation of the responses by the various respondents and experts and taking into cognisance the dynamic nature of the coastal environment, a sustainable management plan for the preservation and restoration of the Fosu and Essei Lagoons are proposed. This new proposed plan is based on a bottom-up approach which is integrated in nature and has the local residence at heart. The need for management solution to the factors causing the changing dynamics of the Fosu and the Essei Lagoons is essential (see Figure 39). This solution is enshrined

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in the National Environmental Policy (2014) of Ghana. The intended outcome of the policy is to help the country adapt to changing trends and new development in the management of its environment. Its vision is 'to manage the environment and to sustain society at large'. The policy takes into account the new paradigm of sustainable development based on integrated and coordinated environmental management and seeks to ensure citizens' quality of life and their environments, equal access to land and other natural resources, more efficient use of social, cultural, natural resources and public participation and environmental governance. The environmental policy of Ghana aims at ensuring a sound management of resources and of the environment and avoiding any exploitation of these resources in a manner that might cause irreparable damage to the environment (Soeftestad, 1996).

It is on this basis that after a careful consultation with experts in the field of coastal zone management, the researcher is proposing a bottom-up approach to coastal lagoon management in Ghana. The framework is illustrated in figure 37 and the linkages between them are shown and discussed. To ensure an integrated bottom-up approach to coastal lagoon management, decision makers and experts on aquatic policy should employ approaches such as ecosystem-based management (EBM), integrated coastal-zone management (ICZM),community based management approach (etc) and blend them together. The blending should take into account local knowledge around which policy formulation and decision making revolved. The local people should be given the opportunity to take active part in all the deliberations at each level of planning.

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Proposed Bottom-Up Approach to Lagoon Management

The bottom-up approach to coastal zone management framework is to ensure an integration of numerous but related management plans in the spirit of bridging the missing link between the so called owners and managers of the lagoon. This is to prevent the perceived intricate conflict between the district assemblies, traditional authorities, NGOs and CBOs, researchers, academics, residents and other users as revealed by the study

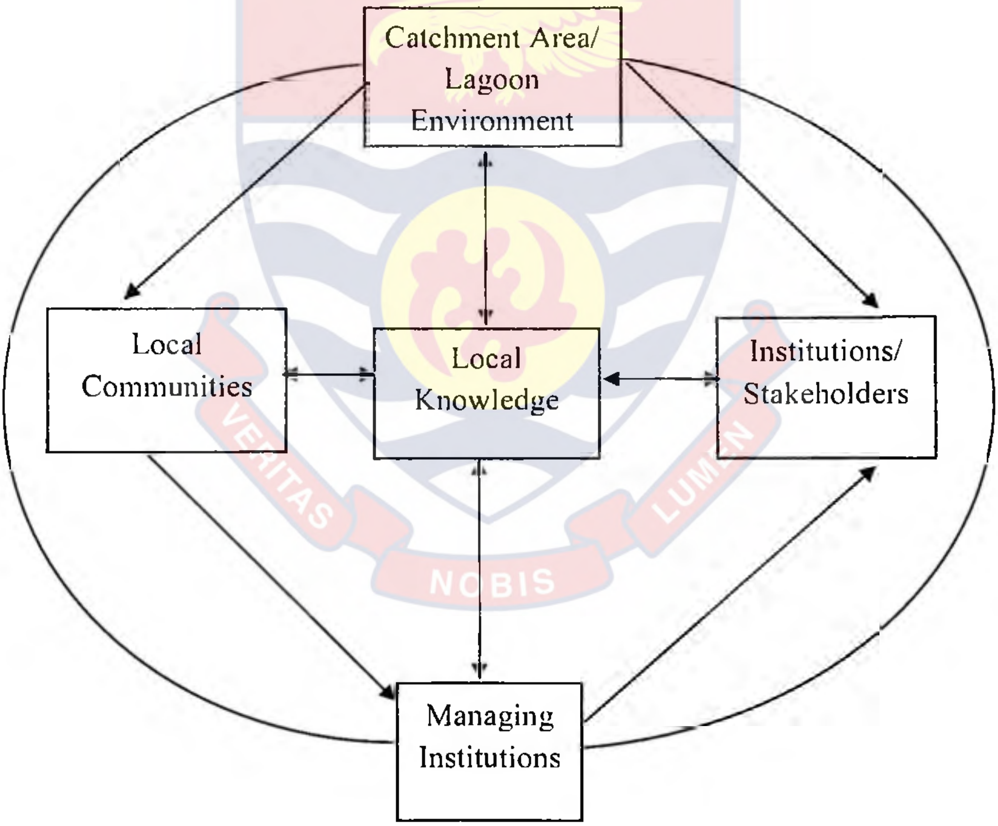

Figure 39: Proposed Bottom-Up Approach to Coastal Lagoon Management

Source: Author's construct (2015)

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The study discovered that the interface between the ownership and management of the Fosu and the Essei Lagoons are not clear and it is problematic in nature. Hence, the incorporation of the local content knowledge, (interests, skills, perceptions, and values of the local people) has been indicated to be low or non-existent in the current management strategies (top-down approach) of the lagoons. The respondents, therefore, were of the view that, if residents identify themselves with the decisions, they will accept them and enforce its compliance by the various users of the lagoon. This, they reiterated, as building consensus among the various users and interest groups in lagoon management.

The government of Ghana acknowledges that, in ensuring effective management of the environment and its resources, there is a need to integrate environmental considerations with social, political and economic justice. This will help in addressing the needs and rights of all communities, sectors and individuals. The National Environmental Policy (2014) states these principles as the fundamental principles which will be employed by government to direct actions including decision making, legislation, regulation and enforcement. In effect, the policy subscribes to the principle of environmental justice proposed by Ekow and Adu-Boahen (2014), in managing the coastal zone of Ghana in a sustainable manner. The new management approach will take into account the pivotal roles played by local knowledge which is represented by the traditional authorities in most jurisdictions. In this context, the values, interests, aspirations and decision making processes of the residents, who are the first to experience the effects of any environmental injustices, are taken into consideration.

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The frame work is expected to work taking cognisance of the institutions or stakeholders. By improving planning, implementation, monitoring and evaluations at all levels of the economy are among the processes through which the coastal zone could be managed effectively and sustainably. Due to the multifaceted nature of the coastal zone, there is a need for policies prepared by both local and central governments and other stakeholders taking the beliefs, skills and aspirations of the local people into account. In this newly developed framework, these groups of people are termed "the institutions or stakeholders". Improved planning aims at providing a balance between environmental protection and human activities.

There is also a need to have a strategy that provides a balanced and long-term strategic management framework for the integrated and ecologically sustainable use of lagoons. There is a need to generate latest scientific information, combined with community and stakeholder feedback, to develop coastal lagoon management plans that originate from the local people. The primary purpose is to describe what can be done by whom, how and where. When this is done, it will help other public authorities and communities in general to address priority management issues over a defined implementation period. For the institution and stakeholders to effectively work, there is a need for a laid down strategy on how each of the managing institutions are expected to do and at what stage is their mandated supposed to curtailed. The following are the strategic arrangements for improving the quality of the lagoons. These strategies include:

- Resettlement of mechanic shops;

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- Periodic water parameter analysis;
- Periodic stakeholder meetings;
- Monitoring pressures on coastal ecosystems;
- Evaluating community use of the coastal lagoons; and
- Managing risks to public safety and built assets.

As shown in Figure 40, the strategies outlined for the successful management of the lagoon include encouraging sustainable coastal resource use. This could be done in the form of mangroves protection by local communities, protected area management by vigilante group and volunteers, coastal research and monitoring by experts etc. in the case of supporting bottom-up approach to lagoon management, the various catchment areas of the lagoons should put in place feasible management and monitoring plans. There should be corroboration between the stakeholders and among other related agencies. There should also be consensus building to benefit the stakeholder. This could be done in the form of education, awareness creation, network building and others. The final stage of the plan is to encourage adaptation to improved management approaches such as governance and tools for building resilience, socio-economic adaptation capacity and socio-ecological vulnerability resilience and among other good sustainable lagoon management practices.

All these activities should be undertaken in consultation with the local communities. This will ensure consensus building and creation of trust among the various stakeholders. The expectation is that stakeholders share ideas and discuss case studies on improving strategic directions. The interaction among these

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stakeholders should be all encompassing and roles assigned to each of the stakeholders. By so doing, the diverse groups would understand their schedule and may be able to evaluate themselves appropriately. This will prevent conflict of interest and confrontation in the sense that each group of people knows what is expected of them at the period of evaluation. When this occurs, the local people will feel part of the process and be involved as they participate at each level of the process, thereby encourage ownership and the urge to safeguard the resource.

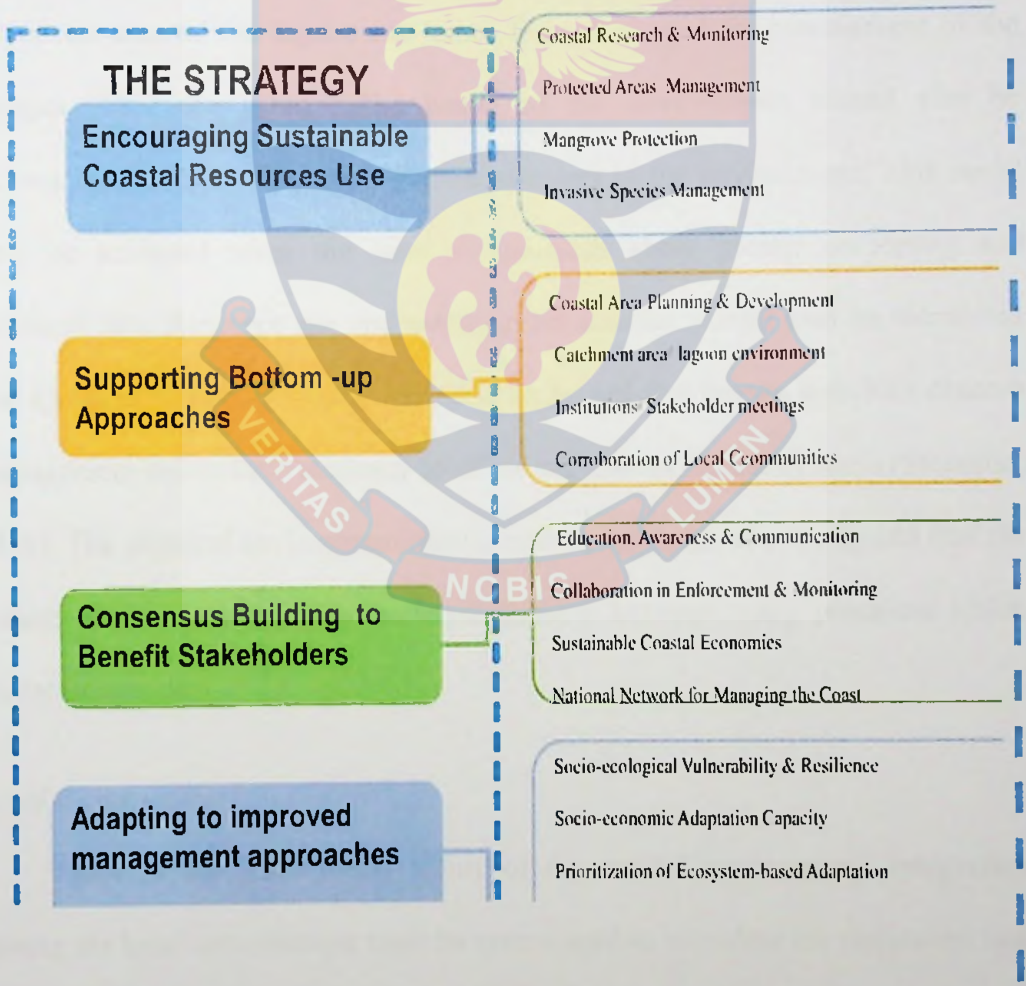

Figure 40: Strategic Plan for Institutions/ Stakeholders

Source: Field Data (2015)

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Catchment Area/Lagoon Environment

The study revealed transformation of the lagoon environment from one dominated by wetland and coastal scrub and mangroves to an urban, industrial and agricultural land. In addition, the lagoon environment has been polluted, in the case of the Essei Lagoon in Sekondi-Takoradi due to the absence of adequate storage and treatment facilities in the area. Domestic and industrial wastes are mostly directed into the lagoon. These activities and others have affected the catchment area of the lagoon and hence there is a need for resettlement of the garages along the lagoon. The health of the environment should also be sustainably maintained by reducing the stressors in the environment. This could only be achieved when the local communities show greater ownership and responsibility. Resource use and management conflict should also be monitored and curtailed in the catchment area. It is on record that human activities deserve management due to their tendency to affect and disrupt natural systems (Steenson, 2010). The physical environment should also be reflected as a whole and that the coastal environment has a dynamic relationship between many processes which are interdependent.

Local Communities

Due to the multifaceted nature of the coastal environment, integration among the local communities must be encouraged to stimulate the realisation that the lagoon and its resources are common property goods and hence should be managed in a coordinated manner. In this regard, the communities along the

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lagoons and its surrounding areas should have a common goal of sustainably utilising the resource to guarantee something for future generations. Therefore, local communities should play key roles in all aspects of the management process, from planning and identifying common goals to the implementation and monitoring stages. The inclusion of the local community at the various stages is an attempt to stress the value placed on local knowledge, memory and interests. This could be in the form of formation of vigilante/ volunteer groups, employment of locals as guards etc. this will place the local people at the centre of the management process and let them feel as part of the planning and implementation process.

Traditional/Local Knowledge

At the core of the framework is managing institutions. Ellsworth, Hildebrand and Glover (1997) are of the view that the allocation of responsibilities across various levels of government and sectoral lines severely limit the ability to address coastal zone issues. This is because the approach fails to facilitate the collective management of the coasts. The approach normally focuses on the space with absolute no disregard to the people and hence fail to address the cultural, social, economic as well as the environmental needs and aspirations of the people. The notion expressed above is the characteristics of most top-down approach to coastal zone management. Local people are not involved in the project initiation or planning, implementation, monitoring and evaluation. Top management members have the sole priority to formulate and implement the policies.

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The proposed framework is in direct contrast to the views expressed above as this framework is expected to give opportunity to the local people whose livelihoods are dependent on the coastal environment and are made the integral or the center of attraction in decision making. Ellsworth et al. (1997) are of the opinion that local communities rarely have the power to influence the decisions that affect them; their voices are seldom satisfying for decision makers. The authors went on to develop a five level scale for evaluating public involvement in decision making. These are:

- *Public information or education effort*: This means the public should be informed of plans that have already been deliberated on. It is the least amount of public involvement with respect to decision making;
- *Requesting for comments from the public*: When the plans are generally already made, with the government merely seeking affirmation from the public to gauge possible success of the plans;
- *Public consultation*: It is the commonest practise amongst management approaches where changes or advice from the public is taken into consideration before implementing a pre-conceived plan;
- *Public advisory committee*: It is an organised group that delivers a more formal type of public consultative advice. They are meant to be representative of the public; and
- *Multi-stakeholder process (joint planning):* It recognises the rights of all interested parties to be included in the decision making process. It leads to

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greater ownership and responsibility for the public as the proposed initiatives involve the public.

The performance of the functions by the local people is the reflection of their role in the management of the coastal zone. When the community members are engaged this way, it leads to greater ownership and responsibility among the public as the proposed initiatives involved them from the beginning to the end. It is at this level that their interests, opinions, knowledge and values are brought on board. The local knowledge is also considered as an important link that can provide feedback between the local scale management and the local environment.

Gunderson and Hollings (2002) aver that local knowledge is the knowledge generated through observations of the local environment. In this context, the local knowledge is expected to rest on the traditional authorities and the stakeholders in the various communities and their roles and involvement should reflect the embodiment of the local people as a whole. Since local communities have the greatest interest in the conservation and sustainable use of coastal resources, they should have incentives, resources and capacity for marine and coastal ecosystem conservation. The above discussion was supported by the chief of Bakakyir in Sekondi that:

> *The lagoon is ours they should allow us to use our customs and traditions to control and manage it.*

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Managing Institutions

Another important aspect of the framework is managing institutions. Many sectors and institutions operate within the coastal environment; these institutions include the Wildlife Commission, Environmental Protection Agency, district, municipal, metropolitan assemblies, traditional councils, individual users such as tourism operators, fishermen, researchers and many others. According to the Head of Forestry Commission in Cape Coast, there are of two main groups of managing institutions.

The direct managers and the indirect managers. The direct mangers are the local communities who live at the catchment areas of the lagoons, whilst the centralised managing institutions such as the Wildlife Commission, Water Resources Commission, District Assembly's etc. form the indirect managers. Consultations and interviews with the stakeholders showed that the Fosu and the Essei Lagoons are not protected by law compared to the Muni lagoon, which is protected by the Ramsar convention. The Essei Lagoon for instance is public property and is expected to be managed, protected and held in trust for the people by the district assembly while with the Fosu Lagoon is not well defined and may be regarded as mixed tenure between public ownership, customarily owned or stool lands for festive occasions like the annual Fetu Afahye.

The ownership and management of the lagoons are therefore in a "missing link" or an over-lap. With the choice for a bottom-up approach to lagoon management, it is expected that roles are assigned and management and tenure status as well as protection status established for the various lagoons.

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Summary

The chapter presented the factors causing the changing physical features of the Fosu and the Essei Lagoons. The topics discussed concentrated on both natural and anthropogenic processes. The study revealed that the lack of commitment on the part of stakeholders is among the contributory factors affecting the changing features of the lagoons. The chapter conclude with a proposed framework for managing coastal lagoons.

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CHAPTER SEVEN

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter is devoted to the summary of the study's findings, conclusions, recommendations, and suggested areas for future research.

Summary of Thesis

This thesis sought to investigate the changing dynamics of the Fosu in (Cape Coast Central Region) and the Essei (Sekondi-Takoradi Western Region) Lagoons in Ghana. The purposive sampling technique was employed to select fifteen (15) respondents to participate in an in-depth interview (IDI). Content analysis were undertaken to validate the responses obtained from the field. The research instruments used were in-depth interview (IDI) guide, observation checklist, content analysis, field measurements, laboratory analysis and the application of remotely sensed data (satellite imagery) and the 1973 Topographical map of Ghana's coastline . The Multi- Parameter water quality checker was used to measure water quality; and heavy metals concentrations were analysed at the Water Research Institute (WRI) of the Centre for Scientific and Industrial Research (CSIR) of Ghana in Accra using the Perkin-Elmer flame Atomic Absorption Spectrophotometer (AAS).

Major Findings of the Study

1. The changing physical feature of the Fosu and Essei Lagoons with regard to their physico-chemical parameters shows significant differences in their distribution. The variation is due to the entry of sea water into the Essei

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Lagoon during high tide and retreat at low tide. On the other hand, the Fosu Lagoon exhibited different nature with the distribution of the parameters. The lagoon has expanded in its area extent. Based on the 1973-2014 topographical map and the Landsat images used for the analysis and the field measurements carried out, the lagoon's extent and size show contraction and expansion. The changes in the lagoon environment have been observed by the communities through the people's interactions and experience with the environment and Non-Governmental Organisations. Climatic variables such as reduced rainfall and increased temperature were also revealed as the cause these developments;

2. The heavy metal concentrations from the study confirm that, there were high levels of lead in the Fosu Lagoon during the wet and dry seasons. The high level recorded is attributed to the lead deposit on the road close to the lagoon which is plied on by vehicles. The study revealed that the source of most of the metal pollutants in the Fosu Lagoon is from the industrial area, especially the automobile garages close to the lagoon who are involved in the encroachment of the area covered by the lagoon. With the exception of lead which had the highest level, the concentrations of the other heavy metals such as cadmium, manganese and copper were very low and therefore, posed no threat to the flora and fauna of the lagoons. The result is an indicated by the level of contamination of samples collected from those areas because they contained significant levels of the metals. The higher heavy metal values recorded in the dry season could also be the result of difference in evaporation

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and precipitation rates. It can therefore be said that seasonal disparity exists between the metal and physico-chemical parameters and their influence on the quality of water;

3. The study reveals a wide range of factors affecting the changing dynamics of the physical features the Fosu and the Essei Lagoons. Several physico-chemical factors, such as salinity, temperature, dissolved oxygen, pH, TDS and sea-lagoonal water interaction caused the changing physical features of the lagoon. Among the anthropogenic factors were sewage discharges from domestic and industrial areas, urban surface run-off, agricultural run-off, altered water quality, reclamation and redevelopment. The action of sea waves and tides, in addition to climatic variability were among the natural phenomena;
4. Finally, it was established that the interface/relationship between the ownership and management of the Fosu and the Essei Lagoons were problematic; there is a 'missing link' or an over-lap. There were ineffective decision-making processes that seek to connect the interests, knowledge and experiences of all stakeholders (from civil society, the private and public sectors as well as local communities). The incorporation of the local content knowledge (thus views, ideas, local knowledge, customs, traditions, skills etc) was low or non-existent in the management strategies on the Fosu and Essei Lagoons. When local people come out or formulate their decisions, they will accept them and enforce the compliance by various users of the lagoons. The existing management plans are not sustainable and effective due to lack of

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commitment on the side of stakeholders including government and other users of the Fosu and Essei Lagoons.

Conclusions

Based on the key findings, the following conclusions are drawn:

1. The water quality of the lagoons is increasingly being lowered although it has not reached the USEPA/EPA standard limits. The lowered elements in the Fosu and Essei Lagoons include high dissolved oxygen, temperature, and electric conductance. There is also emergence of algae blooms on the lagoon surfaces especially during the dry season. The degraded environments of the lagoons need immediate attention and long-term data collection to investigate the causes of the excessive high lead concentration levels, high temperatures, etc. measured in the lagoons.
2. Natural factors played a very insignificant role in causing the changing dynamics of the physical features of the Fosu and Essei Lagoons. Human-induced factors caused the changing dynamics of the lagoons between the period 1973–2014. Among the human induced factors that affected the Fosu and the Essei Lagoons are; fresh water pollution, introduction of exotic species by run-off, infrastructures expansion and industrial activities. These factors induce consequences that require restoration and safeguarding measures.
3. There is a growing concern at local and national levels over the fate of the lagoons. It is on this basis that efforts are being made by stakeholders to apply different management strategies to recuperate the lagoons. The locals are

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devising various fishing methods as well as research by NGOs and CBOs to adapt to the changing situation. At the national level, some actions have been initiated to manage the diminishing lagoons in a form of restoration projects. The international community has also come up with a number of programmes to complement regional efforts in the form of research, capacity building and education. All the actions are geared towards restoring the lagoons for sustainable use. Unfortunately, these efforts have not yet yielded any appreciable results as the lagoons keep decreasing at an alarming rate. There is therefore the need to evaluate the challenges of the stakeholders and management institutions in coastal lagoon management so as to provide support and relief in the form of funding, logistics and human resources ;

4. It is concluded that when the bottom-up approach to coastal lagoon management is integrated into the national framework, consensus building would be encouraged. The cooperation and coordination among different sectoral agencies with competing interests in the coastal zone will allow for the development of plans that reduce conflicts. This will enhance sustainable development while protecting the country's natural resources and habitats. This final conclusion demands an immediate needs assessment into the local knowledge, skills and practices that will ensure the sustainable management and utilisation of water resources.

Recommendations

Based on the findings and conclusions of the study, the following recommendations are made:

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1. It is recommended that in ensuring sustainable management and effective utilisation of the lagoons and their resources, local communities are permitted to design programmes or measures. With local participation, the local communities are given authorities that allow them the freedom to propose policies that meet local needs and aspirations. Participatory approach is a valuable exercise in the sense that it provides the opportunity to promote local participation, understand divergent opinions of the public and facilitate communication among stakeholders and increase public awareness about future problems concerning the coast. Participatory approach also aids the decision making process for coastal zone planning and management. Participatory approach allow policies to be designed in a more robust manner, thereby accounting for critical analysis and helping to select the path to the most desirable future;
2. The Wildlife Division of the Forestry Commission, mandated by law, should monitor the lagoons at least once every year on all water quality elements or parameters. When the commission conduct surveillance monitoring which aim at giving information on the condition of the lagoons and to act as a basis for conducting operational monitoring based on the information collected from the surveillance. Operational monitoring becomes imperative when a water body is at risk of failing to meet good status or standard required and monitors the quality elements that are indicative of pressures that cause the lagoon to meet good status. Investigative monitoring should be undertaken when the reasons for failing to meet good status are not clear.

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3. The EPA, Wildlife Division, and other stakeholders should be encouraged to promote scientific cooperation between particular environmental disciplines such as geomorphology and aquatic sciences. These disciplines have the potential to combine information on specific local biological dynamics to ensure the conservation and preservation of lagoons and their resources. Such a corroborative study is capable of providing information on how residents would be affected by human interventions such as water pollution, deposition of waster or urban expansion. These interventions could be used through a management link by engineers to fit urban projects such as shoreline developments and restoration strategies;
4. There should be initiatives that raise public awareness and participation by improving linkages among schools, colleges, universities and the general public, in the form of environmental education. Such environmental education programmes should also be encouraged to improve commitment, since public commitment is an essential aspect of any conservational practice. This could be initiated by the EPA, educational institutions and researchers. Although education alone may not always change behaviour, providing the necessary scientific information on the value of mangroves to fish stock as well as the value of restoration programs to the fishermen in the study areas as a whole may go a long way towards helping to restore the fishery in the lagoon and improving the health of the lagoons;
5. The numerous garages at Siwdu in Cape Coast and along Fosu Lagoon and the Essei Lagoon in Sekondi and the palm kernel extractors at Adisadel

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village in Cape Coast should be resettled by city authorities (CCMA and STMA) to prevent the deposition of metal waste and domestic waste into the lagoons.

6. The study further recommends and proposes a bottom-up approach to coastal lagoon management in Ghana by Water Resource Commission and the Environmental Protection Agency of Ghana.
7. The study also recommends resourcing of institutions by the central government in terms of logistics, finance and personnel. This will go a long way to ensure efficient and effective monitoring and management of the lagoons.

Contributions to Knowledge

The research has contributed to knowledge in two ways. First, it has added to the stock of literature on coastal zone management, therefore, researchers in this specialty and students can consult to this document to improve their understanding of CZM. Second, the study has contributed to environmental policy, in the form of proposing a framework that could help manage coastal lagoons in Ghana and by extension to the whole world in the form of as academic writing. The bottom-up approach to lagoon management is therefore recommended.

Area for Further Research

The present study was concerned with the changing dynamics of coastal lagoons in Ghana. Further research may be carried out to investigate the interface or the missing link between management and ownership of coastal lagoons in

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Ghana. Such a study should consider designing a rehabilitation model for the restoration of lagoons.

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APPENDIX

UNIVERSITY OF CAPE COAST

COLLEGE OF HUMANITIES AND LEGAL STUDIES

DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING

IN-DEPTH INTERVIEW GUIDE FOR SELECTED KEY INFORMANTS

CHANGING DYNAMICS OF COASTAL LAGOONS: A CASE STUDY OF THE FOSU AND THE ESSEI LAGOONS IN GHANA

SEX:

POSITION:

AGENCY:

CITY:

AGE:

EDUCATION:

PART ONE: Monitoring Coastal Lagoons

1. What are the various uses of the lagoon, most important aspects/uses?
2. Have you observe any changes on the lagoon, if yes what are these changes(hydrodynamics, ecological, social, economic)
3. Key environmental factors affecting coastal lagoons (seasonal flooding/hydrology, herbivory, fires, urban expansion, industrial activities, over fishing etc)

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4. What has been the nature of Land use history of the selected lagoons (past and current land history including offsite use
5. What is the nature of Tenure: public, private, customary law, leased
6. What is the protection status of the lagoon (legal, traditional/customary, reserve, no protection)
7. What should be and have been the bank characteristics, discharge, sedimentation,
8. Is there any evidence of disturbance of the lagoonal environment
9. What do you consider to be among the current management problems of lagoons in Ghana?
10. What do you think to be the most crucial factors causing the changes/ disappearance of the selected lagoons(anthropogenic and geomorphic factors)
11. Are there any principal traditional management practices employed in the management of the lagoons under study?Closed fishing days, seasons and areas. Restriction of certain gears. Regulation of entry, Taboos, Fines,Mesh size regulation etc.

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PART TWO: Rank the following Management procedures in order of importance/ priority where 1 is the most important and 7 is the least. {1-7}

Site management strategy	Code for estimating priorities	Reason for choice
Environmental education		
Fencing (stock-control and regeneration space)		
Regeneration/ Restoration (or failure)		
Visitor Management		
Monitoring programme (Ecosystem function)		
Others (including traditional efforts and policy):		

1. Are you aware of any management plans regarding these lagoons
2. What should be the nature of the coastal lagoon management plan for Ghana?
3. Who should be the stakeholders in the development of lagoon management plans in Ghana?
4. Should we encourage the cooperation of local community in the lagoon's management?
5. What should be the system of monitoring coastal lagoons in Ghana?

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6. Should there be dredging of the lagoons and if yes how often should that be done?

7. Will you encourage regular breaching of the sand bar to allow sea-brackish water interactions?

   Are there any local lagoon management plans in Ghana?

8. Any other lagoon management plan you consider to be appropriate for the lagoon management?

9. What do you think should be done with the garages along the lagoons?

10. What do you think will be the impact of the changing nature of the lagoons on the catchment residence?

11. Will you propose a bottom-up approach to coastal lagoon management, if yes why and how should it be done?

12. What other recommendations will you make on the sustainable management of coastal lagoons in Ghana?

Thank you.

VERITAS LUMEN NOBIS

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