RAPID BIODIVERSITY ASSESSMENT ON THE ESSEI AND BUTUAH LAGOONS AND THE WHIN RIVER ESTUARY IN THE SEKONDI-TAKORADI METROPOLIS OF THE WESTERN REGION OF GHANA

Technical Report

Implemented by the Coastal Resources Center-Ghana and Friends of the Nation in partnership with:

United States Agency for International Development (USAID)
The University of Rhode Island
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SustainaMetrix
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Hɛn Mpoano

THE UNIVERSITY OF RHODE ISLAND GRADUATE SCHOOL OF OCEANOGRAPHY

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Cover Photos:

Top row from left to right: Crab species (*Cardiosoma armatum*) from the Butuah lagoon, fish sampling in the Butuah Lagoon, Marine turtle at the mouth of Butuah lagoon.
Middle row from left to right: Hermit crab, *Littorina* sp., Mangroves (*Rhizophora mangle*) at the Whin estuary.
Bottom row from left to right: Collection of fish species from the Whin Estuary, Barnacles and Mud skippers (*Periopthalmus barbarus*) at the Whin estuary.

Photo Credits: S-P. K. Aheto

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The data have shown that the wetlands have a vast economic and conservation potential. However, deplorable management, ignorance or conflict of interest on the part of users has led the wetlands onto a path of potentially irreversible destruction. Certainly, a new coastal management thinking and practice are needed taking into account a Ghanaian economic, socio-cultural and environmental perspective. It is argued here that development as a whole cannot be the adaptation of external views but should be based on local empirical evidence. This allows to defend an own view placing in the context of global trends. Such a holistic approach would be necessary calling for stronger partnerships including scientists, local and government actors as well as the international community.

- By Denis Aheto (2010) *Daring to know our wetlands.* Rapid Ecological Assessment of Urban Wetlands of the Western Region of Ghana

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ACRONYMS

BMBF	Bundesministerium fuer Bildung und Forshung (German Foreign Ministry for Education and Research)
CBD	Convention on Biological Diversity
CRC	Coastal Resources Center-Ghana
D	Margalef‘s Richness Index
DFID	Department for Foreign and International Development
DO	Dissolved Oxygen
DSS	Decision Support System
EPA	Environmental Protection Agency
FoN	Friends of the Nation
GIS	Geographic Information System
GPS	Global Positioning System
H'	Shannon-Wiener Diversity Index
ICFG	Integrated Coastal and Fisheries Governance Initiative
J'	Pielou‘s evenness
Mg/L	Milligrams per liter
MPA	Marine Protected Area
REA	Rapid Ecological Assessment
SAMP	Special Area Management Plan
UCC	University of Cape Coast
USAID	United States Agency for International Development
µs/cm	Microsiemens per centimeter

EXECUTIVE SUMMARY

The overall objective of this study was to provide basic scientific data relevant for biodiversity assessment of the Essei and Butuah lagoons and Whin estuary in the Sekondi-Takoradi Metropolis of the Western Region of Ghana in order to determine their relative ecological health. This largely involved the estimation of the present functions of the wetlands, their services and biodiversity, together with analysis of prevailing threats and challenges. Therefore it was of crucial importance to assess the hydrographical parameters as well as carry out field and laboratory studies on the general flora and fauna species content of the wetlands. Additionally, mapping of the major terrestrial, land use/ cover around the marine habitats was conducted based on a GIS and remote sensing application. This was supported by ground based habitat mapping procedures using a GPS receiver.

The study largely based on a *Rapid Ecological Assessment (REA)*, consistent with the Ramsar Framework for Wetland Inventory. The analysis therefore involved many steps and considerations. Thus, knowledge of integrative approaches was applied. It aimed to cover part of the analysis by assessing those factors which may differ among the wetlands but with focus on issues that have previously not been studied.

Information has been provided relative to biodiversity assets of the wetlands and possible impacts on them to allow for full consideration or mitigation of those impacts based on the following classification scheme:

- Phytoplankton community
- Zooplankton community
- Benthic fauna
- Littoral fauna
- Fisheries
- Grass species
- Riparian vegetation mainly grasses, sedges, shrubs, and trees
- Mangroves
- Providing indications of reptile, amphibian and birds data that could be derived.

To understand the possible threats, the analysis reviews the condition of the habitats considered being of high or low biodiversity significance. This was done relative to the occurrence, species composition, richness and diversity of the general fauna. For the riparian vegetation, a species list has been generated. A database of biodiversity assets has been generated as a preliminary measure for future studies and information systems monitoring of species.

Particularly at Essei and Butuah, it was concluded that there would be a need to enhance marine wildlife and biodiversity. Friends of the Nation (FoN) and other stakeholders must be proactive in matters of conservation of the wetlands in order to keep pace with the human impacts where necessary.

1) For instance the setting up of Protected Areas at Essei following the removal of the lagoon defence walls (groins) constructed across the lagoon for the restoration of fisheries. Such an action would potentially expand the wetland corridors at Essei.
2) The development of Special Management Plans for the Whin estuary for development of ecotourism would be relevant for conservation purposes of the already ―pristine" environment of the estuary and to also generate some income for the local people.
3) The Essei and Butuah lagoons and associated vegetation are presently faced with serious human encroachment which may aggravate with time if serious interventional measures are not instituted.

4) Mangrove restoration is highly encouraged in adjacent areas of the lagoon. Attempt must be made to balance the interests of various multiple groups in balance with marine biodiversity conservation.
5) This study also prompts the need to engage in further scientific studies at the postgraduate and undergraduate levels.
6) It encourages the need to use databases and develop information systems monitoring concept for the wetlands.
7) Capacity building for the monitoring of hydrological factors, beach front monitoring, assessing the potential impacts of sea level rise on biodiversity in those wetlands would be necessary. Basic and secondary school students including their teachers could be deployed for these tasks with some motivation infused into the process.
8) For other scientific considerations, these aspects should also consider the effects of large scale physical ocean processes that address future impacts of climate change and ocean acidification.

For the habitats studied, it was of special interest to notice that the overall area of the Butuah Lagoon and Whin Estuary had increased in water surface area by a margin of 17 % and 14. 6 % respectively between the period between 1973-2010. This may be attributed to possible impact of climate variability maybe due to increased water temperatures, precipitation or sea level rise. What is not apparent is the overall change in biodiversity during the period due to the absence of long-term data on the biodiversity assets. On the contrary, it was revealed that Essei lagoon had decreased in its entire surface area by a margin of about 80% over the period of about 30 years (1973-2010).

The implications of the spatial change of the wetlands on their biodiversity assets are unclear due to the lack of long-term data on biodiversity information. However, the overall increase in area of the Butuah lagoon and the Whin estuary may have had positive impact on biodiversity assets, possibly through the creation of new breeding and feeding grounds for fisheries productivity and the development of plankton and invertebrate communities. Habitat loss at the Essei lagoon may have contributed to a possible loss in biodiversity to a great extent. In addition, habitat fragmentation of the Essei lagoon through creation of the defense wall (groin) in the middle of the wetland targeted towards flood control possibly aggravates the situation.

The water quality parameters provided indications of the changing conditions across the habitats and distribution of fisheries resources and other relevant aquatic flora and fauna. In principle, the Whin estuary recorded fairly stable conditions relative to the survival and proliferation of fish species and aquatic fauna and flora. Indeed, Whin recorded the best water quality standards. The low oxygen content of the Essei Lagoon calls for serious management intervention on curbing the organic inputs through control of effluent discharge or run-offs. Optimum levels for fish survival and growth is about 5mg/L.

However, oxygen content of the Essei lagoon was at a critically low levels ranging between 0.1-1.27 mg/L, which may be regarded as near deoxygenation. This may have accounted for the very low fisheries content of the lagoon. Turbidity in the Butuah lagoon showed record high values that may have impacted negatively on the productivity of the system in general. This may be due to the intense human activities around the lagoon such as agricultural and organic effluent discharge.

In terms of the flora, majority of the grasses are utilised as feed for livestock while the herbs are use in the communities for feeding ruminants e.g. *Tridax procumbens, Aspilia africana,*

Euphobia heterophylla, Euphorbia hirta, Phyllantus amarus, Boerhavia diffusa, Ipomoea cairica and Ipomea barbata. Besides, some of these herbs are used for medicinal purposes e.g. *Physalis angulata* is used for treating palpitation of the heart, *Acanthospermum hispidum* for curing leprosy. The leaves of *Achyranthes aspera* are used for treating itching and for headaches. Whin had the highest diversity in mangrove species namely *Rhizophora mangle, Avicennia Africana, Laguncularia racemosa.* Essei and Butuah lagoons habour single species mangroves namely *Avicennia portulacastrum and Avicennia africana* respectively.

The recommendations provide for a timeline of short- to long-term management actions intended to halt possible decline in biodiversity and ecosystem functionality. The proposals target some individual species or group of species, while others have aimed to target the overall habitat and their biodiversity, and socio-cultural aspects. This report underscores the strong need to step up and scale up efforts to reduce the increasing impacts on these vulnerable ecosystems from pollution, resource depletion and other threats. Species of conservational importance have been clarified, classifying them as either threatened or rare in support of restoration efforts.

1. INTRODUCTION

This report addresses the issue of –Biological diversity" in three urban wetlands in the Sekondi-Takoradi Metropolis of the Western Region of Ghana. It provides baseline scientific information that could be used to strengthen the management of coastal wetland ecosystems to assure livelihoods and food security, ecotourism as well as biodiversity conservation in the region. In broader terms, –Biological diversity refers to *the variability among living organisms from all sources including, inter alia- terrestrial, marine and other aquatic ecosystems and their ecological complexes of which they are part. This includes the diversity within species, between species, and of ecosystems* (CBD, 1992). For the purposes of this project, the term has been used in the context of the selected wetlands of concern. –Biological diversity" is often pronounced –Biodiversity", and is often used as a relative measure of ecosystem health. Usually high level of biodiversity is desirable and provides an indication of relative good health status of the ecosystem concerned. Therefore, maintaining biodiversity is necessary in order to assure the survival and productivity of ecosystems and livelihoods.

Relative to the Western region, a larger segment of the human population is heavily dependent on the sea and its associated ecosystems mainly lagoons and estuaries for food, and medicine and to provide other basic necessities of life. But for most part of the population, the implications of their activities on these ecosystems are either unknown or largely ignored. Expanding population in coastal areas has led to rapid urbanization and intense economic activities around wetland ecosystems, which have been observed to be of great concern. These include beach sand winning activities, the use of explosive devices in fishing, use of nets of small mesh-sizes for fishing and widespread mangrove exploitation. In addition, poor sanitation mainly disposal of domestic waste and sewage into wetlands are crucial concerns. There are implied consequences of these activities including loss of vast expanse of wetland habitats leading to the dwindling of fish stocks and other relevant aquatic flora and fauna. Pollution is evident and its attendant health implications are enormous. The situation calls for major strategic interventions not only on environmental education but also commitment of political and non-government actors to relevant restoration measures based on relevant scientific information. Unfortunately,

baseline data on available species in the wetlands are lacking. Furthermore, spatial information on the present natural boundaries, extent of loss of the wetlands or encroachment on adjacent riparian vegetation has not been quantified. However, for the implementation of effective ecosystem management programme, these data are mandatory requirements.

The study was commissioned by the Friends of the Nation (FoN) against this background for conservation purposes and to recommend improvement measures at the selected sites. The project had as a primary objective to conduct rapid ecological surveys to estimate the biodiversity status of selected wetlands namely the Essei and Butuah lagoons and the Whin River estuary. Among others, the information could be used to advance effective collaboration with local Government authorities and other stakeholders in advocating for necessary bye-laws on their wise use. The Project was based on a three-week field sampling and laboratory investigations, as well as the use of Geographic Information Systems (GIS) and Global Positioning Systems (GPS). The mass of information gathered is numerous, and goes beyond what could be handled in single report. This therefore required to focus on particular aspects, in particular relating the scientific findings to possible mitigation actions to reduce impacts on biodiversity assets identified.

1.1 The Terms of Reference

1. Collect data on the general flora and fauna species content of the wetlands
2. Identify any rare and threatened species within the wetlands ecosystems
3. Identify the breeding patterns and habitat of the rare and threatened species needs to support enrichment planting and management plan preparation
4. Provide monitoring and evaluation indicators for the biological systems within the wetlands ecosystem

1.2 Research objectives

Specifically, the study aimed at ensuring that:

- an inventory of flora and fauna present in the wetlands, including their composition is made available.

- a database on the classification of the flora and fauna species, providing information on their breeding patterns are provided.
- GIS and remote sensing techniques are deployed to characterize the spatial extent of the wetlands, including an assessment of their natural borders (contours) of the wetlands and settlement areas, including any assessment of change in land use/ estimate change in area of surface water over the past 3 decades where necessary.
- degradation or sanitation issues are addressed.
- socio-economic and environmental values are addressed.
- water quality data of the wetlands is analysed;
- conservation priorities for the wetland areas are suggested.

Fig. 1 provides a conceptual framework used as a guidance to implement the rapid assessment. It was adapted from, and consistent with the Ramsar Framework for Wetland Inventory. However, it must be noted that certain steps were minimized in order to take account of the very short time required to undertake such a preliminary assessment.

The next section provides a background overview of the distinguishing features of lagoons and estuaries studied addressing relative importance for fisheries production. The policy issues have been documented, in particular looking at related programmes that have been implemented in the country. The methods employed have been described in an outlined extent. This is followed by the results. A discussion is made in the light of key findings and conclusions have been drawn. Attempt has been made at recommending remediation and management actions.

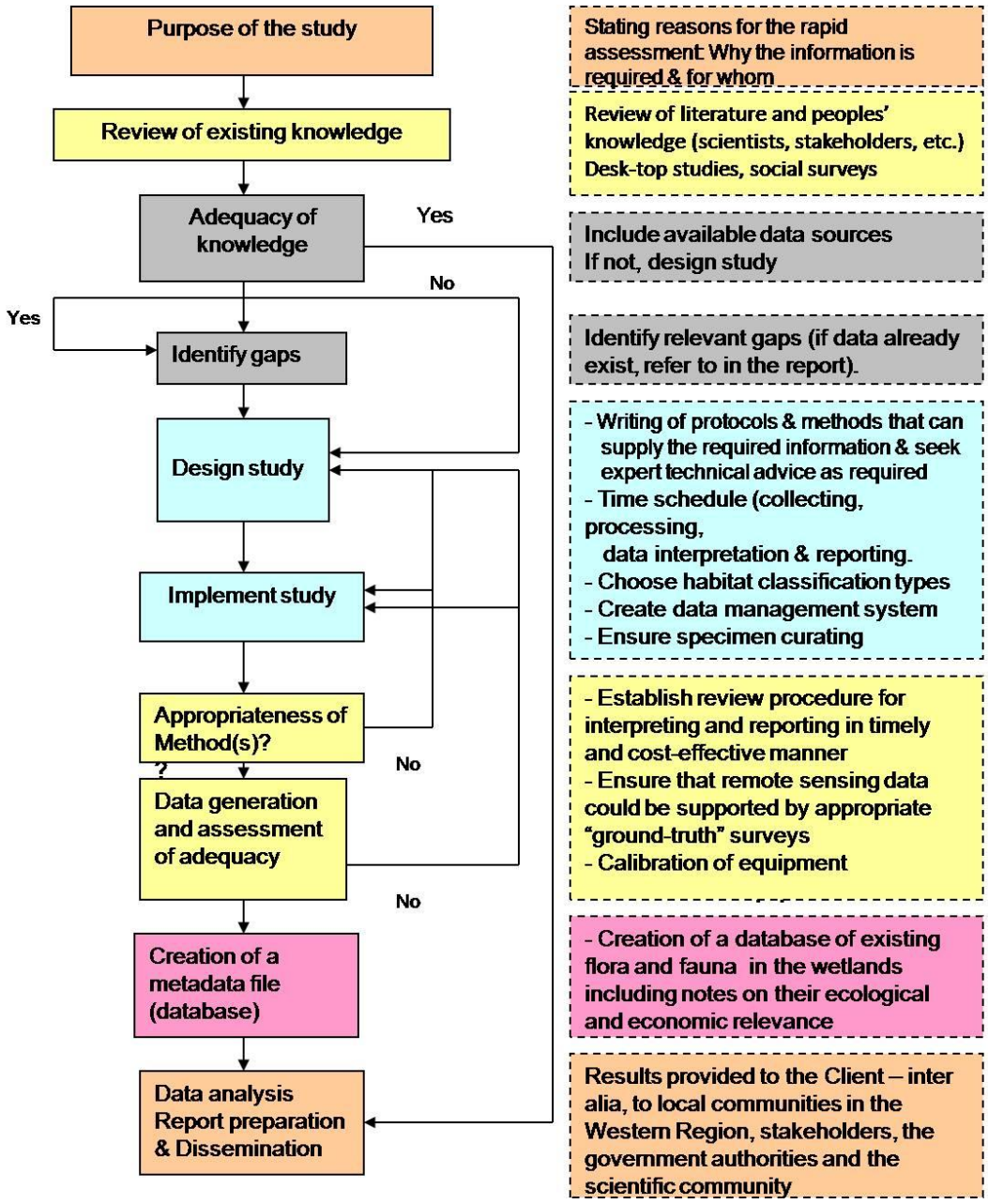

Figure 1: Conceptual framework for the Rapid Ecological Assessment in the Sekondi-Takoradi Metropolis of the Western Region (modified from the Ramsar Framework for Wetland Inventory (Resolution VIII.6).

2. BACKGROUND

Globally, lagoons and estuaries are among the first ecosystems to receive international attention through the "Convention on Wetlands of International Importance, which opened for signature at Ramsar, Iran, in February 1971. Lagoon and estuarine wetlands are among Ghana‘s most valuable wetlands. These wetlands are closely tied to salt marshes, mangroves swamps and tidal flats which constitute significant features of Ghana‘s coastline providing critical habitats for many fish and wildlife species that support Ghana‘s economy.

2.1 Lagoons

By definition, lagoons are shallow coastal water bodies separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets, and usually oriented shore-parallel (Kjerfve, 1994). Coastal lagoons of Ghana have been classified into two types namely ―open" and ―closed". Yankson and Obodai in 1999 provided a vivid account on the different types of lagoons in Ghana, classified as follows:
Open lagoons: These are characterised by the infrequent closure to the sea. There are two main types existing in Ghana:

(a) Classical open lagoons: These are usually open to the sea but seldom barred from it by a sand bar; and

(b) Man-made open lagoons: These maintain a permanent contact with the sea as a result of human intervention e.g. The Essei lagoon.

Closed lagoons: These lagoons are usually closed to the sea but occasionally opened due to factors such as rainfall or floods, or due to the incidence of high tides. Three types of closed lagoons have been identified in Ghana namely:

(a) Lagoons which get cut off from the sea by sand bar for greater part of the year, but open for a short period during the rainy season, and are regarded as ―Classical closed. E.g. Butuah lagoon falls in this category of lagoons:

(b) Those in which the sand bar is low enough, even at the peak of the dry season, to permit sea water spillage at high spring tides (1.95m tidal range). There is no obvious reverse flow of water from such lagoons except during the rainy season when the sand bar is breached. These are also referred to as ‗Spring-tide fed closed‘ lagoons; and

(c) The non-brackish, small sized coastal water bodies which lie _permanently' behind a sand bar and may be regarded as _isolated closed' lagoons.

2.1 Estuaries

Estuaries are partially enclosed coastal water bodies that have a free connection with the open sea, but whose water is diluted by fresh water from a river or stream. Estuaries provide interaction between the sea, river and land. Their orientation is more or less perpendicular to the sea, and has a funnel shape permitting a large seawater-freshwater interchange. The sources of estuarine water, like some lagoons, are land drainage, direct rain and the sea, but in this case the volume of land drainage far exceeds that of lagoons and therefore influences the salinity to a larger extent (Yankson and Kendall, 2001). The classification of estuaries is based on various parameters including the nature sediment, salinity and mode of formation. Yankson and Kendall in 2001 provided a functional classification based on salinity as follows:

(a) Positive estuary: when seawater enters it as a bottom current with the lighter freshwater leaving as a surface current into the sea. This is the most common type of estuary that is more prevalent in temperate regions and also when there is a large volume of freshwater discharge.

(b) Negative estuary: occur when the rate of evaporation exceeds the freshwater input and therefore results in hypersaline estuarine water which sinks and enters the sea as a bottom current. This type is more prevalent in the tropics and the Whin estuary is no exception.

(c) Neutral estuary: when there is a balance between evaporation and freshwater input, causing a more or less uniform salinity profile from the surface to the bottom. This type of estuary is rather rare.

In principle, lagoons differ geologically from estuaries, which are defined in terms of the hydrological conditions and gradients of salinity and temperature (density) (see Cameron and Pritchard, 1963, Yánez-Arancibia et. al. (1994). Further distinction is provided in Table 1. A common feature of all estuaries is that there is salinity gradient which decreases from the seaward end to the riverine end. However, the salinity at any point in an estuary is determined by various factors including the tide, temperature, rainfall,

season among others. The sediment in estuaries is predominantly mud and therefore usually contains very little oxygen. This tends to render estuaries unsuitable for active, mobile animals while it encourages burrowing and low oxygen tolerant forms.

Table 1: Differences between lagoon and estuary

LAGOONS	ESTUARIES
Shallow coastal water bodies separated from the ocean by a barrier, connected at least intermittently to the ocean by one or more restricted inlets	Partially enclosed coastal water bodies that have a free connection with the open sea, but whose water is diluted by fresh water from a river or stream
Usually oriented shore-parallel	Orientation is more or less perpendicular to the sea, and has a funnel shape permitting a large seawater-freshwater interchange
Horizontal salinity gradient established	Salinity gradient decreases from the seaward end to the riverine end
Lower sediment load due to lower input from fresh water sources and land drainage	High sediment input from land drainage (rivers or streams
Connected to the sea either by natural factors or human interference and the connection may be permanent or periodical/occasional or even seasonal.	Have permanent connection with the sea
Classified as open (*classical and man – made*) or closed (*classical, spring tide – fed and isolated*) based on the mode of formation and seasonality of connection to the sea	May be classified as positive, negative or neutral based salinity profile

2.3 Literature review of wetlands in the Western Region

The Western Region of Ghana has an area of about 21,391 km^2 (estimating to about 10% of the total land area of Ghana) with a 202 km coastline. The Western Coastline is made up of six districts which cover approximately 203 km. The coastal habitats of the Region are of various types. These include sandy beaches, lagoons and estuaries, mangroves and inland wetlands. Despite their importance in sustaining the flows of environmental goods and services, they face a variety of threats.

Review of literature done by deGraft-Johnson *et al.* (2010) documents the following as the major threats to the survival and management of coastal water bodies in the Western Region include:

- Overexploitation of marine fisheries resources due to overcapitalization of the fishing industry, use of small mesh nets in the beach seine fishery and other illegal fishing methods
- Loss of coastal habitat through establishment of monocrop plantations, destruction of wetlands for infrastructure development, solid waste disposal, harvest of mangrove forests, beach sand mining and tourism development
- Pollution of the marine and coastal environment from domestic and industrial solid waste, siltation, sewage disposal, mining waste, pesticides and fertilizers
- By-catch of endangered species like seabirds, sea turtles, sharks, dolphins and manatees from the use of nonselective gears in the fishing industry
- Accelerated coastal erosion from deforestation, sand and stone winning, and infrastructure development as the Takoradi Port and the nearby fishing harbor
- Increasing population density which could bring about an increase in the rate of exploitation of resources of fragile ecosystems
- Weak governance, legislation and institutional framework due to the fragmented nature of environmental legislation and lack of political will to enforce legislation
- Development of oil and gas resources which has the potential to increase conflicts with the fishing industry over the use of marine space, and its potential negative impacts on coastal and marine habitats

- Climate change and sea level rise which has the potential to severely impact the shoreline and further weaken the resilience of coastal habitats and biodivervsity and human communities
- Spread of invasive species such as the Water hyacinth *Eichhornia crassipes* in the wetlands and blooms of the green alga *Enteromorpha flexuosa* in the marine coastal waters could significantly hamper fishing activities and affect the livelihoods of coastal communities.

Relevant national wetland policies and programmes have been outlined in Appendix 10.

3. METHODOLOGY

Rapid Ecological Assessment (REA) methods were deployed for the study of the wetlands. REA is regarded as a suite of methods that are usually used to assess wetlands. For the surveys in the Whin estuary, Butuah and Essei lagoons, key aspects of biodiversity were investigated covering information about their species e.g. their rarity, endemism, range, and habitat requirements. Information on habitat condition and threats were also recorded. Attempts were made to generate a species lists for these habitats. Not only address the prevailing threats to the environment, but also aspects of their socio-economic and cultural implications were documented.

3.1 Site description

(i) Essei lagoon: This lagoon maintains a permanent opening into the sea as a result of human interference. The wetland areas could be described as low-lying occurring around the lagoon. The lagoon is located in Sekondi and is bordered to the north by the STMA road, east by the Bakaakyir road and west by the Bakaano road. Fishing in the lagoon is carried out by about twenty resident fishermen.

(ii) Butuah lagoon: The Butuah lagoon is located in New Takoradi, a suburb of Takoradi. It is bordered to the north by the Sekondi-Takoradi Road. This lagoon is the classically closed lagoon type that is cut off from the sea for a greater part of the year but opened for a relatively short period of time during the rainy season. According to key informants, fishermen fishing in this system number about twenty-five, and fishing activities managed under the leadership of a Chief fisherman.

(iii) Whin estuary: The Whin river is stretched into two branches forming a Y-shape structure joining and pouring into the estuary. The larger arm lies on the Western side of Adakope, a suburb of Takoradi while the smaller arm is sandwiched between Adakope and Kokompe on the Eastern side of Adakope. The mouth of the estuary lies on the Western side of the African Beach Hotel located on the Habour Road parallel to the shoreline. The bank of the estuary is a mix of beach sand to the Western side and rocky beaches to the Eastern side. Moving away from the mouth of the estuary, the banks are

heavily vegetated with tickets of mangrove stands, and the indication of a closed vegetation pattern surrounding the estuary. Interviews reveal that there are about 50 fishermen working within the estuary alone.

3.2 Methodology for mapping boundaries and land use change

In order to provide data on the current boundaries and land use patterns around the Butuah and Essei lagoons and estuary of the Whin river, these water bodies were mapped using Trimble Juno ST Global Positioning System Receivers (GPS). This information was complemented by data extracted from georeferenced google earth images. To provide an indication of changes in the areal extent of the water bodies and also in the land use patterns within the immediate surroundings of the three water bodies, the current boundary and land use data were processed and compared with boundary and land use data extracted from a 1973 1:50,000 topographic map of the area.

3.3 Measurement of hydrographic factors

Water quality was assessed relative to predetermined standards for critical concentrations for certain hydrographic factors and pollutants. The water samples were collected at different locations and depths namely surface and bottom from selected water bodies of critical importance. Hydrographic parameters measured were**:**

- Salinity,
- Dissolved Oxygen (DO)
- pH,
- Conductivity,
- Temperature; and
- Turbidity

These were achieved with the help of Water quality checker (Model: Horiba Water Quality Checker U-10).

3.4 Plankton, benthic and littoral macroinvertebrate sampling

The phytoplankton and zooplankton were sampled with a 40 cm long plankton net (net aperture 20 cm and mesh size 200 microns) and fixed with 10 % formalin. In the

laboratory, the phytoplankton and zooplankton were examined under high power objectives of compound microscope and identified using plankton manuals (Newell and Newell, 1963).

Three replicates of benthic and littoral samples were taken from five stations designated A – E in each of the three water bodies for studies on the benthic and littoral fauna; where A was the station closest to the mouth of the water bodies, and E referring to the upper limits of the northern section of the water bodies (Figure 2). An Ekman grab (15 cm × 15 cm) was used in collecting benthic sediments while littoral samples of soft banks were collected by sweeping the sediments using a 50 cm × 50 cm quadrat with fixed net (800 μm). The random quadrat sampling method (Krebs, 1999) was adopted at the mouth of the Whin Estuary (Station A) due to the rocky nature of the banks (quadrat size: 50 cm × 50 cm), and macrofauna occurring within the area enclosed by the thrown quadrat were collected. The sediment samples were screened in the field using a set of sieves of mesh sizes 4000 μm, 2000 μm and 500 μm, and the animals retained in the sieves were preserved in 10% formalin for detailed examination in the laboratory. Prior to sorting, a pinch of Bengal rose dye was added to the samples to stain the organisms and enhance their visibility.

The macrofauna found were examined under a dissecting microscope and identified with the aid of laboratory manuals (Edmunds, 1978; Dejoux *et al*., 1982; Yankson & Kendall, 2001; Hauer & Lamberti, 2006). Counts of the different taxonomic groups in the samples were recorded separately for further analysis.

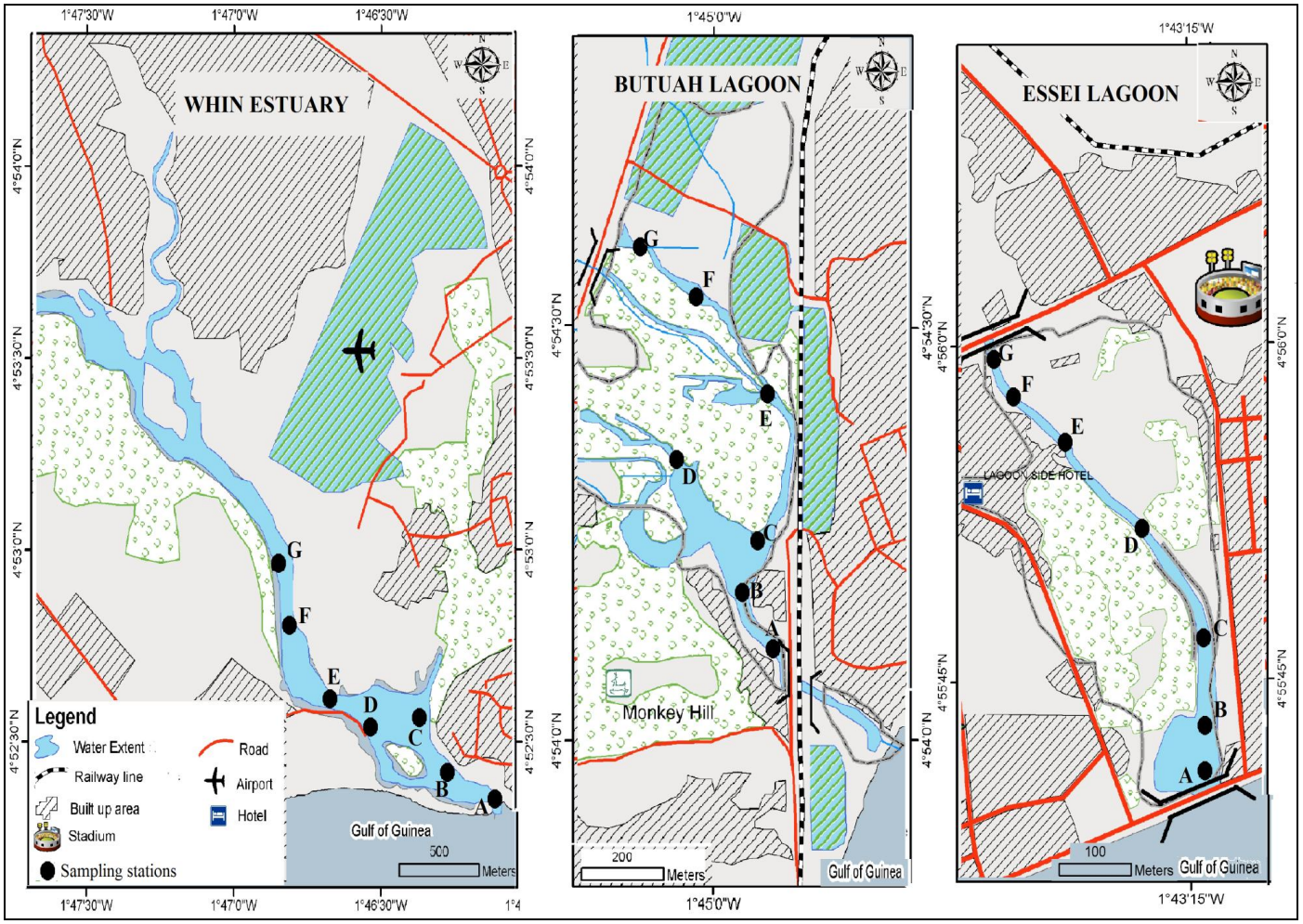

Figure 2: Map of study area showing locations for benthic and littoral sampling (A-E) and collection of water samples for water quality analysis (A-G).

It is important to note here that, larger wetland areas exist beyond the study area. These existing wetland areas were not included in this study for lack of resources. Notice must however be given that wetlands have been developed such as places west of Essei lagoon and behind the Effia Nkwanta Hospital. These would require further studies. For the Whin river, larger tributary areas exist to the east and west exist that were not assessed in this present study, and across the main highway to the north. This also applies for the north of the road at Butuah lagoon.

3.5 Fish sampling and measurements

A pole-seine net (7 m long and 1.5 m deep) with stretched mesh size of 5mm was used for the fish sampling. This particular net was used because of the small size, shallowness and soft bottom of the water bodies; another reason was to ensure the capture of small fishes. Fish samples were also purchased from the local fishermen as complementary information. The fishes were preserved in 10% formalin and transported to the laboratory for further examination. The fish were sorted and identified to their families and species using manuals and keys on fin fishes and shellfishes in Ghana and West Africa (Dankwa *et al.*, 1999; Schneider, 1990; Holden and Reed, 1991; Paugy *et al*., 2003; Kwei and Ofori-Adu, 2005), and the number of individuals belonging to each species from the water bodies was recorded. The total length (TL) of fish specimens was measured to the nearest 0.1cm.

3.6 Analysis of invertebrate and fish data

The invertebrate and fish samples from the water bodies were analyzed for species richness, diversity and species composition. Species richness was determined using Margalef index (d) given as $\frac{(s-1)}{\ln N}$, where s is number of species in the sample, and N is the number of individuals in the sample (Krebs, 1999). Diversity of the communities was ascertained by the Shannon-Wiener index (H′) given as $H' = -\sum_{i=1}^{s} P_i(\ln P_i)$, where s is the number of species in the community and P_i is the proportion of individuals belonging

to species *i* in the community (Krebs, 1999). The evenness or equitability component of diversity was calculated from Pielou's index (Pielou, 1996 in Blay, 1997) given as $J' = H'/H_{max}$ where $H_{max} = \ln s$. The degree of similarity between the communities in the different water bodies was determined as $C_s = \frac{2j}{a+b}$ (Krebs, 1999), where C_s is Sorensen's index, *j* is the number of species common to a given pair of water bodies, and *a* and *b* are the number of species occurring in either of the pair.

The richness and diversity of littoral invertebrates at each of the five sampling stations of the three water bodies was determined while the benthic macrofauna were analysed for their densities at these stations.

In computing the density of the benthic invertebrates, the procedure provided by Elliot (1977) was followed due to the small number of grab samples taken from each station (n= 3). Counts of individuals belonging to each taxon in a sample were log transformed. Where all three samples contained organisms, the number of individuals, x, belonging to each group of invertebrates was transformed as $\log_{10} x$, and where zero counts occurred, $\log_{10}(x+1)$ was used for the transformation. The arithmetic mean of the transformed counts was then calculated, and the derived mean (= geometric mean) which is the mean number of individuals of each taxon per dredge area (225 cm^2 = 0.0225 m^2) was computed as the antilog of the mean of transformed counts. The derived mean value was converted to mean number of individuals per 1 m^2 by multiplying this number by a factor of 44.4. Size range of fish samples from each of the water bodies was determined.

3.7 Questionnaire surveys

A social survey would be conducted for a socio-economic and cultural evaluation of study sites using questionnaires. Key informants would be contacted and focused group discussions conducted where necessary. The data are anticipated to support evaluation of both threats and opportunities for conservation. Additionally, broad demographic and regulatory information would be collected on:

- population size of dependent population
- cultural issues such as customary laws regarding the use of the natural
- habitats and traditional conservation values
- economic activities and development being pursued
- reliance on natural habitats for food, medicines, fuel, building
- materials, etc.
- address land ownership issues, including customary and those
- belonging to government.

Information on the human activities taking place in the region regarded as threats were collated. Such documentation will enable to link observed or possible environmental impacts with their probable uses, and predict likely impacts in the future.

3.8 Additional considerations:

(a) Rarity: Rarity in this sense would refer to local or country rarity. It will exclude regional considerations. This may be of crucial importance for the local inhabitants or provide for income generation in the context of ecotourism. This is because when a species is rare, it is obvious that efforts should be mustered to conserve it to the latter.

(b) Geographic range/ endemism: Geographical distribution is a major factor used for estimating the biological value of a species. The highest value is given to species (called local endemics) that only exist in a small area. Due to their small distribution range, it is imperative to preserve their limited natural habitats, because otherwise they may rapidly become endangered. The survival of such species largely depends on conservation efforts.

(c) Habitat specialization: this criterion was used to determine the conservation needs of a species. The more specialized a species is in terms of its habitat requirements, the more exposed or vulnerable it could become if efforts are not made to preserve its preferred habitats. Habitat considerations, in terms of habitat distribution are also paramount to be assessed and documented whether continuous or in small their occurrence in small patches must be noted.

(d) Flagship species: This refers to identifying single species that appeal to a wider segment of the local population to be of great importance to the area. Usually, these require large expanses of habitat, which is likely to help conserve many other animals and plants with much smaller habitat requirements.

3.9 Limitations of the assessment:

- The rapid nature did not allow for full wetland inventory. However, it was generally possible to collect initial baseline data or provide preliminary results for early management interventions. The information could be used for detailed assessment at a later stage depending on level of resources available.
- Time limitation for data collection, data processing and reporting
- Study could did not capture data on seasonality
- Did not capture information on trends.

4. RESULTS

4.1 Spatial information on the wetlands

The areal coverage of the Butuah lagoon in 2010 is 86404 (sq. meters) whilst Essei lagoon covered an area of 110,902 (sq. meters). The Whin estuary spanned an area of 652,202 (sq. meters) as shown in Figures 3-5.

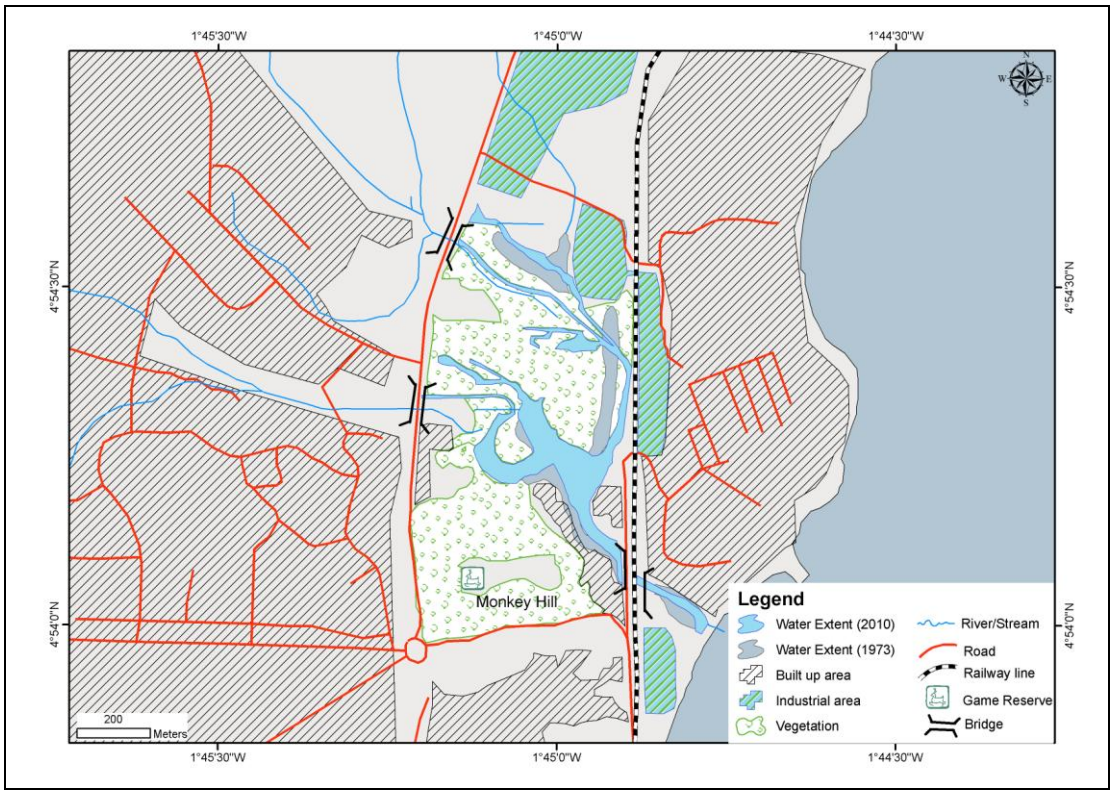

Figure 3: Spatial structure of the Butuah Lagoon comparing change in area of water body between 1973- 2010.

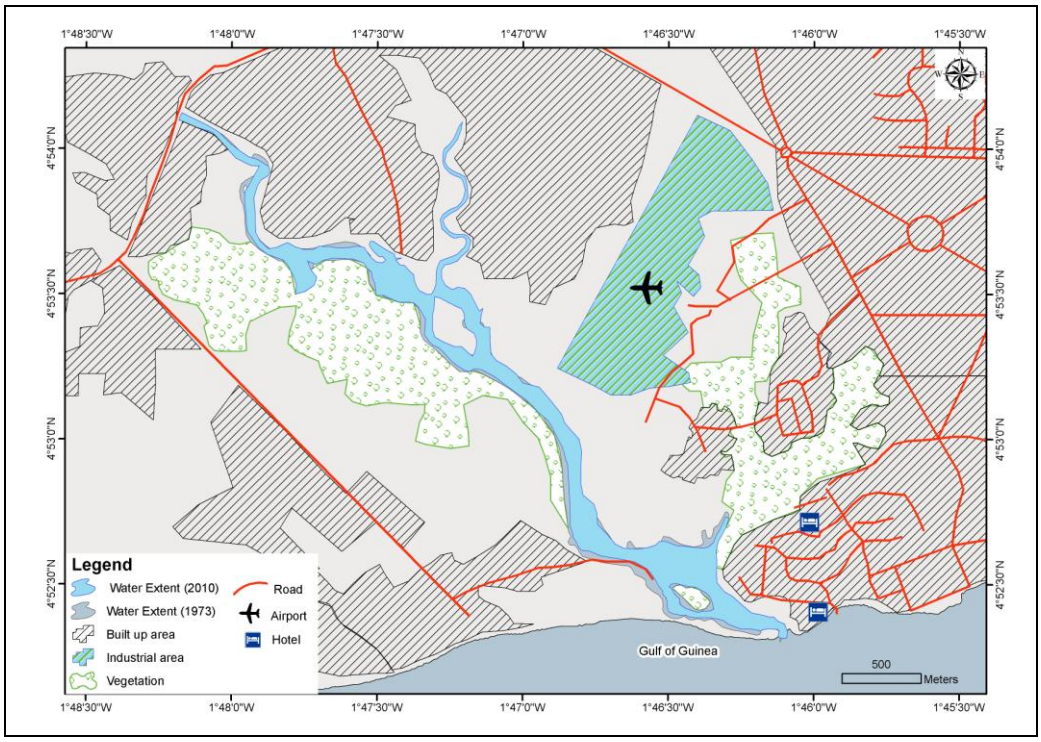

Figure 4: Spatial structure of the Whin estuary comparing change in area of water body between 1973- 2010.

The changes in the areal extent of water surface of the lagoons from 1973 to 2010 are shown in Table 2. As shown in Table 2, Essei lagoon had significantly decreased in water surface area by 82.10%. However, the Butuah lagoon and the Whin estuary rather experienced some increase in their water surface area extent.

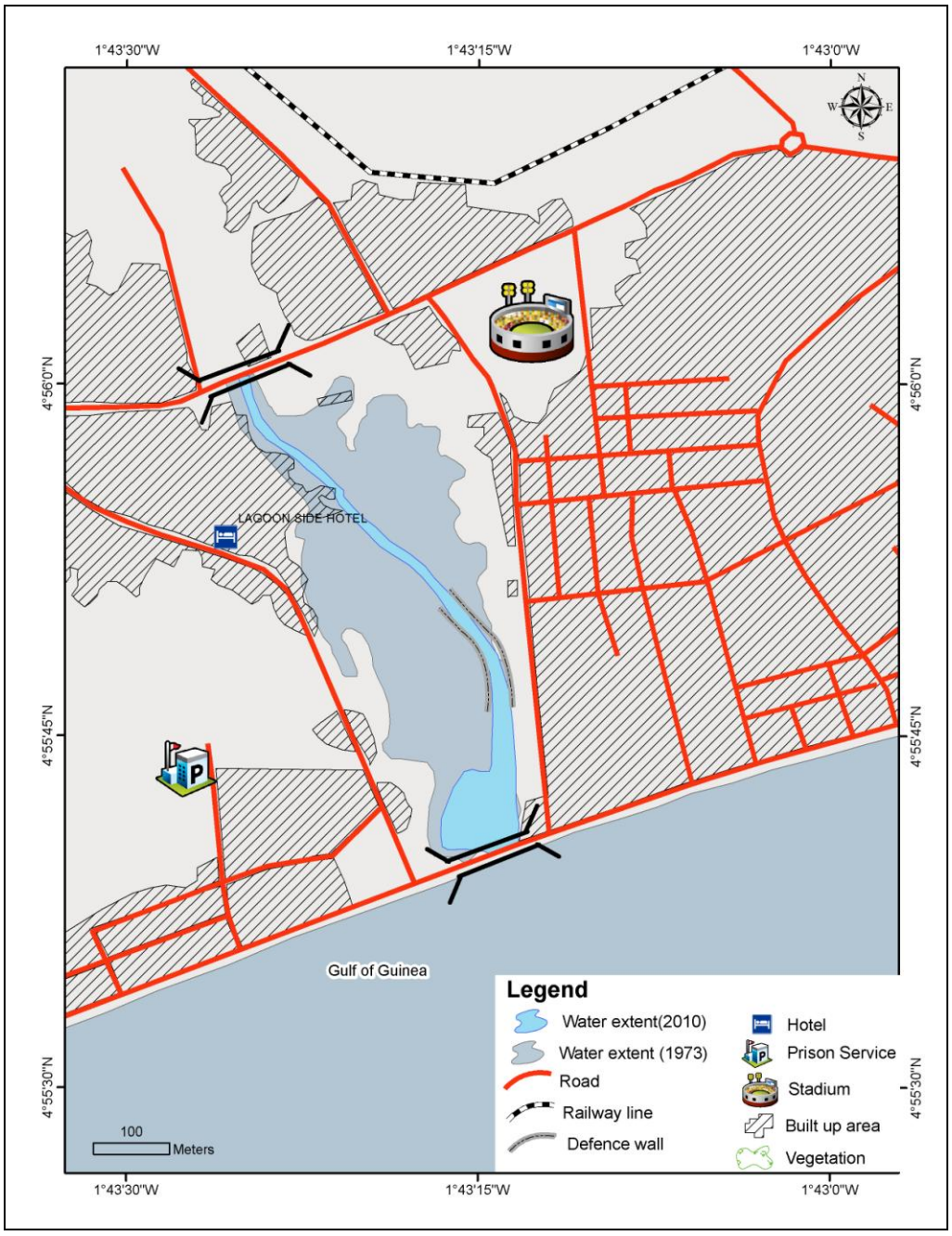

Figure 5: Spatial structure of the Essei Lagoon comparing change in area of water body between 1973- 2010.

Table 2: Water Extent in 1973 and 2010

Water body	Extent in 1973 (sq. meters)	Extent in 2010 (sq. meters)	Percentage Change
Essei	110,902	19,855	-(82.10)
Butuah	73,774	86,404	17.12
Whin	652,202	747,911	14.67

Currently, the land use/ cover pattern within the natural boundaries of the three water bodies shows three main classes/categories (Table 3). These categories were identified as built up area, Industrial and Vegetation.

Table 3: Land use/ cover pattern around the water bodies

Land use/cover	Area					
	Essei		Butuah		Whin	
	(sq meters)	Percent	(sq meters)	Percent	(sq meters)	Percent
Vegetation	61189	38.38	186887	44.13	1301206	21.06
Built up area	13871	8.7	3265	0.77	1601561	25.92
Industrial	-	0	33276	7.86	24855	0.40
Unused/Vacant	84366	52.92	200071	47.24	3250693	52.62
Total	159422	100	423520	100	6177676	100

The current pattern around the Essei lagoon shows that the land use/cover around the estuary was 38.38% natural vegetation and 8.7 % built up. The remaining land use (52.62%) within the natural boundary is unused (Fig. 6).

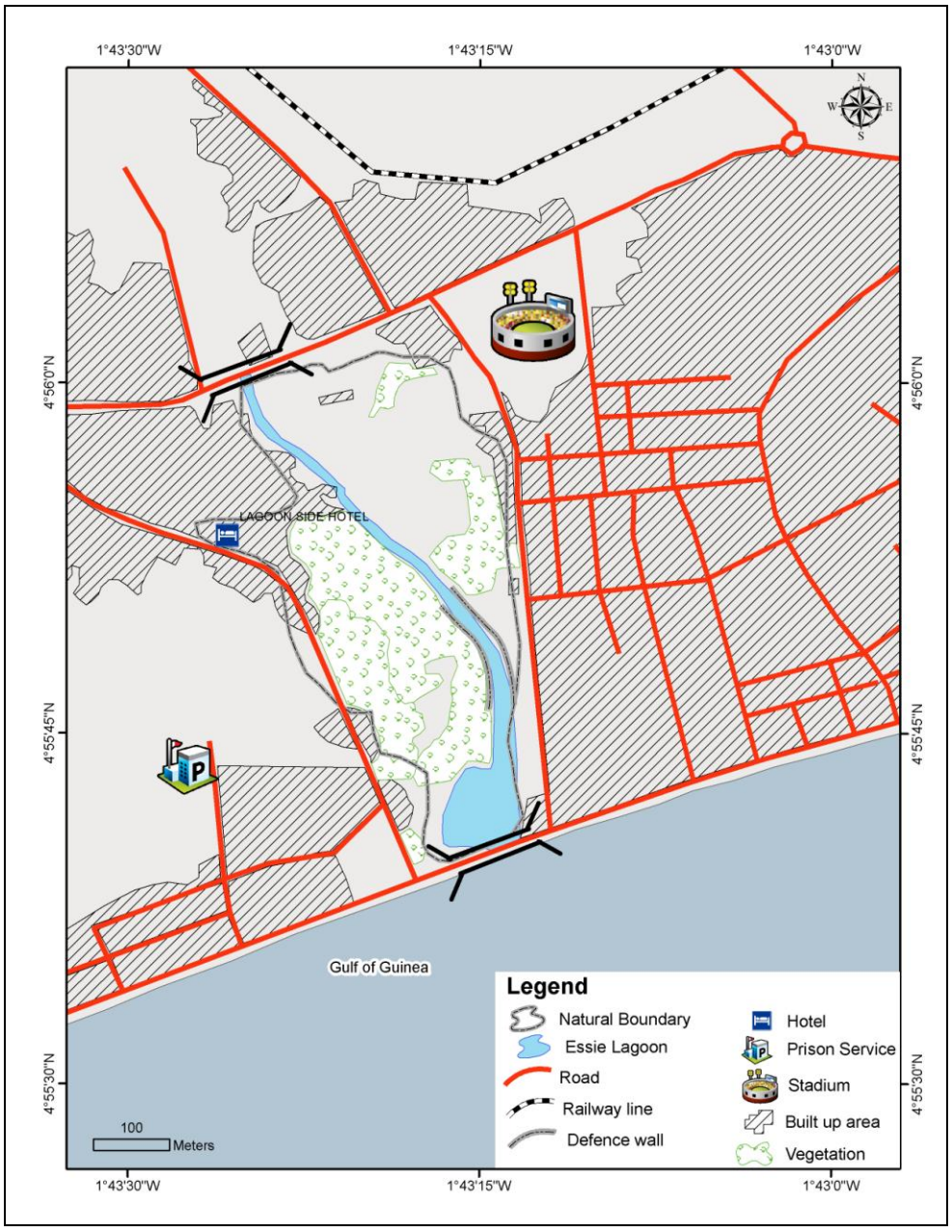

Figure 6: Land use/ land cover scenario around Essei lagoon in 2010.

Similarly, the area within the natural boundary of the Butuah Lagoon recorded natural vegetation as the largest land cover with mostly mangrove and some scattered patches of reeds, vegetation covered 44.13% of the area. Encroachment into the boundary is considerably minimal. Most of the settlements were found to

be 50 feet above sea level. Consequently, 0.77% of the boundary has been settled and 7.86% for Industrial activities (Fig. 7).

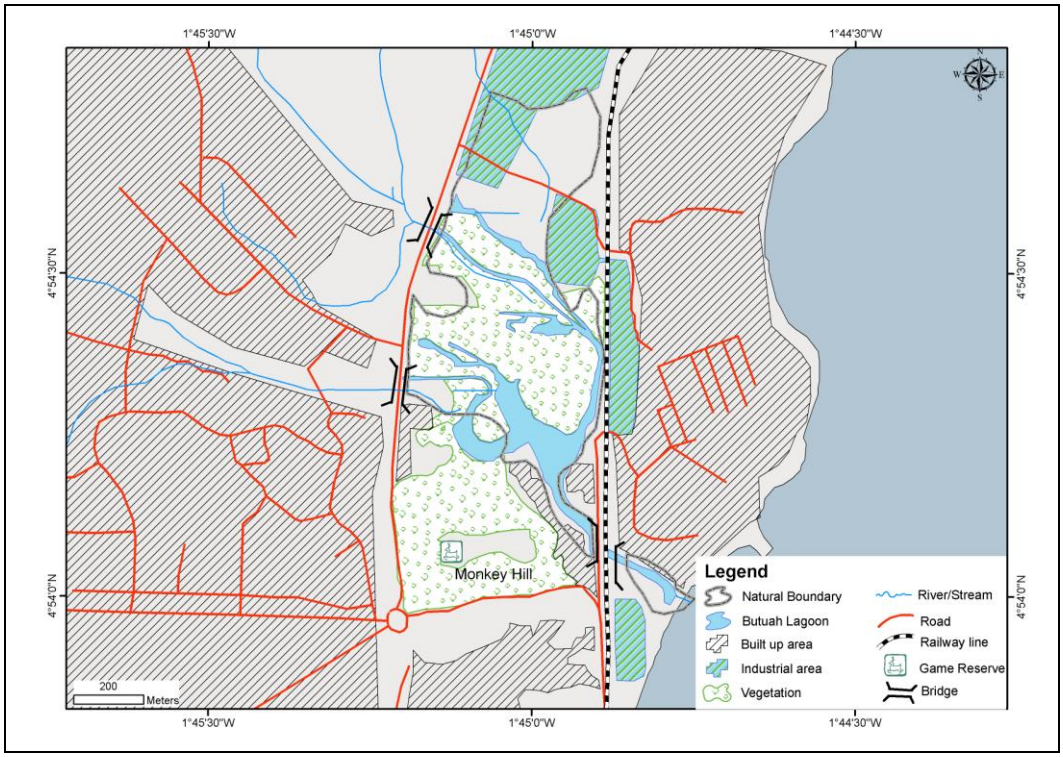

Figure 7: Land use/ land cover scenario around Butuah lagoon in 2010.

About 52% of available land around the estuary is unused (Fig. 8). Vegetation and Built up areas constitute 21.06% and 25.92 % respectively. Industrial sitings makes up the least component amounting to 0.40%. The data points to the fact that the natural boundaries surrounding the Whin estuary is the least encroached upon.

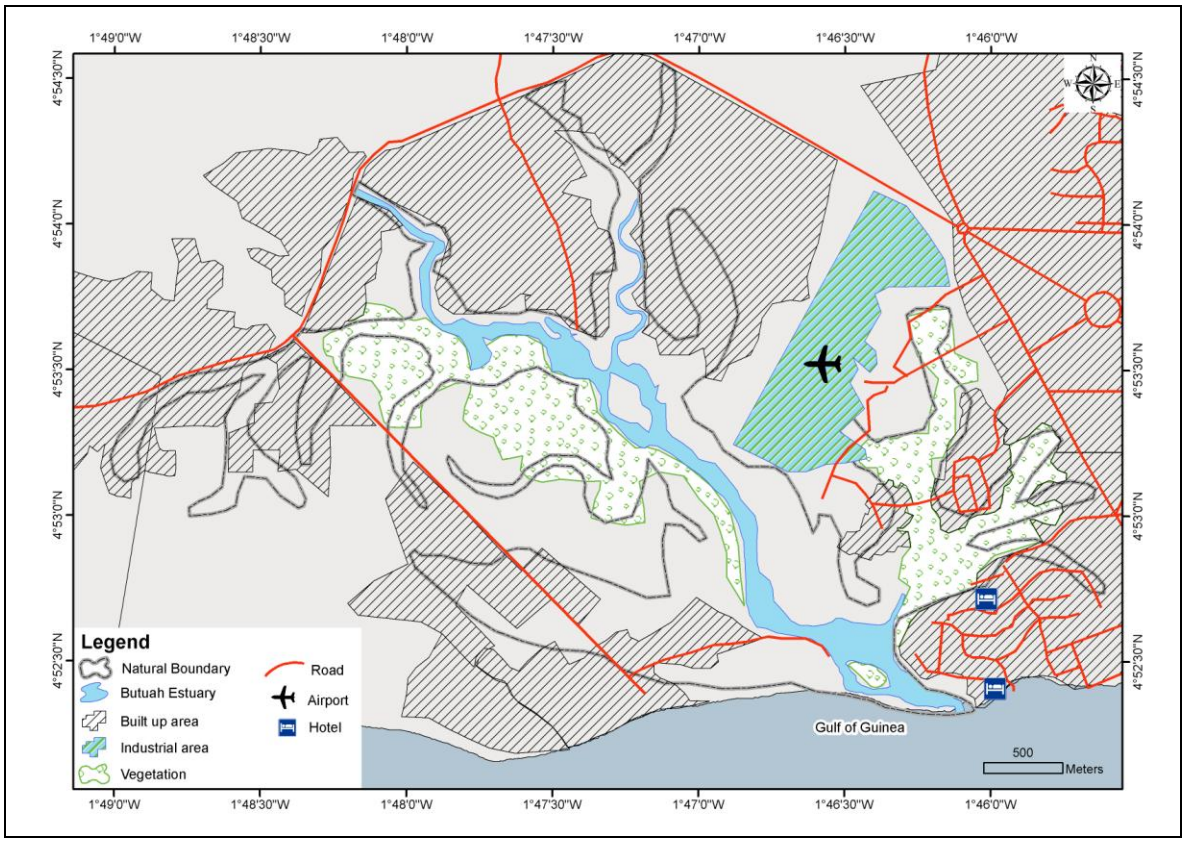

Figure 8: Land use/ land cover scenario around Whin estuary in 2010.

4.2 Hydrographic profiles

4.2.1 Temperature

Temperature levels have many fundamental effects on water quality. For example, colder water can hold more oxygen than warmer water. Several environmental factors affect the growth and development of fish more than temperature per se. Spawning and the hatching of eggs are geared more towards annual temperature changes. Fig. 9 shows comparatively higher temperatures in the Butuah lagoon relative to Essei lagoon and the Whin estuary. On the whole, mean temperature for Butuah was 32.95^{o}C compared to Essei and Whin which recorded 25.98 ^{o}C and 25.57 ^{o}C respectively. In general, temperatures are much higher at the mouth of Butuah and Essei lagoons compared to the upper limits of the lagoons (i.e. G).

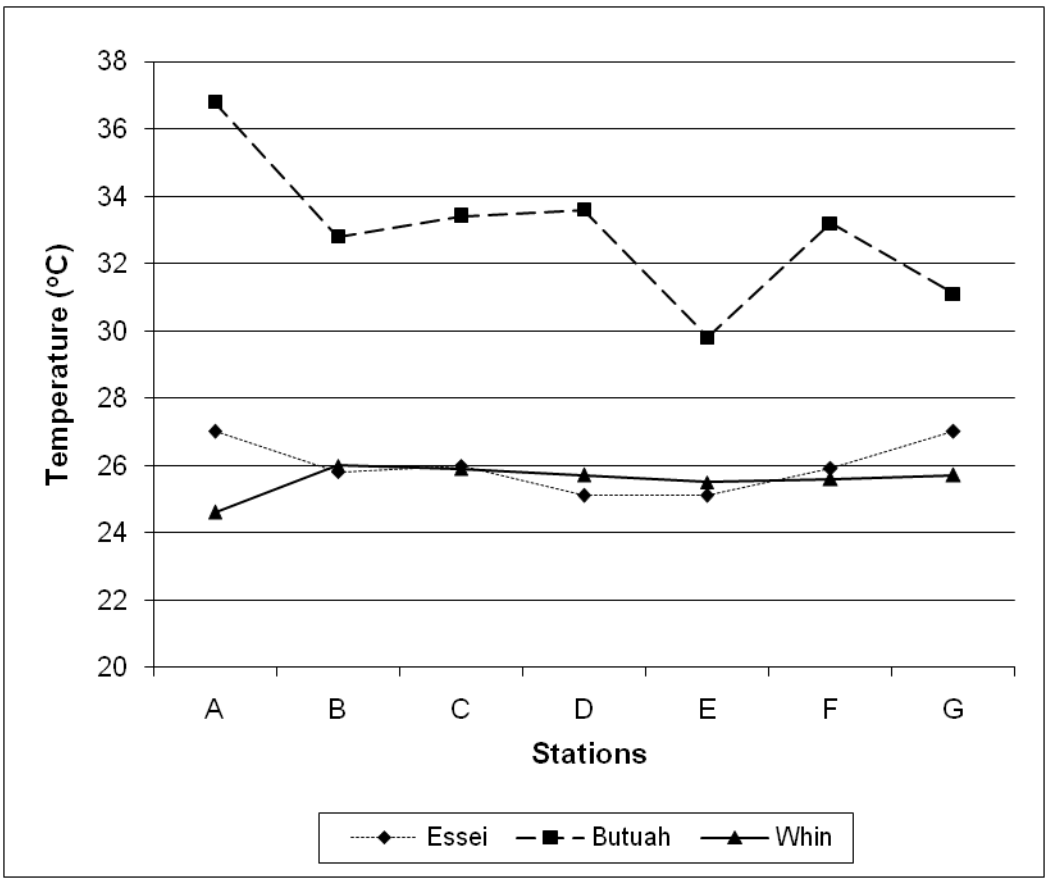

Figure 9: Temperature profile of the wetlands

4.2.2 Dissolved Oxygen (DO)

DO is a critical water quality parameter for characterizing the health of an aquatic system. It is a measurement of oxygen dissolved in water which is available to fish and other aquatic life. The DO content of water results from photosynthetic and respiratory activities of the flora and fauna in the system, and the mixing of atmospheric oxygen with waters through wind and stream current action. The data showed that DO was highest at the mouth of Butuah lagoon at 9.51 mg/L and the lowest at the mouth of Essei lagoon at 0.1 mg/L. DO parameters were fairly stable from the mouth to the upper limits of the estuary with an average value of 3.11 mg/L (Fig. 10).

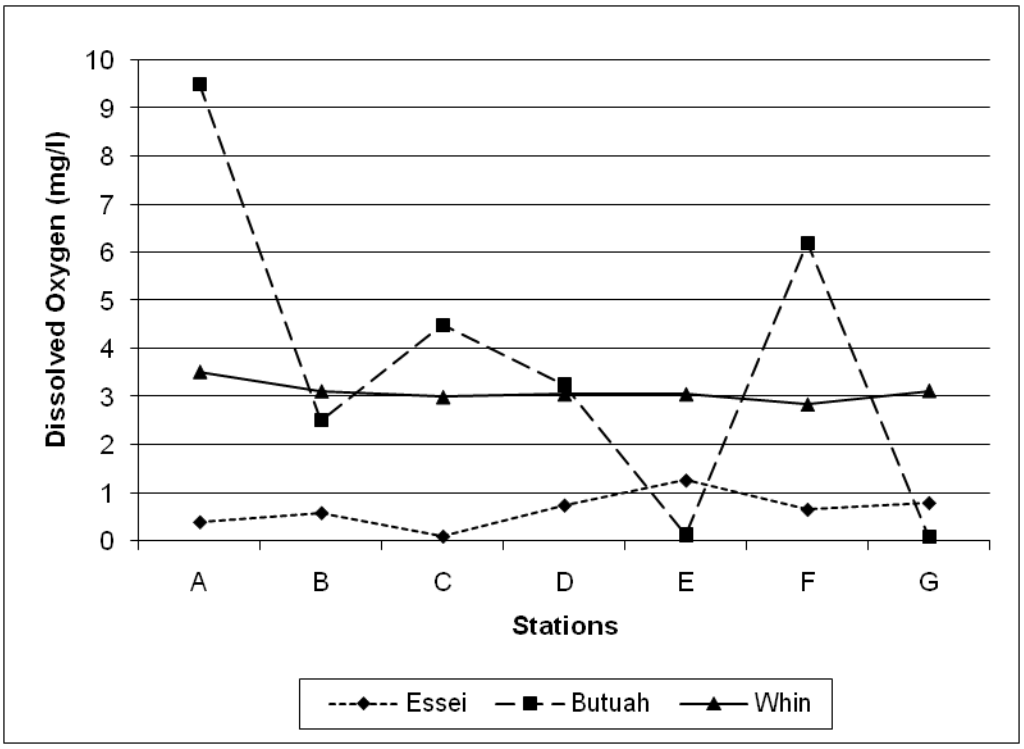

Figure 10: Dissolved Oxygen (DO) profile of the wetlands

4.2.3 Salinity

Highest salinity was recorded at the mouth of the Whin estuary with an average value of 37.01‰. Compared to Essei and Butuah, salinity ranges at Whin was highest. Average salinity values measured at Essei and Butuah was 18.78‰ and 19.01‰ respectively (Fig. 11). Generally, the salinity levels in the estuary are duly expected due to the influx of seawater into the estuary. The salinity values measured at Essei and Butuah lagoons generally reflect brackishwater conditions, providing moderate conditions for other brackish and marine species.

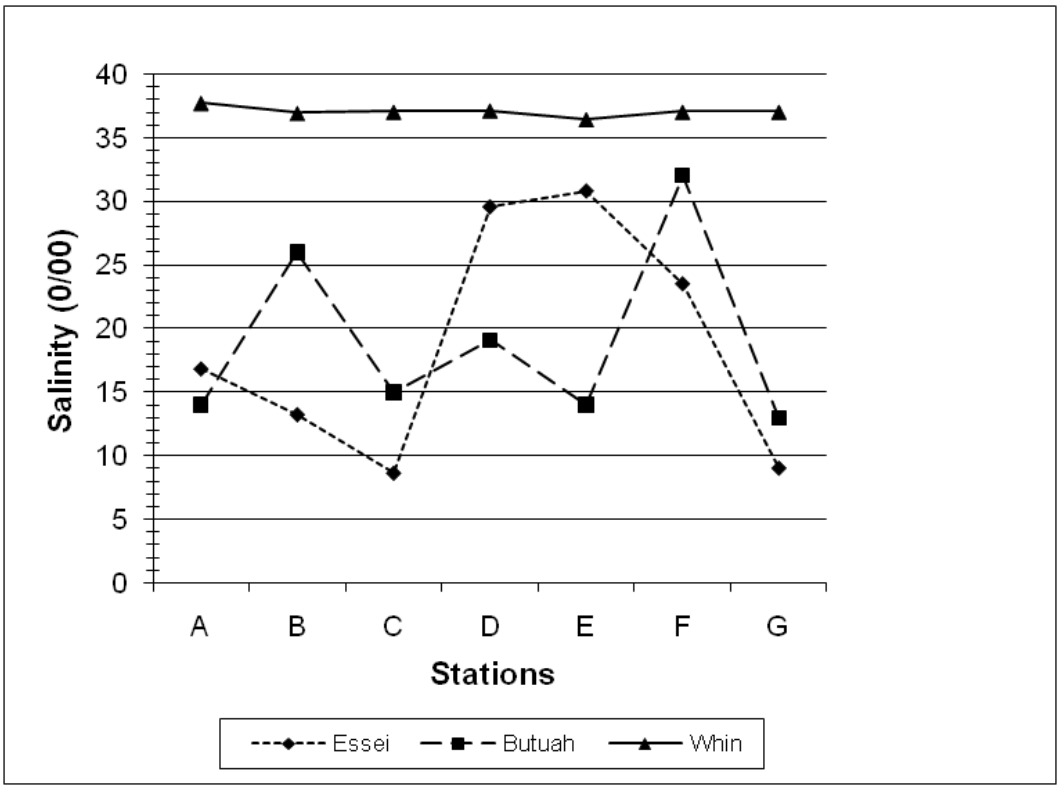

Figure 11: Sanity profile of the wetlands

4.2.4 Conductivity

Conductivity test measures aims at measuring conductance which is the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, sulfate, sodium, calcium, etc. Conductivity in water bodies is affected by the geology of the area through which the water flows. E.g. water bodies that run through granite bedrock will have lower conductivity, and those that flow through limestone and clay soils will have higher conductance. High conductance readings could also come from industrial pollution or urban runoff -- water running off of streets buildings, parking lots or garages. Also, extended dry periods and low flow conditions also contribute to higher specific conductance readings. Again, oil spill tends to lower the conductivity of the water. This is because organic compounds such as oil do not conduct electrical current very well. Specific conductance is measured in microsiemens per centimeter (µS/ cm). In Figure 12, the average trend in conductivity data mirrors that of the salinity data. In general, highest conductivity was recorded at the mouth of Whin at 55.61µs/cm and least values measured at Butuah amounting to 2.9

µs/cm. For Essei higher conductivity values were recorded at the middle portions of the lagoon from points D-E, and subsequently dropped sharply to G. Nevertheless, Butuah had the overall least values at 2.97µs/cm (Fig. 12).

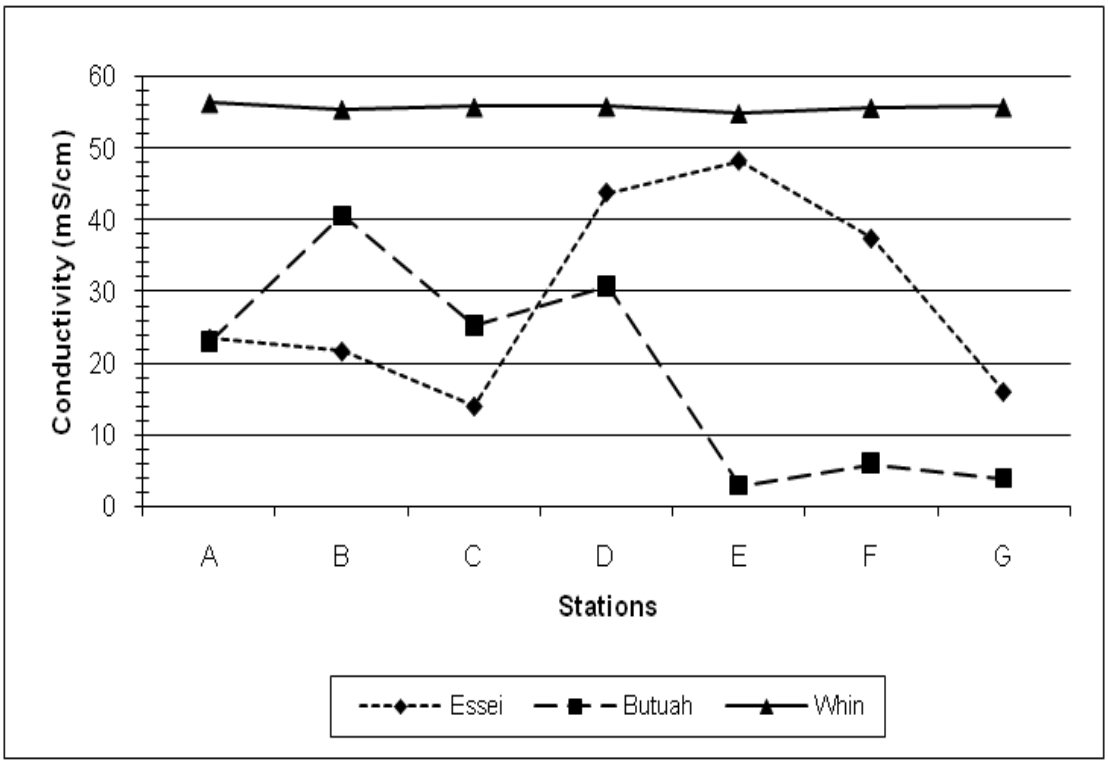

Figure 12: Conductivity profile of water bodies

4.2.5 Turbidity

Turbidity is a measure of the light scattering properties of the water. Suspended solids (including total dissolved solids) in water can reduce the transmission of light either through absorption or by scattering. High turbidity can have a negative impact on submerged aquatic vegetation, benthic organisms and the ability of juvenile fish to catch prey. Turbidity gradients are also useful indicators of places where fishes spawn. In order of increasing levels of turbidity, the data indicated that Butuah was most turbid with an average value of 180.07ppm. This was followed by Essei which recorded 55.79ppm. Generally, Whin was least turbid with an average value of 42.29ppm (Fig. 13).

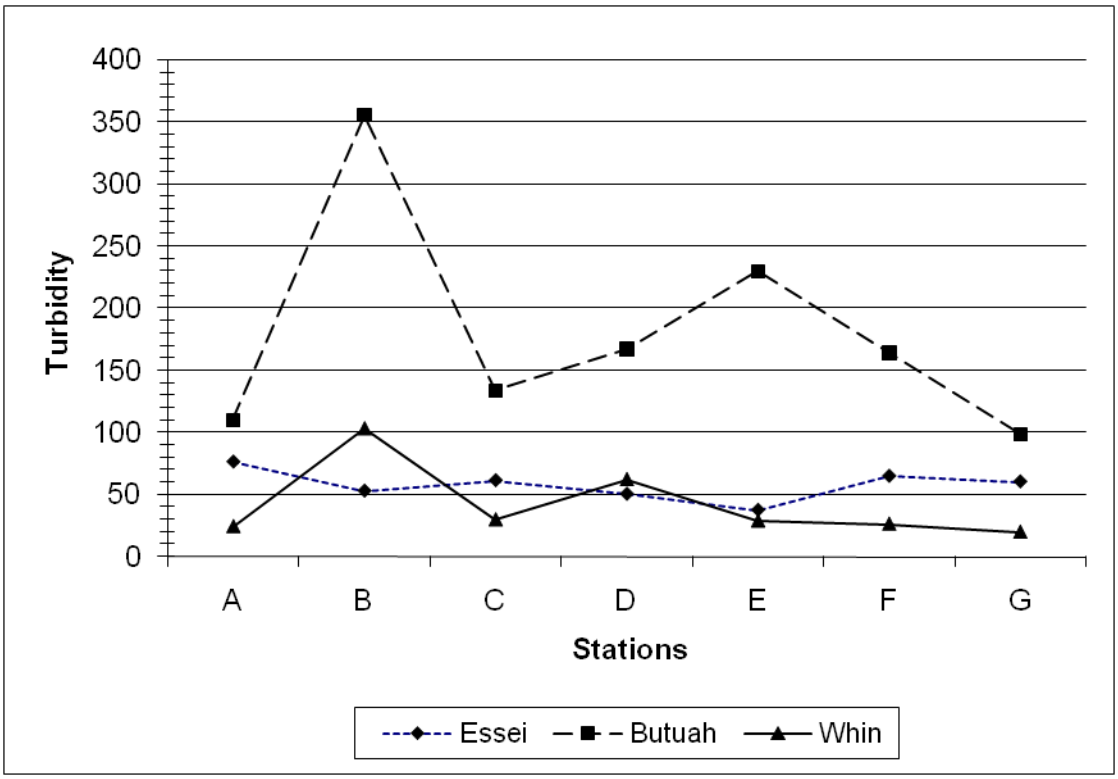

Figure 13: **Turbidity profile of the water bodies**

4.2.6 pH

The pH test measures the hydrogen ion concentration of water. It provides a gauge of the relative acid or alkaline nature of a sample. The scale is logarithmic, thus there is a tenfold change in acidity or alkalinity per unit change. For example, water with a pH of 6 is ten times more acidic than water with a pH of 7. The data showed that relatively alkaline conditions exist in the water bodies. However, Whin estuary recorded an average highest value of 8.08 followed by Essei and Butuah at 7.76 and 7.62 respectively (Fig. 14)

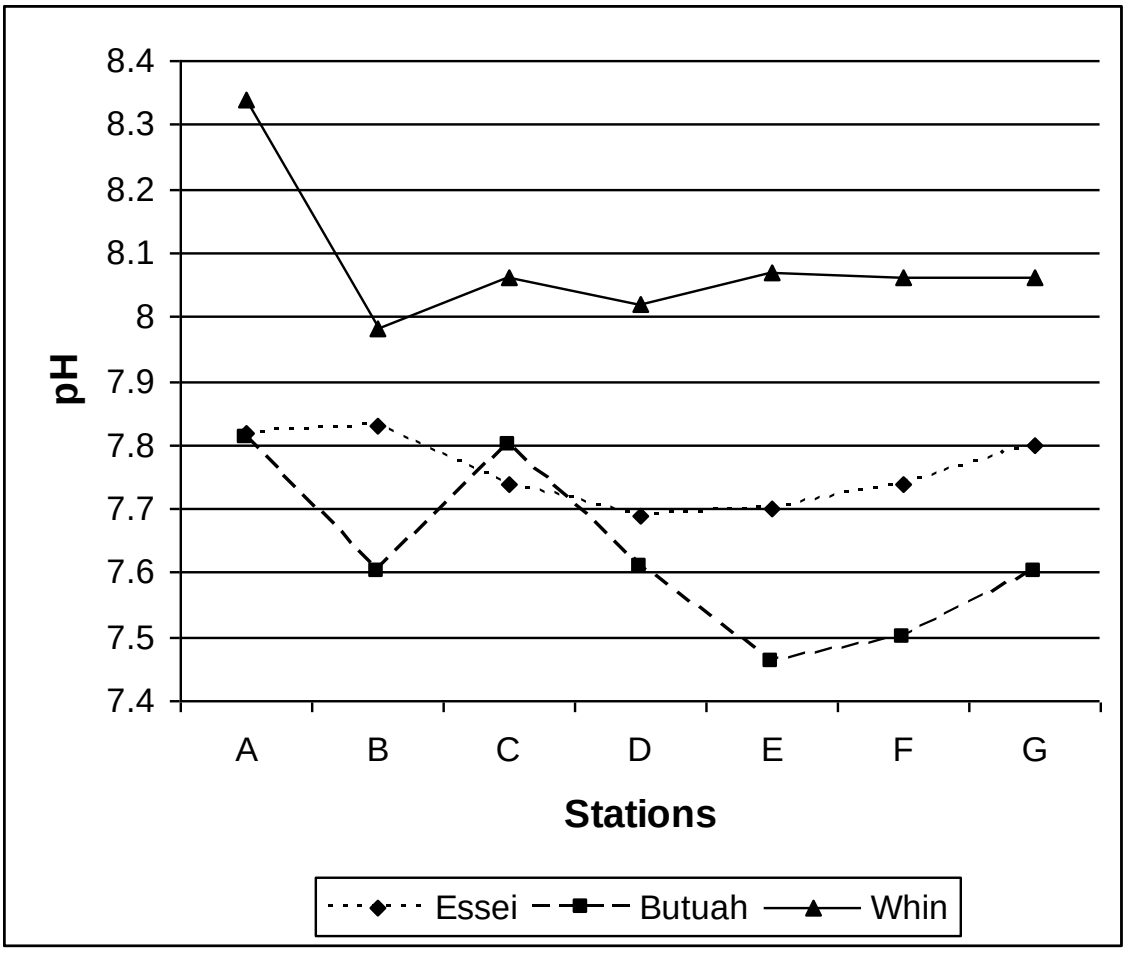

Figure 14: pH profile of the wetlands

4.3 The Plankton community

Plankton diversity were measured and used as indicators for comparative assessment of the primary productivity of the wetlands to be able to support fish resources.

Phytoplankton

As shown in Tables 4-6, the phytoplankton identified from the three water bodies includes species of blue-green algae, green algae and diatoms. The blue-green algae found include *Anabaena* spp., *Oscillatoria* spp., *Chroococcus* sp., *Microcystis* sp. etc., while the green algae were mostly desmids such as *Closterium* sp. and *Scenedesmus* sp., unicellular forms (eg. *Pediastrum* sp. and *Staurastrum* sp.) and a few filamentous types

such as *Spirogyra* sp.. The most common diatoms present include species of *Navicula*, *Rhizosolenia*, *Gyrosigma*, *Diatoma* spp. and *Stephanodiscus*.

Table 4: List of phytoplankton in Essei Lagoon in the Sekondi – Takoradi metropolis

PHYTOPLANKTON	ABUNDANCE
Blue - green algae	
*Oscillatoria*spp.	++
Anabaena spp.	++
Lyngbya sp.	++
Spirulina spp.	+
Microcystis spp.	+++
Chroococcus sp.	++
Aphanizomenon sp.	+
Diatoms	
Navicula spp.	+++
Nitzschia spp.	++
Gyrosigma sp.	+
Coscinodiscus spp.	+++
Stephanodiscus spp.	+++
*Melosira*sp.	+
*Rhizosolenia*spp.	++
Diatoma spp.	+++
Asterionella sp.	+
Synedra spp.	+
Green algae	
Staurastrum spp.	++
Pediastrum sp.	+
Spirogyra sp.	+
*Netrium*spp.	+
Microspora sp.	+
Closterium sp.	+
*Chaetomorpha*sp.	+

+ = occurred sparingly
+ + = moderately abundant
+++ = highly abundant

Table 5: List of phytoplankton in Butuah Lagoon in the Sekondi – Takoradi metropolis

PHYTOPLANKTON	ABUNDANCE
Blue - green algae	
*Oscillatoria*spp.	++
Anabaena spp.	+++
Lyngbya sp.	+++
Spirulina spp.	++
Calothrix sp.	++
Microcystis spp.	+++
Chroococcus sp.	+++
Aphanizomenon sp.	+
Diatoms	
Navicula spp.	++
Nitzschia spp.	+
Pleurosigma sp.	+
Stephanodiscus spp.	+
*Rhizosolenia*spp.	++
Diatoma spp.	++
Synedra spp.	+
Green algae	
Staurastrum spp.	+
*Netrium*spp.	+
Microspora sp.	++
Scenedesmus sp.	+

\+ = occurred sparingly
+ + = moderately abundant
+++ = highly abundant

Table 6: List of phytoplankton inWhin Estuary in the Sekondi – Takoradi metropolis

PHYTOPLANKTON	ABUNDANCE
Blue - green algae	
*Oscillatoria*spp.	+
Anabaena spp.	++
Spirulina spp.	+
Microcystis spp.	++
Chroococcus sp.	++
Diatoms	
Navicula spp.	+++
Nitzschia spp.	++
Gyrosigma sp.	+
Pleurosigma sp.	+
Coscinodiscus spp.	+
Stephanodiscus spp.	+
*Melosira*sp.	+++
*Rhizosolenia*spp.	++
Diatoma spp.	+++
Asterionella sp.	++
Synedra spp.	++
Cyclotella sp.	+
Green algae	
Staurastrum spp.	+++
Pediastrum sp.	+++
Spirogyra sp.	+
*Netrium*spp.	++
Microspora sp.	+++
Closterium sp.	+++
Scenedesmus sp.	++
*Chaetomorpha*sp.	++

\+ = occurred sparingly
+ + = moderately abundant
+++ = highly abundant

A total of 25 genera of phytoplankton occurred in the Whin Estuary, 24 in the Essei Lagoon and 19 in Butuah Lagoon (Table 10). Generally, more genera of diatoms and

green algae occurred in the Whin Estuary than Essei and Butuah, while Butuah had the highest number of genera of blue – green algae. There was a high abundance of blue – green algae than green algae and diatoms in Butuah, and green algae were highly abundant in Whin. The abundance of diatoms was higher in Essei and Whin than Butuah.

The list of zooplankton identified from the three water bodies is presented in Tables 6-8. Species of copepods (*Calanus* sp., *Sappharina* spp., *Cyclops* spp., *Thermocyclops* sp., and *Copepodite* sp.), rotifers (*Brachionus* sp., *Keratella* spp., *Kellicottia* spp., and *Trichocera* sp.) and a cladoceran (*Bosmina* sp.) were the zooplankton encountered. A total of 10 zooplankton genera were found in Whin, and 7 in each of Essei and Butuah Lagoon (Table 10). A higher number of genera of copepods and rotifers occurred in Whin Estuary than Essei and Butuah, while the 1 cladoceran genus occurred in the three water bodies.

Table 7: List zooplankton in the Essei Lagoon in the Sekondi – Takoradi metropolis

ZOOPLANKTON	ABUNDANCE
Copepods	
Calanus sp.	+
Cyclops spp.	++
Sappharina sp.	+
Rotifers	
*Brachionu s*sp.	+
*Keratella*spp.	+++
*Kellicottia*spp.	++
Cladocerans	
Bosmina sp.	++

+ = occurred sparingly
+ + = moderately abundant

ZOOPLANKTON	ABUNDANCE

+++ = highly abundant

Table 8: List of zooplankton in the Butuah Lagoon in the Sekondi – Takoradi metropolis

Zooplankton	Abundance
Copepods	
Cyclops spp.	++
Sappharina sp.	+
Thermocyclops sp.	++
Copepodite sp.	+
Rotifers	
*Brachionus*pp.	+
*Kellicottia*spp.	+++
Cladocerans	
Bosmina sp.	+

+ = occurred sparingly
+ + = moderately abundant
+++ = highly abundant

Table 9: List of zooplankton in the Whin Estuary in the Sekondi – Takoradi metropolis

ZOOPLANKTON	ABUNDANCE
Copepods	
Calanus sp.	+++
Cyclops spp.	+
Sappharina sp.	+
Thermocyclops sp.	++
Copepodite sp.	+++

ZOOPLANKTON	ABUNDANCE
Rotifers	
*Brachionus*sp.	+++
*Keratella*spp.	+
*Kellicottia*spp.	+++
*Trichocera*sp.	++
Cladocerans	
Bosmina sp.	+++

+ = occurred sparingly
+ + = moderately abundant
+++ = highly abundant

Table 10: Richness of plankton and zooplankton genera of the three water bodies

	NUMBER OF GENERA		
PHYTOPLANKTON	ESSEI	BUTUAH	WHIN
Blue-green algae	7	8	5
Diatoms	10	7	12
Green	7	4	8
Total	**24**	**19**	**25**
ZOOPLANKTON			
Copepods	3	4	5
Rotifers	3	2	4
Cladocerans	1	1	1
Total	**7**	**7**	**10**

4.4 The Benthic macroinvertebrate community

Occurrence, richness and diversity

The benthic communities of the three water bodies included mainly oligochaetes, polychaetes and insect larvae, with echinoderms, nemertine worms and gastropods occurring sparingly (Tables 11-13). The polychaetes found belonged to the families Capitellidae, Nereidae, Cirratulidae, Opheliidae, and Maldanidae while the insect larvae encountered were dipterans of the families Chironomidae and Ceratopogonidae. The only gastropod collected was *Tympanotonus fuscata* of the family Potamididae. Oligochaetes,

capitellid polychaetes and chironomid larvae were present in all three water bodies while the other macrofauna occurred in one or two of the wetlands.

A total of 7 families of the zoobenthos were collected from Essei, 4 of which were polychaetes, and 6 families were sampled from Butuah of which 2 were polychaetes (Table 14). The 5 macrobenthic families present in Whin comprise 2 insect families.

Richness and diversity of benthic invertebrate communities of Essei (d = 1.18, H' = 1.22) and Butuah (d = 1.09, H' = 1.21) were very close, with Whin being slightly lower than the two (d = 0.89, H' = 1.02) Table 14. However, the distribution of the individuals among the various benthos groups was somehow even in all the three communities ($J' > 0.6$). As shown in Table 15, there was a higher similarity between the Essei and Whin communities than (Cs > 0.6) than any of the other pairs.

Table 11: List of benthic macroinvertebrates of the Essei Lagoon in the sekondi-Takoradi metropolis

CLASS	ORDER	FAMILY
OLIGOCHAETA		
POLYCHAETA		Capitellidae
		Nereidae
		Opheliidae
		Maldanidae
INSECTA	DIPTERA	Chironomidae
Others		
Nemertea		

Table 12: List of benthic macroinvertebrates of the Butuah Lagoon in the sekondi-Takoradi metropolis

CLASS	ORDER	FAMILY
OLIGOCHAETA		
POLYCHAETA		Capitellidae
		Nereidae
		Cirratulidae
INSECTA	DIPTERA	Chironomidae
		Ceratopogonidae
GASTROPODA		Potamididae
Others		
Echinodermata		

Table 13: List of benthic macroinvertebrates of the Butuah Lagoon in the sekondi-Takoradi metropolis

CLASS	ORDER	FAMILY
OLIGOCHAETA		
POLYCHAETA		Capitellidae
INSECTA	DIPTERA	Chironomidae
		Ceratopogonidae
GASTROPODA		Potamididae
Others		
Nemertea		

Table 14: Richness of benthic invertebrate families of the three water bodies

INVERTEBRATE GROUP	NUMBER OF FAMILIES		
	ESSEI	**BUTUAH**	**WHIN**
OLIGOCHAETA	1	1	1
POLYCHAETA	4	2	1
INSECTA	1	2	2
GASTROPODA		1	
ECHINODERMATA		1	
NEMERTEA	1		1
TOTAL	**7**	**7**	**5**

Table 15: Richness and diversity indices for the benthic invertebrate communities of the three water bodies

Water body	Margalef's Richness (d)	Shannon – Wiener diversity (*H'*)	Pielou's evenness (*J'*)
Essei	1.18	1.22	0.63
Butuah	1.09	1.21	0.68
Whin	0.89	1.02	0.63

Table 16: Sorensen's similarity index for pairs of benthos communities of the three water bodies

	Essei	Butuah
Butuah	0.46	
Whin	0.66	0.54

Composition of benthic invertebrate fauna

The most common and dominant macrobenthic fauna in all the three wetlands were Oligochaeta, Capitellidae and Chironomidae (Figure 15). The composition of Oligochaeta were 17.5 %, 41.3 % 45.3 % in Butuah, Whin and Essei respectively, that of Capitellidae were 34 %, 27.5 % and 27.3% in Butuah, Whin and Essei respectively, while Chironomidae made up 31 %, 25.2 % and 23.1 % of the communities in Butuah, Whin and Essei respectively. Potamidiae constituted 10 % of the Butuah community. The composition of the other benthic groups varied between 0.5 and 4 % in all the three wetlands.

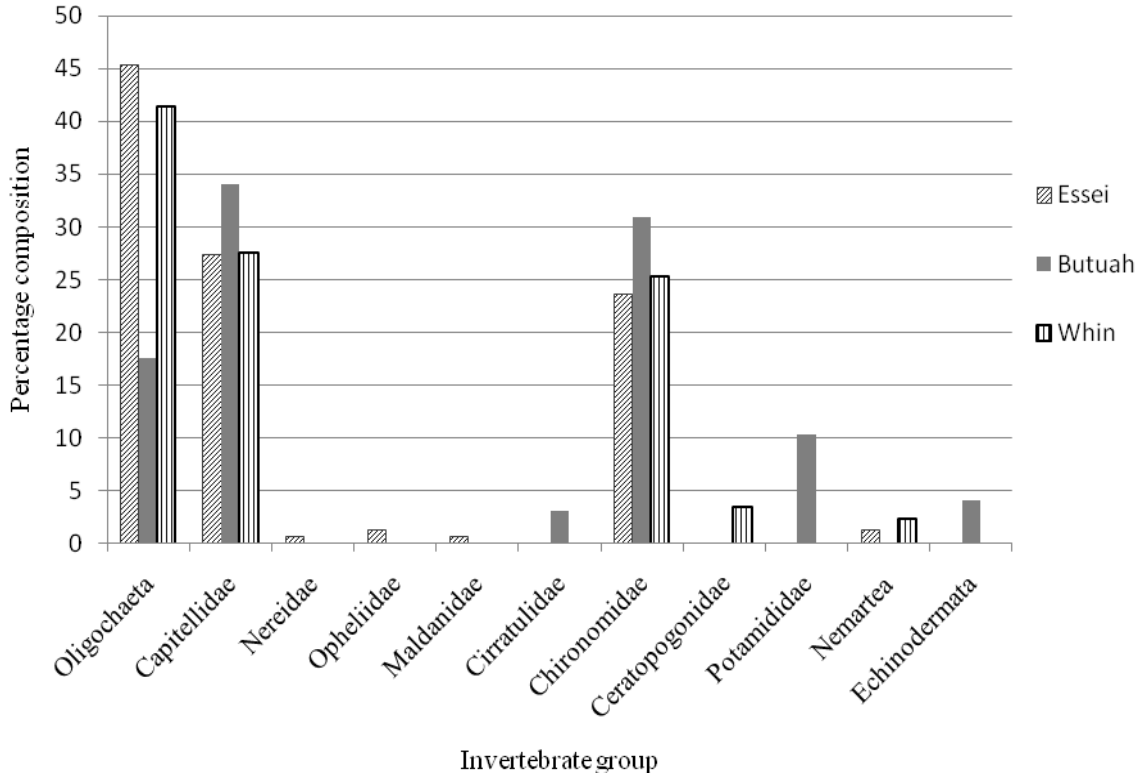

Figure 17: Percentage composition of benthic invertebrate groups in the three water bodies

Density of benthic invertebrates

In Essei Lagoon, the density of oligochaetes was higher at stations A (367 individuals / m^2) and E than the stations in between (< 110 individuals / m^2), with the density at Station E (581 individuals / m^2) being the highest. (Figs. 16-18). Capitellid polychaete density was lower in at Stations A – D (> 100 individuals / m^2) but higher at station E (500 individuals / m^2). Similarly, chironomids also had lower densities at stations A – D (< 56 individuals / m^2) and higher at Station E (490 individuals / m^2). The densities of the remaining benthos varied between 0 and 64 individuals / m^2 at the various stations.

Oligochaete density in Butuah Lagoon ranged in density from 56 individuals / m^2 (Stations A & E) to 138 individuals / m^2 (Station D) while the density of the capitellid polychaetes varied between 80 individuals / m^2 and 100 individuals / m^2 at Stations A – D, 161 individuals / m^2 at Station E. Chironomids occurred at Stations D and E and had densities 89 individuals / m^2 and 287 individuals / m^2 respectively. The gastropods also occurred at two Stations (A and B) at densities of 128 individuals / m^2 and 56 individuals / m^2 respectively. The other organisms were less than 90 individuals / m^2 and occurred at 1 or two stations.

In the Whin Estuary, Oligochaeta density increases progressively from 56 individuals / m^2 (Station A) to 266 individuals / m^2 (Station E) while Capitellidae densities were 81, 56, 203 and 56 individuals / m^2 at Stations B – E respectively. Chironomidae increased in density from 56 individuals / m^2 at Station C to 166 individuals / m^2 at Station E.

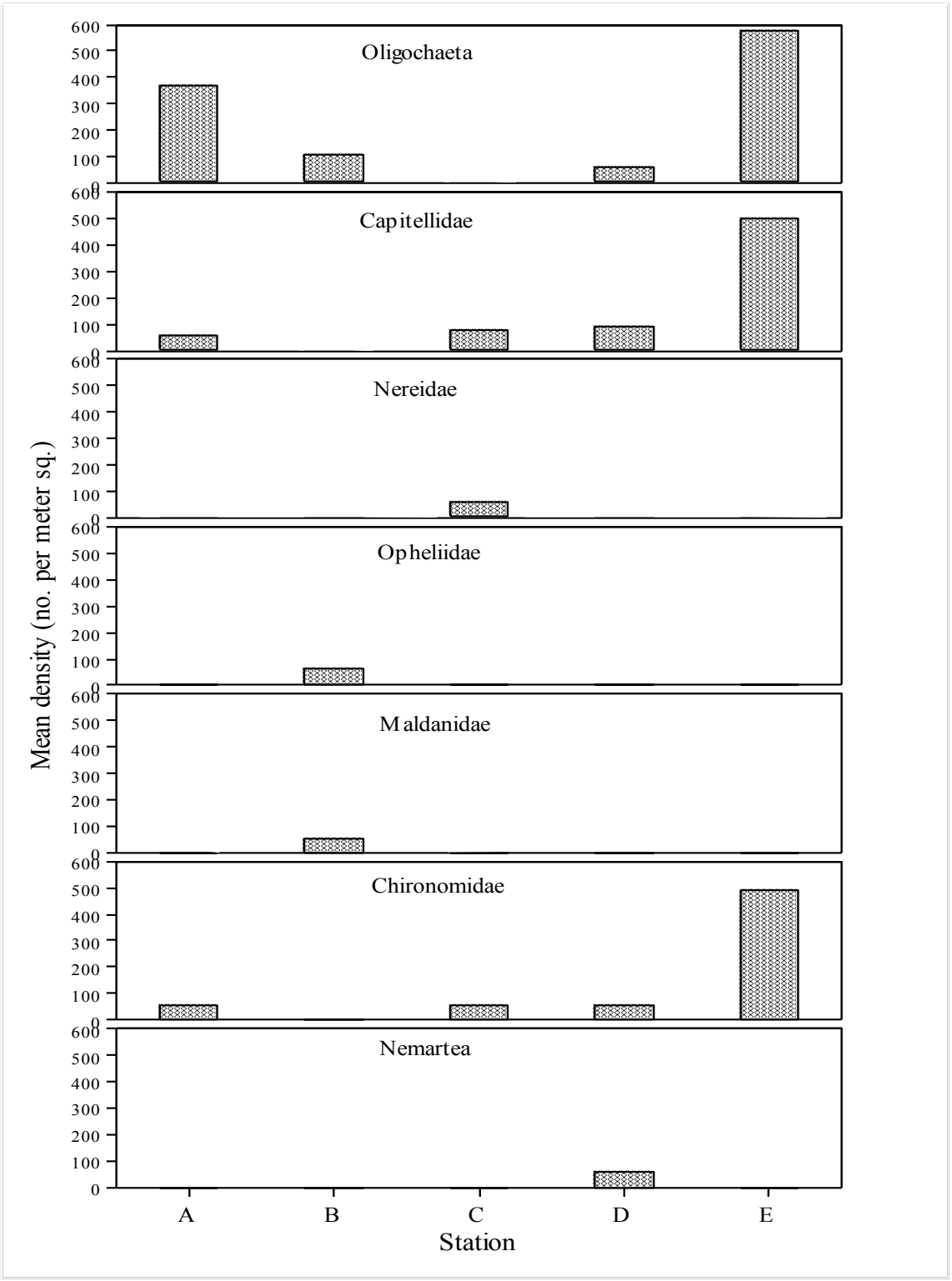

Figure 16: Density of benthic invertebrate groups at five stations in the Essei lagoon

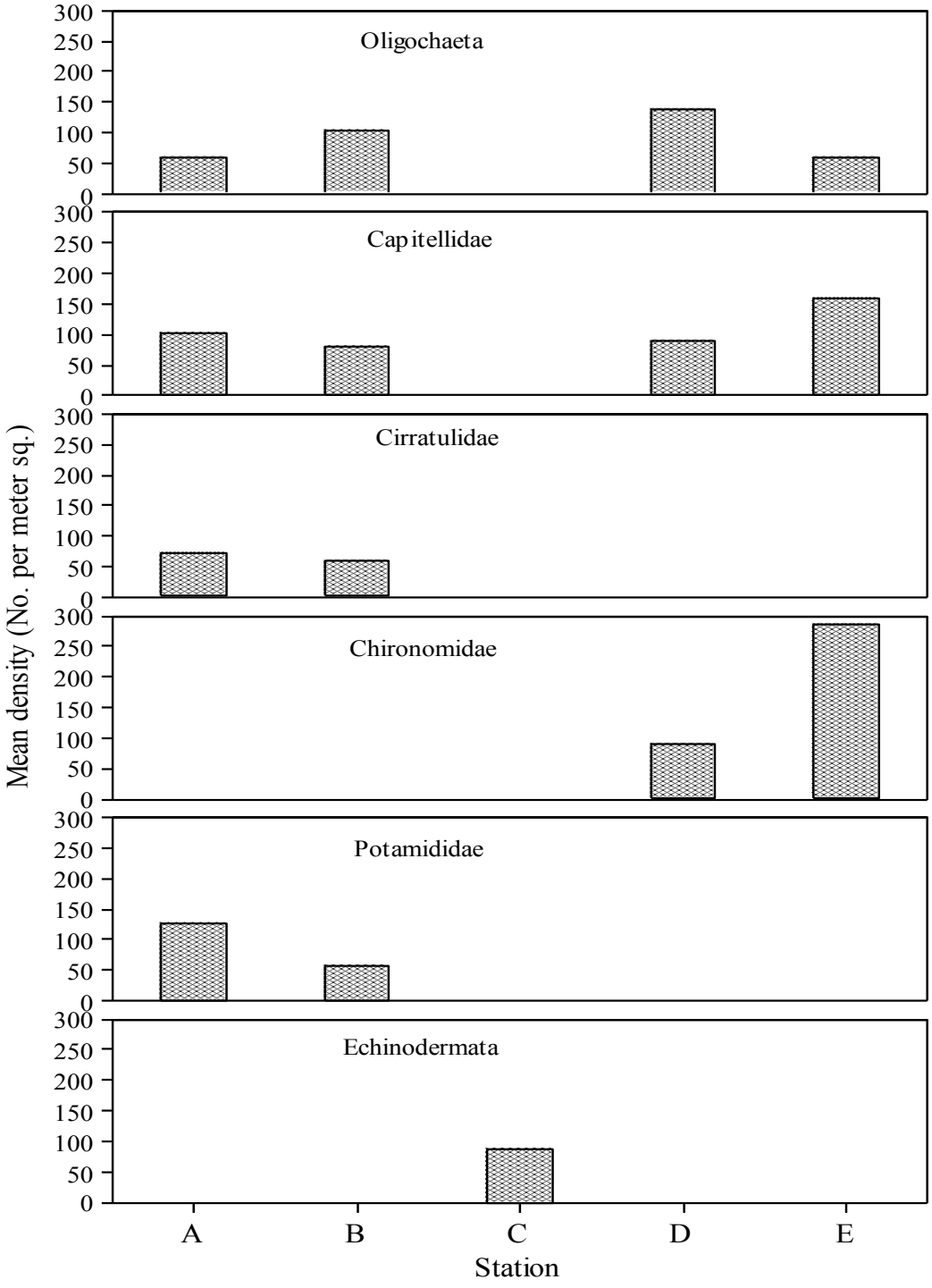

Figure 17: Density of benthic invertebrate groups at five stations in the Butuah lagoon

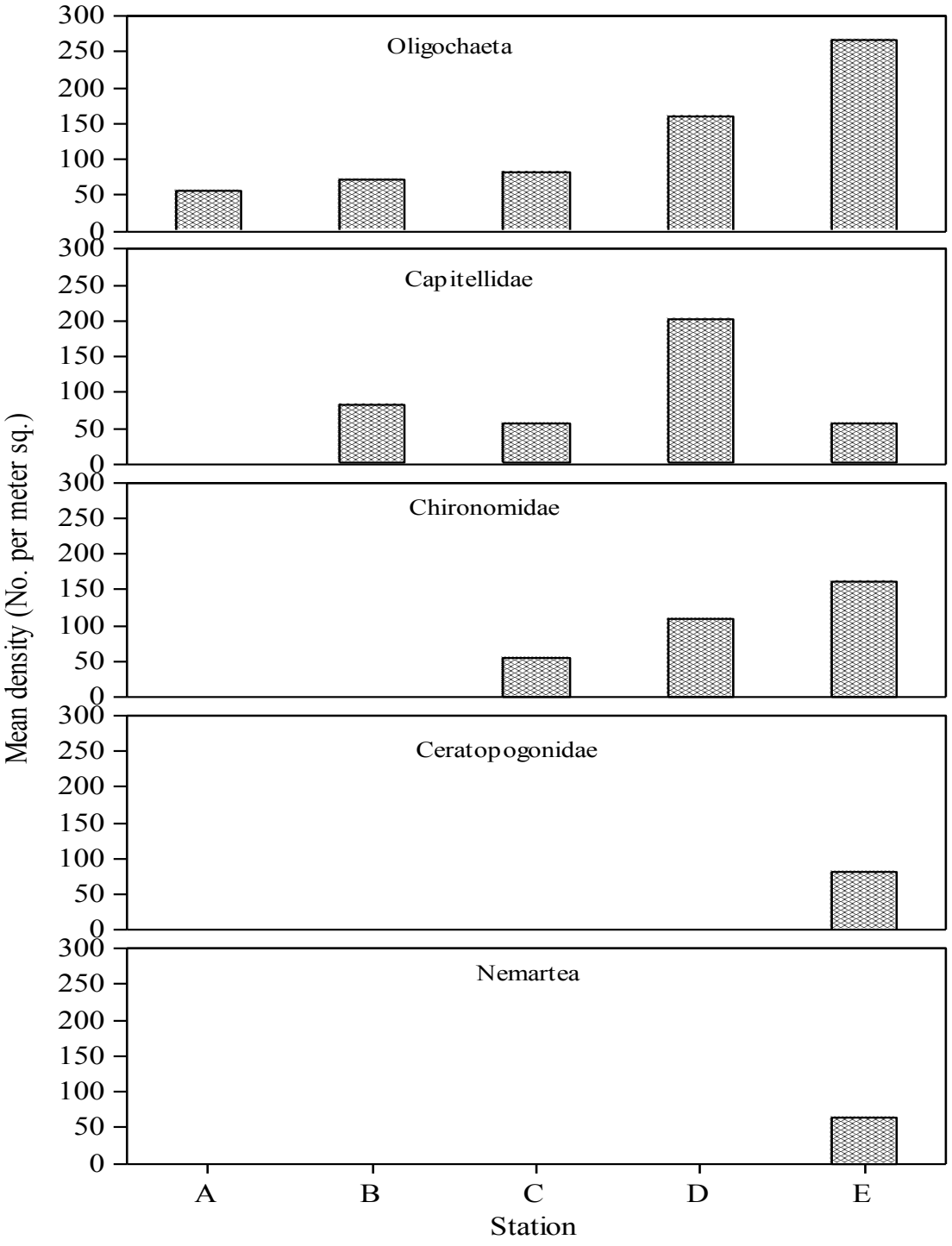

Figure 18: Density of benthic invertebrate groups at five stations in the Whin Estuary

4.5 The Littoral community

Occurrence, richness and diversity

As presented in Table 17-19, the littoral invertebrate communities of the three water bodies include oligochaetes, polychaetes, insects, gastropods, bivalves and crustaceans. The polychaetes found belonged to the families Capitellidae, Nereidae, Cirratulidae and Opheliidae while the insect larvae encountered were dipterans of the families Chironomidae Aedinae and Ceratopogonidae, and odonatans of family Coenagriidae. The gastropods collected were from the families Potamididae, Patellidae, Neritidae, Muricidae and Littorinidae while the bivalve families were Mytilidae, Ostreidae and Arcidae. Crustaceans present were barnacles *Ballanus pallidus*, and hermit crab.

Oligochaeta, Capitellida and Chironomidae were present in all three water bodies while the gastropods, bivalves and crustaceans were found at only Whin, except Potamidiae which was also present at Butuah. The other littoral fauna occurred in one or two of the wetlands. A total of 14 families of littoral macrofauna were collected from Whin, 8 from Essei and 4 from Butuah (Table 20).

Of the three wetlands, Whin had the most rich and diverse littoral invertebrate community (d = 2.16, H' = 2.41) (Table 21). Diversity was same for Butuah and Essei (H' = 1.50) although richness differed slightly. Distribution of the individuals among the various invertebrate groups was highly even in Butuah and Whin ($J' > 0.9$) than Essei ($J' = 0.72$). The littoral communities of the two lagoons were highly similar ($C_s > 0.6$), but these communities were not much similar to the Whin community (Table 22).

Table 17: List of littoral macroinvertebrates of the Essei Lagoon in the Sekondi-Takoradi Metropolis

CLASS	ORDER	FAMILY
OLIGOCHAETA		
POLYCHAETA		Capitellidae
		Nereidae
		Cirratulidae
INSECTA	DIPTERA	Chironomidae
		Ceratopogonidae
		Aedinae
	ODONATA	Coenagriidae

Table 18: List of littoral macroinvertebrates of the Butuah Lagoon in the sekondi-Takoradi metropolis

CLASS	ORDER	FAMILY	SPECIES
OLIGOCHAETA			
POLYCHAETA		Capitellidae	
		Nereidae	
INSECTA	DIPTERA	Chironomidae	
		Ceratopogonidae	
GASTROPODA		Potamididae	*Tympanotonusfuscata*

Table 19: List of littoral macroinvertebrates of the Whin Estuary in the Sekondi-Takoradi metropolis

CLASS	ORDER	FAMILY	SPECIES
OLIGOCHAETA			
POLYCHAETA		Capitellidae	
		Onuphidae	
INSECTA	DIPTERA	Chironomidae	
		Aedinae	

CLASS	ORDER	FAMILY	SPECIES
GASTROPODA		Potamididae	*Tympanotonusfuscata*
		Muricidae	*Thais hemastoma*
			Thais forbesi
		Neritidae	*Neritasenegalensis*
		Littorinidae	*Littorinapunctata*
			Littorinacingulifera
			Tectariusgranosus
		Patellidae	*Patella safiana*
BIVALVIA		Mytiliidae	*Pernaperna*
		Arciidae	*Anadarasenelis*
		Ostreidae	*Crassotreatulipa*
CRUSTACEA			*Balanuspallidus*
			Hermit crab

Table 20: Richness of littoral invertebrate families of the three water bodies

INVERTEBRATE GROUP	NUMBER OF FAMILIES		
	ESSEI	BUTUAH	WHIN
OLIGOCHAETA	1	1	1
POLYCHAETA	3		2
INSECTA	4	2	2
GASTROPODA		1	4
BIVALVIA			3
CRUSTACEA			2
TOTAL	**8**	**4**	**14**

Table 21: Richness and diversity indices for the littoral invertebrate communities of the three water bodies

Water body	Margalef's Richness (d)	Shannon – Wiener diversity (*H'*)	Pielou's evenness (*J'*)
Essei	1.12	1.50	0.72
Butuah	0.95	1.50	0.93
Whin	2.16	2.41	0.91

Table 22: Sorensen's similarity index for pairs of littoral invertebrate communities of the three water bodies

	Essei	**Butuah**
Butuah	0.61	
Whin	0.27	0.31

Composition of littoral invertebrate fauna

The Essei community was dominated by Oligochaeta, Capitellidae and Chironomidae (19.3 %, 29.2 % and 36.9 % respectively) while the Butuah community was dominated by Oligochaeta, Chironomidae and Potamididae (Tympanotonus fuscata) with compositions of 24.2 %, 31.8 % and 21.2 % respectively, with Ceratopogonidae also constituting 16.6 % (Fig. 19). Whin was dominated by Oligochaeta (18.3 %), Capitellidae (12.4 %) and Littorinidae (*Littorina punctata*) (14.2 %). The composition of the other fauna varied between 0.5 % and 8 % in the wetlands.

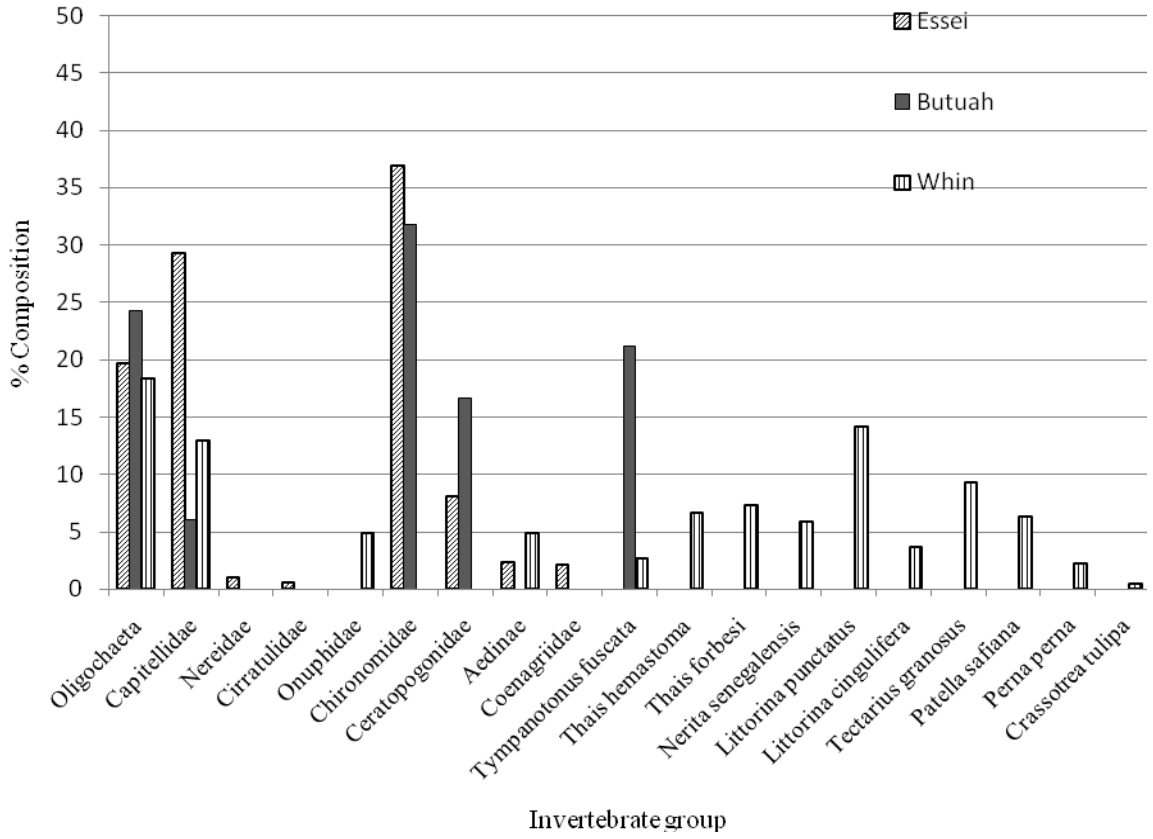

Figure 19: Percentage composition of littoral invertebrate groups in the three water bodies

Littoral fauna diversity at various stations of the wetlands

In the Essei Lagoon, Station A had the lowest richness and diversity of littoral fauna (d = 0.42, H' = 0.35) while Station B had the highest ((d = 1.06, H' = 01.35) (Fig. 20). Diversity and richness seem uniform at the other stations. Diversity and richness of the littoral community in Butuah is higher at Stations A (d = 1.21, H' = 1.39) and C (d = 1.13, H' = 1.44) than the other stations. The highest richess and diversity of littoral invertebrates in the Whin Estuary was recorded at Station A (d = 1.64, H' = 2.09) while Station B recorded the lowest (d = 0.48, H' = 0.14). Very little variations occurred among the other stations.

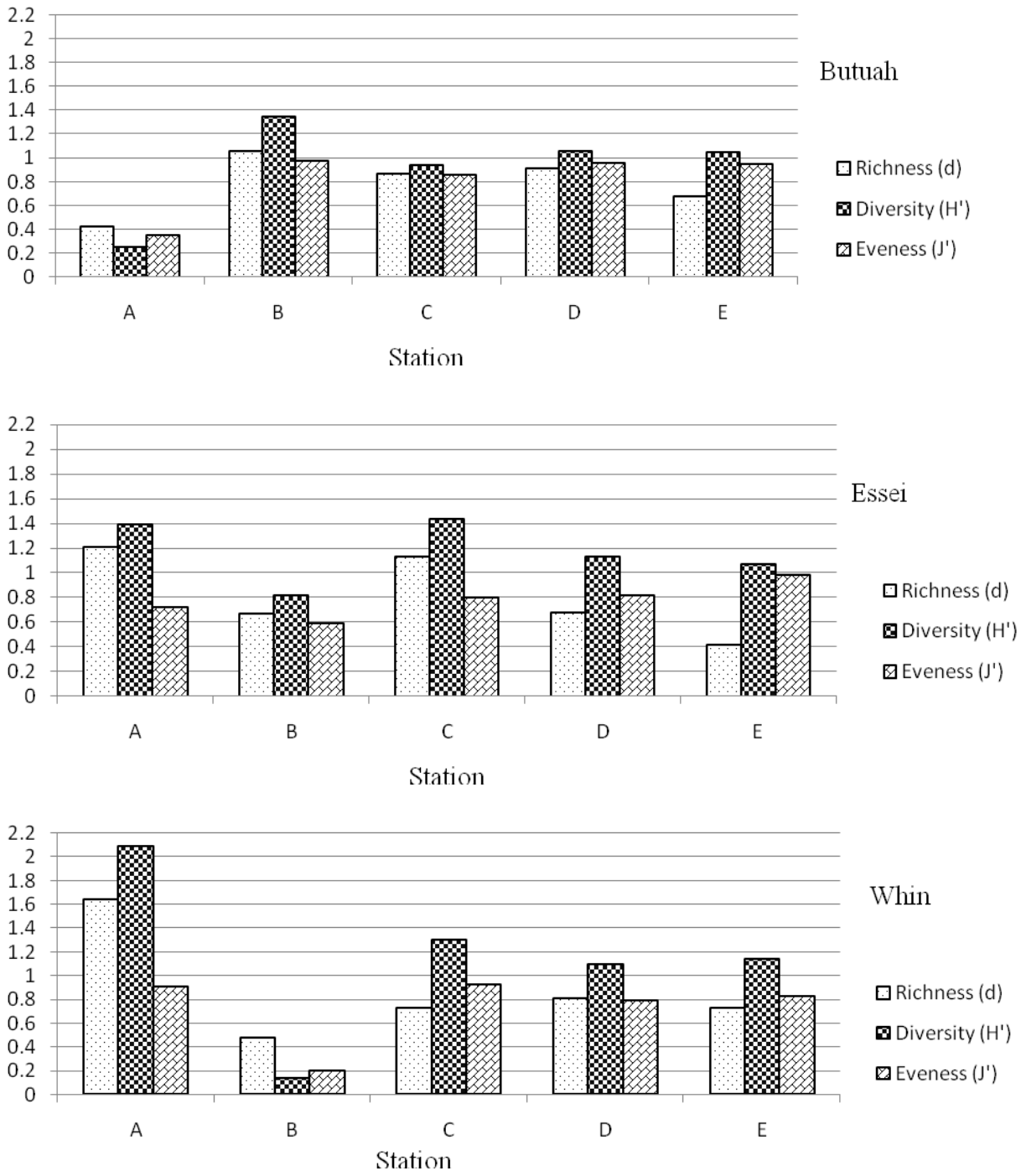

Figure 20: Richness and diversity of littoral invertebrates at the different stations of the three water bodies

4.6 The Fish Community

Occurrence of fish species

A total of 26 species of shellfishes and finfishes from 18 families comprising freshwater, brackishwater and marine fishes were collected from the three water bodies (Table 23-25). The lagoon tilapia *Sarotherodon melanotheron*, the mudskipper *Periopthalmus barbarus,* the sickle fin mullet *Liza falcipinnis*, the swimcrab *Callinectes amnicola* and the land crab *Goniopsis cruentata* were present in all the three wetlands. The other species occurred in one or two of the water bodies.

The 8 species recorded from Essei comprised 5 and 3 crabs. The fish community in Butuah was made up of 14 species, of which 10 were fishes and 4 were crabs. From Whin, 20 species were collected with 16 being fishes; most of which were marine species, and the remaining 4 being crabs.

As shown in Table 27, Whin had the most rich and diverse fish community (d = 3.21, H' = 1.62), followed by Butuah (d = 1.54, H' = 1.56), with Essei having the least (d = 0.99, H' = 1.02). Distribution of the individuals among the various species was more even in Butuah (J' = 0.68) than the other two (J' = 0.57). Like the littoral communities, the fish communities of the two lagoons were also highly similar (C_s > 0.6), but the communities were not much similar to the Whin community (Table 28).

Table 23: List of fish species of the Essei Lagoon in the Sekondi – Takoradi Metropolis

Family	Species
Mugilidae	*Liza falcipinnis*
Cichlidae	*Sarotherodonmelanotheron*
Gobiidae	*Periopthalmusbarbarus*

Serranidae	*Serranusaccraensis*
Portunidae	*Callinectesamnicola**
Gecarcinidae	*Cardiosomaarmatum***
Grapsidae	*Goniopsiscruentata***

* = Marine crab ** = Land crab

Table 24: List of fish species of the Butuah Lagoon in the Sekondi – Takoradi Metropolis

Family	**Species**
Mugilidae	*Liza dumerilii*
	Liza falcipinnis
	Mugilbananensis
	Mugilcurema
Clupeidae	*Odaxothrissamento*
Cichlidae	*Oreochromisniloticus*
	Sarotherodonmelanotheron
Gobiidae	*Periopthalmusbarbarus*
Clariidae	*Clariasgariepinus*
	Heterobranchuslongifilis
Portunidae	*Callinectesamnicola**
Gecarcinidae	*Cardiosomaarmatum***
Grapsidae	*Goniopsiscruentata***
Sesarmidae	*Sesarmaharzudii***

* = Marine crab ** = Land crab

Table 25: List of fish species of the Whin Estuary in the Sekondi – Takoradi Metropolis

Family	Species
Mugilidae	*Liza dumerilii*
	Liza falcipinnis
	Mugilbananensis
	Mugilcephalus
	Mugilcurema
Clupeidae	*Sardinellamaderensis*
Cichlidae	*Sarotherodonmelanotheron*
Gobiidae	*Bathygobiussoporator*
	Periopthalmusbarbarus
Acanthuridae	*Acanthurusmonroviae*
Labridae	*Xyrichthysnovacula*
Bothidae	*Scyaciummicrurum*
Haemulidae	*Plectorhynhusmediterraneus*
Lutjanidae	*Lutjanusgoreensis*
Eleotridae	*Eleotrissenegalensis*
Gerreidae	*Eucinostomusmelanopterus*
Portunidae	*Callinectesamnicola**
Ocypodidae	*Ucatangeri***
Grapsidae	*Goniopsiscruentata***
Sesarmidae	*Sesarmaharzudii***

* = Marine crab ** = Land crab

Table 26: Species richness of fish communities of the three water bodies

Water Body	No. of Families	No. of fish species	No. of crab species	Total no of species
Essei	8	5	3	**8**
Butuah	9	10	4	**14**
Whin	15	16	4	**20**

Table 27: Richness and diversity indices for the fish communities of the three water bodies

Water body	Margalef's Richness (d)	Shannon – Wiener diversity (*H'*)	Pielou's evenness (*J'*)
Essei	0.99	1.02	0.57
Butuah	1.54	1.56	0.68
Whin	3.21	1.62	0.57

Table 28: Sorensen's similarity index for pairs of fish communities of the three water bodies

	Essei	**Butuah**
Butuah	0.64	
Whin	0.36	0.53

Composition of fish communities

The two main species which dominated the Essei fish community were *Periophthalmus barbarus* (51.3 %) and *Liza falcipinnis* (34.3%) while *Odaxothrissa mento* dominated the Butuah community (49.1 %), followed by *Sarotherodon melanotheron* (16.3 %) (Fig. 21). The Whin community was dominated by *S. melanotheron* (26.5 %) and the snapper

Lutjanus goreensis (Lutjanidae) (13 %). Compositions of the remaining species varied between 0.5 % and 8.5 % in the communities in which they occurred.

Size range of some common species

The size range of the species collected from the three water bodies is presented in Table 29. Populations were generally bigger in the estuary than their counterparts in the lagoons. Specimens of the common species such as *Liza falcipinnis* ranged from 2.9 cm - 5.0 cm TL in Essei, 5.6 cm - 10.1 cm TL in Butuah and 9.0 cm – 27.0 cm in Whin Estuary. *S. melanothreron* specimens measured 4.0 – 7.1 cm, 1.4 – 10.5 cm and 8.0 cm – 15.5 cm TL in Essei, Butuah and Whin respectively. The second dominant species in Whin, *Lutjanus goreensis* had a total length range of 8.9 – 12.3 cm.

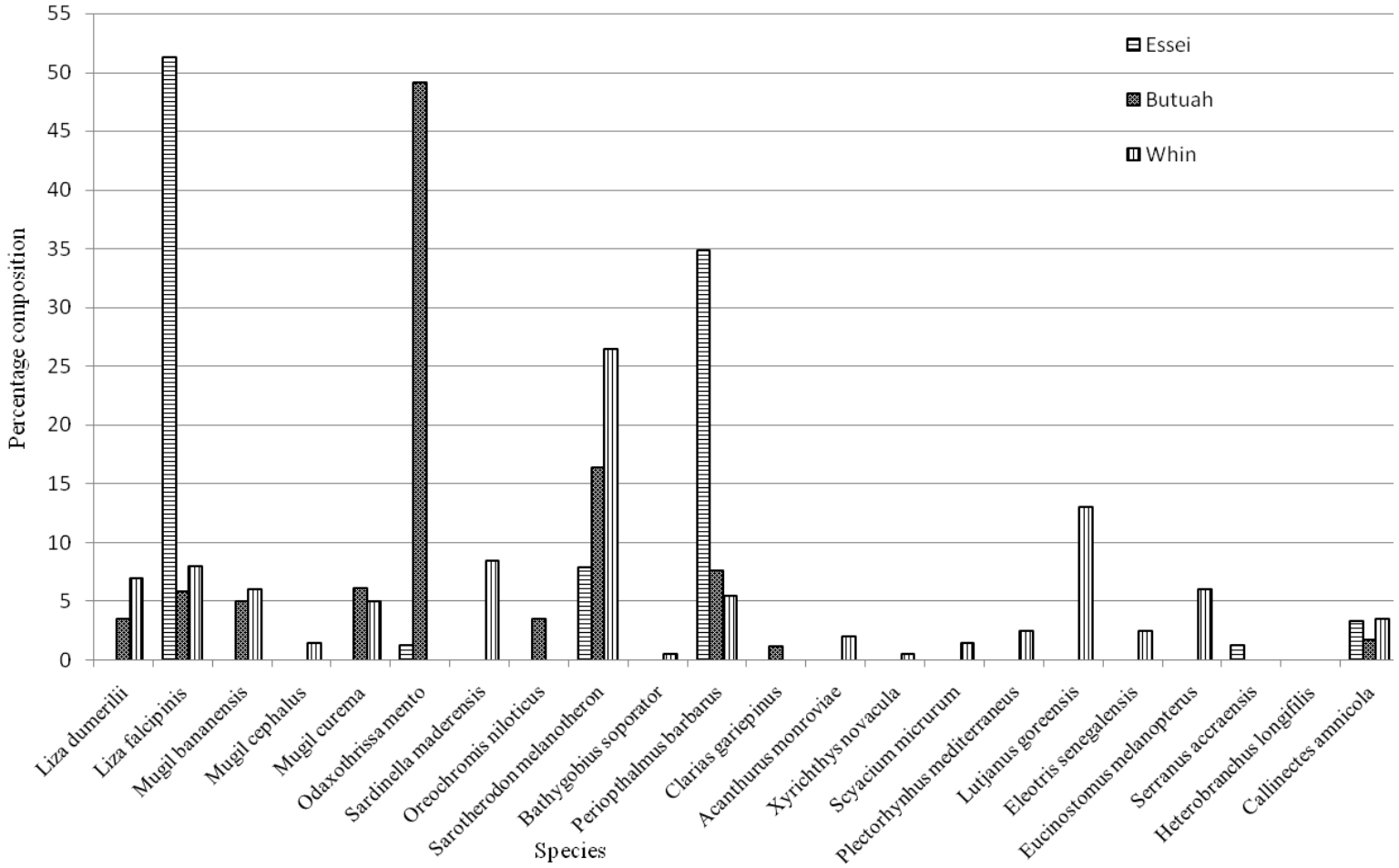

Figure 21: Percentage composition of fish species in the three water bodies

Table 29: Size range of fish species in the three water bodies

		Essei			Butuah			Whin		
Family	Species	N	Min. TL(cm)	Max. TL(cm)	N	Min. TL(cm)	Max. TL(cm)	N	Min. TL(cm)	Max. TL(cm)
Mugilidae	*Liza dumerilii*				12	5.0	10.4	14	7.2	16.9
	Liza falcipinis	78	2.9	5.0	20	5.6	10.1	16	9	27
	Mugil bananensis				17	4.3	12.1	12	7.5	14.3
	Mugil cephalus							3	6.9	14.2
	Mugil curema				21	5.2	11.4	10	9.3	15.1
Clupeidae	*Odaxothrissa mento*	2		5.6	168	11	27.1			
	Sardinella maderensis							17	4.3	7.3
Cichlidae	*Oreochromis niloticus*				12	5.4	18.5			
	Sarotherodon melanotheron	12	4.0	7.1	56	1.4	10.5	53	8	15.5
Gobiidae	*Bathygobius soporator*							1	10.9	
	Periopthalmus barbarus	53	4.6	5.1				11	6.2	16.3
Serranidae	*Serranus accraensis*	2	3.6	7.0						
Acanthuridae	*Acanthurus monroviae*							1		7.3
Labridae	*Thalassoma pavo*							1		16.4
Bothidae	*Scyacium micrurum*							1		7.1
Haemulidae	*Plectorhynhus mediterraneus*							5	4.1	4.2
Lutjanidae	*Lutjanus goreensis*							26	8.9	12.3
Eleotridae	*Eleotris senegalensis*							5	9.3	10.6
Gerreidae	*Eucinostomus melanopterus*							12	8.2	11.1
Clariidae	*Clarias gariepinus*				4		8.1			
	Heterobranchus longifilis				6		8.3			

Table 30: Classification of fish communities found

CATEGORIES OF FISH SPECIES	WATER BODY		
	Essei	**Butuah**	**Whin**
a) Truly estuarine/lagoon that spend their entire lives in estuary/ lagoon.	*Periopthalmus barbarus,* *Sarotherodon melanotheron*	*Periopthalmus barbarus,* *Sarotherodon melanotheron*	*Periopthalmus barbarus,* *Sarotherodon melanotheron* *Uca tangeri*
b) Estuarine-marine species that use estuaries and lagoons primarily as nursing and spawning grounds, spending adult life at sea and returning occasionally to estuaries and lagoons.	*Liza falcipinnis* *Callinectes amnicola* *Serranus accraensis*	*Callinectes amnicola* *Liza dumerilii* *Liza falcipinnis* *Mugil bananensis* *Mugil curema*	*Liza dumerilii* *Liza falcipinis* *Mugil bananensis* *Mugil cephalus* *Mugil curema* *Callinectes amnicola* *Sardinella maderensis* *Bathygobius soporator* *Periopthalmus barbarus* *Acanthurus monroviae* *Scyacium micrurum* *Plectorhynhus mediterraneus* *Lutjanus goreensis* *Eucinostomus melanopterus* *Callinectes amnicola*
c) Freshwater species that occasionally enter brackishwater		*Odaxothrissa mento* *Oreochromis niloticus* *Clarias gariepinus* *Heterobranchus longifilis*	*Eleotris senegalensis*
d) Occasional visitors occurring irregularly			*Thalassoma pavo*

Table 31: Rare and threatened species and breeding patterns (Species of conservational importance)

(HT = Highly threatened**; T** = Threatened and **R** = Rare**)**

No.	Rare/ threatened species	Wetland type			Estimations on the breeding patterns
		Essei	**Butuah**	**Whin**	
	Fisheries				
1	*Sarotherodon melanotheron* (Lagoon tilapia)	HT	T		- Breeds in the lagoon
2	*Liza falcipinnis (sickle fin mullets)*	HT	T		-Species live inshore in estuaries and lagoons - Breeds in sea and young ones come to feed in the lagoons and estuaries
3	*Periopthalmus barbarus (mud skippers)*	T			- breed in the lagoons and estuaries
4	*Serranus accraensis*	R			- marine species that breed in the sea - young ones use lagoons and estuaries as feeding grounds
5	*Callinectes amnicola (Marine crab)*	HT	T		- breeds in the lagoons and estuaries
6	*Cardiosoma armatum (Land crab)*	HT		R	- breeds on land adjacent water mostly in the riparian vegetation
7	*Goniopsis cruentata (mangrove crab)*	T	T		- Adult shrimps live in deeper water away from the shore - During spawning, fertilized eggs are released into the sea - Eggs hatch and develop through several planktonic larvae forms - Larvae drift into inshore nursery areas, most probably mangroves - Larvae grow into sub-adults before migrating out to join the adults

No.	Rare/ threatened species	Wetland type			Estimations on the breeding patterns
		Essei	Butuah	Whin	
	Sesarma hardii (lagoon crab?)			R	
	Oreochromis niloticus		R, T		- Lives and breeds in freshwater habitats and considered invasive species if found lagoon and estuarine systems
	Thalassoma pavo (ornamental?)			R	- Lives and breeds in rocky bottoms of coastal waters
Mangroves					
	Avicennia portulacastrum		R	R	
	Avicennia africana	R		R	
	Laguncularia racemosa	R	R		
	Rhizophora mangle	R	R		

4.7 Riparian vegetation

Riparian vegetation refers to the plant life and ecosystem that exist alongside a waterway. From an ecological perspective, riparian vegetation is any vegetation that adjoins, regularly influences, or is influenced by a body of water. In good condition, riparian vegetation supports the resilience of both aquatic and terrestrial ecosystems, allows recovery from disturbance and maintains biodiversity. Tables 32- 35, list the components of the vegetation surrounding the wetlands. These comprise grasses, sedges, herbs, shrubs and trees and specialized halophytes mostly mangroves. Whin had the highest diversity in mangrove species namely *Rhizophora mangle, Avicennia africana, Laguncularia racemosa.* Essei and Butuah lagoons habour single species mangroves namely *Avicennia germinans and Avicennia africana* respectively.

Table 32: List of riparian vegetation around the Essei lagoon

Grasses

*Achyranthesaspera species**
Axonogus compressus
Cenchorus ciliaris
Chloris pilosa
Dactyloctenium aegyptium
Eleusine indica grass
Mariscus alteternifolia
Paspalum vaginatum
Sporobolus pyramidalis

Herb

Acanthospermum hispidum
Acligta alba
Alternanthera pungus
Asystasia gigantica
Boerhavia diffusa
Capraria biflora
*Cesuvium portulacastrum**
Desmodium adescendens
Eughorbia hirta
Fleura aestuans
Gomyhrena celosoides
Indiglofera arrecta

*Ipomea pre-caprae**
Kallastroemia pubsceus
Ludigia decurrens
Malvastrum coromandeliamum
Mimosa pudica
Oldelandia corymbosa
Passiflora foetida
Phyllanthus amarus
Physalis angulata
Ruellia tuberosa
*Sida Acuta**
Solanum torvum
Stachytarpheta indica
Synedrella nodiflora
Trianthema portulacastrum
Vernonia cineria

Sedge

*Cynodon dactylon**
Cyperus rotundus

Shrub

Abutilon mauritianum
Avicennia germinans
Calutropis procera
Cassia occidentalis
Crotalasia retusa
Iponea asarifolia
Lantana camara
Securinega virosa
Thespesia populnea
Thevetia peruviana (Milk bush)

Tree

Baghia nitida
Terminalia catapa

Key

* Dominant species present.

Table 33: List of Riparian vegetation around the Butuah lagoon

Grasses
Mariscus alteternifolia
*Panicum maximum**
*Paspalum vaginatum**
Sporobolus pyramidalis
Herbs
Aspilia africana
Calapogonium mucohoides
Capraria biflora
Cassia nigrican
Centrosema pubescence
Chromolaena odoraata
Corchotus aestuans
Hyptis lanceolata
Ipomoea involucrata
Iponea barbata
Iponea Carica
*Mimosa pudica**
Passiflora foetida
Physalis angulata
Portulaca oleracea
Sanseviria liberica
Schwenkia americana
Sesevium portulacastrum
Sida Acuta
Slanum nigrum
Spigelia anthelmia
Stachytarpheta indica
Trianthema portulacastrum
Vernonia cineria
Sedges
Cyperus umbellata

Shrubs
Acacia nolitica
Alchornia Cordifolia
*Avicennia africana**
Baphia nitida
Cassia occidentalis
Cassia tora
Fagara xanthoxyloides
*Flagellaria daemae**
Flaucortia Flavescens
Grewia Carpinifolia
Grifforia simplcifolia
Heslundia opposita
Jatropha gossipifolia
Lantana camara
*Leucaena glauca**
Mallotus oppositifolius
Manihot esculentus
Naudea latifolia
Panthnia piunata
Phoenix reclinata
Securinega virosa
Trichisia subcordata
Waltheria indica
Tree
Antiaris africana
Azadirachta indica
Coco nucifera
Psidium guajava

Key

* Dominant species present.

Table 34: List of Riparian vegetation around the Whin estuary

Grasses

Cenchorus ciliaris
Dactyloctenium aegyptium
Eleusine indica grass
Panicum maximum
Setaria barbata

Herb

Acanthospermum hispidum
Asystasia gigantica
Boerhavia diffusa
Caloponium mucuniodes
Canavalia reseus
Commelina bengalensis
Corchotus aestuans
Croton lobata
Euphorbia heterophylla
Indigofera hirsuta
Oldelandia corymbosa
Passiflora foetida
Phyllanthus amarus
Physalis angulata
Sesamum indicum
Talinum triangulare
Tridax procumbens

Sedge

Cynodon dactylon
Cyperus rotundus

Shrub

Agave sisalana
*Avicennia africana**
Baphia nitida
*Laguncularia racemosa**
Leucaena glauca
*Rhizophora mangle**

Securinega virosa

Thespesia populnea

Tree

Terminalia catapa

Key

* Dominant species present.

Table 35: Floral diversity of the wetlands

Water Body	Grass species	Herb species	Sedges	Shrubs	Tree species	Mangrove species
Butuah Lagoon	4	24	1	22	5	1
Essei Lagoon	8	29	2	9	3	1
Whin Estuary	5	18	2	5	2	3

Table 36: Mangrove stands around the wetlands

Water Body	species
Butuah Lagoon	*Avicennia africana*
Essei Lagoon	*Avicennia germinans*
Whin Estuary	*Avicennia africana* *Rhizophora mangle* *Laguncularia racemosa*

4.8 Biodiversity assessment of the wetlands

Table 37 provides a broad overview of biodiversity assets of the three wetlands. This summary could be used to explain wetland assets that may be regarded to be of high biodiversity significance or otherwise. For example, the plankton community in the Whin estuary is found to be of highest biodiversity significance relative to those of Essei and Butuah, which are comparatively lower. A similar observation is made relative to fisheries. In general, the Whin estuary is observed to be of highest biodiversity significance compared to the two lagoons. Comparatively, the two lagoons were rated to be of the same biodiversity significance. The comparatively equal rating of both lagoons is attributable to the following:

- The bulk of the biodiversity of Essei is largely based on flora than fauna; while
- That of Butuah is largely based on fauna than flora.

Site characteristics and some ecological differences of the sites are differentiated in Table 38.

Table 37: Comparative rating of biodiversity assets of the wetlands

No.	Biodiversity assets	Biodiversity significance		
		Essei lagoon	Butuah lagoon	Whin estuary
1	Phytoplankton community	3	2	4
2	Zooplankton community	2	2	4
3	Benthic fauna	3	3	2
4	Littoral fauna	2	1	5
5	Fisheries	1	4	5
6	Grass species	4	2	3
7	Sedges	2	1	2
8	Herb species	5	4	3
9	Shrubs	2	4	1
10	Trees	2	3	1
11	Mangroves	1	1	4
12	Birds*			
13	Mammals, reptiles and amphibians**			
Total		**27**	**27**	**34**

Comparative rating:
1 = very low biodiversity;
2 = low biodiversity;
3 = medium biodiversity;
4 = high biodiversity;
5 = very high biodiversity.
* To be supplied as an Addendum.
**Detailed studies required since informant information not adequate for classification

Table 38: Site criteria and some ecological differences

No.	Criteria	Site criteria and ecological differences		
		Essei	**Butuah**	**Whin**
Classification, Land use & Protection status:				
1	Type of water body	Man-made open lagoon	Classical closed lagoon	Estuary
2	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, and certain areas owned by private individuals	Not well defined status, and may be regarded as mixed tenure between public ownership, Stool lands and certain areas owned by private individuals
3	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	Legally protected by law as a Public Good but not gazetted as a nature reserve
4	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.	No known managed protection including protection of mangroves. Traditionally, fishing activities are closed (banned) on Wednesdays.
5	Land use	Settlements, small-scale business enterprises e.g. provision kiosks, drinking bars, dump sites for scrap metals, car washing places, and mechanic shops, agriculture, Hotel infrastructure	Agriculture, settlement, fish landing sites, educational institutions, small-scale economic activities and land preparation for industrial establishment	Mainly settlements and hotel tourism infrastructure
6	Drainage	several open drains from settlements	Several open drainages exist from nearby settlements into the lagoon.	Open drains emanating mostly from hotel operations
7	Access/ fencing	Free access granted, anyone could swim or fish in the lagoon. He/ she may even openly mine sand without been questioned by anyone. No fencing	Free access granted. No fencing	Free access granted. No fencing

No.	Criteria	Site criteria and ecological differences		
		Essei	**Butuah**	**Whin**
Water quality, mean value (range):				
8	Temperature	25.98^{o}C (25.1-27.0^{o}C), moderate water temperature for growth and survival of fish and other aquatic organisms	32.95^{o}C (29.8-36.8^{o}C), extremely high water temperature with supposedly negative implications for survival and development of fish and other aquatic organisms	25.57^{o}C (24.6-26^{o}C), moderate water temperature. Moderate water temperature for growth and survival of fish and other aquatic organisms
9	Dissolved Oxygen	0.65 mg/l (0.1-1.27 mg/l), critically low level for fish development and survival	3.74 mg/l (0.09-9.51 mg/l), moderate concentration for fish development and survival	3.11 mg/l (2.85-3.52 mg/l), moderate concentration for fish development and survival
10	pH	7.76 (7.69-7.83)	7.63 (7.46-7.81)	8.08 (7.98-8.34)
11	Conductivity	29.26 µs/cm (14.1-48.2 µs/cm), moderately high	18.95 µs/cm (2.97-40.60 µs/cm), moderately high conductivity	55.61 µs/cm (54.8-56.3 µs/cm), high conductivity
12	Salinity	18.78 ^{0}/00 (8.6-30.8 ^{0}/00), moderate salinity level, potential for fish species with wider salinity tolerance	19.01 ^{0}/00 (13-32 ^{0}/00), moderate salinity level, salinity tolerance levels for brackishwater species	37.01 ^{0}/00 (36.4-37.7 ^{0}/00), Highest salinity due to direct influx of seawater into estuary, narrow salinity range and suggestion for dominant fish species in estuary mainly from marine sources as opposed to fresh water species
13	Turbidity	57.79 ppm (37.5-76.5 ppm), moderate particulate load or suspended materials, ability for moderate light penetration	180.07 ppm (99-355.5 ppm), very heavy particulate load or suspended materials with potentially negative implications for light penetration	42.29 ppm (20-103.5 ppm), least particulate load or suspended materials, relatively good light penetration
Geography of demarcated study area according to GIS records:				
14	Water surface area at study site in 1973 (Km^{2})	0.110902	0.073774	0.652202
15	Water surface area at study site in 2010 (Km^{2})	0.019855	0.086404	0.747911

No.	Criteria	Site criteria and ecological differences		
		Essei	**Butuah**	**Whin**
16	% Change in water surface in demarcated study area	Decrease in water surface area by 82.10%	Increase in water surface area by 17.12%	Increase in water surface area by 14.67%
Biodiversity assets:				
17	Phytoplankton community	Medium biodiversity	Low biodiversity	High biodiversity
18	Zooplankton community	Low biodiversity	Low biodiversity	High biodiversity
19	Benthic fauna	Medium biodiversity	Medium biodiversity	Low biodiversity
20	Littoral fauna	Low biodiversity	Very low biodiversity	Very high biodiversity
21	Fisheries	Very low biodiversity	High biodiversity	Very high biodiversity
22	Mangroves	Low biodiversity, mono-species	Low biodiversity, mono-species	High biodiversity, multi-species
23	Composition of riparian vegetation e.g. grasses, sedges and other tree species excluding mangroves	Very high biodiversity	High biodiversity	Low biodiversity
Some key challenges:				
24	Hydrography	Critically low Dissolved Oxygen (DO) content of the lagoon is of serious concern. Further investigation/ monitoring is required	Extremely high temperatures is of serious concern. Further investigation is required	General conditions satisfactory. However, high conductance readings may be further investigated depending on level of resources e.g. assessing levels of industrial runnoffs generation by hotels
25	Water surface area	Large decline in water surface area is of great concern	Relative increase in water surface area may be due to sea level rise or other climate variability factors. Further investigation is required.	Relative increase in water surface area may be due to sea level rise or other climate variability factors. Further investigation is required.
26	Pollution	High levels of Chironomids and Capitellidae provide indication of organic/ faecal pollution	Detectable levels of Chironomids and Capitellidae provide indication of organic/ faecal pollution	Fairly good environmental quality. Chironomids not detected but Capitellidae found at detectable levels

No.	Criteria	Site criteria and ecological differences		
		Essei	**Butuah**	**Whin**
27	General environmental quality	Very poor environmental quality. Deplorable sanitation conditions around the lagoon including dumping of human excreta and other wastes. Widespread beach sand winning, burrying of garbage in beach sand, political and traditional enforcement of rules virtually non-existent	Poor environmental quality. Unsatisfactory sanitation conditions including dumping of refuse, human excreta and release of effluents from homes into lagoon	No observed dumping of excreta except waste water drains pouring into estuarine habitat from hotels and adjacent settlements
28	Composition of rare/ threatened fish species	Extremely high. Seven (7) fish species and crabs documented from being highly threatened, threatened or generally considered to be rare	Generally high. Five (5) species of fish documented as being threatened, including a freshwater species (*Oreochromic niloticus*) that is generally considered as being rare in brackish systems. It is regarded in this context as either invasive or endemic. Further investigation required	No known species observed to be threatened. Three (3)fish species found that could be described as rare
29	Fisheries management	No closed fishing days or areas in force	No closed fishing areas or days in force	Closed fishing days enforced on Wednesdays but no closed fishing areas

4.7 Issues from the participatory social surveys

These findings were obtained from interviews of key informants, fishermen and through observations in the field.

(i) The Essei lagoon:

Tenure: Public property expected to be managed, protected and held in trust for the people by the District Assembly.
Protection status: Legally protected by law

Protection measure: Presently no protection measure

Land use: development of settlements and encroachment of wetland areas for development of small-scale business enterprises e.g. provision kiosks, drinking bars, dump sites for scrap metals, car washing places, and mechanic shops as well as small-scale agriculture

Site visits: Free access granted, anyone could swim or fish in the lagoon. He/ she may even openly mine sand without been questioned by anyone.

Drainage: Several open drains pouring out into lagoon

Fencing: The lagoon is an open ―market place" for various activities. There is no observed fence around the lagoon apart from the already existing riparian vegetation mainly mangrove stands. Key issues and challenges pertaining to the use and development of the wetland include:

- No chief for the area to strengthen traditional regulation of the Essei wetlands
- Weak enforcement of traditional laws due to virtual collapse of traditional chieftaincy system in the area
- Lack of appreciation of traditional knowledge of natural resources of the wetlands
- There are no known defined laws about the lagoon
- Sand winning activities have virtually transformed the Essei lagoon that was originally known to be a closed lagoon into a man-made open lagoon
- Cleaning of beaches by ZOIL, and collected rubbish buried in beach sand.
- Fishing regulations such as closed days are virtually non-existent
- Very poor fish landing sites due to generally poor sanitation on beaches due to rampant dumping of refuse in the lagoon. Domestic drainage systems also lead directly into the lagoon.

- Prisoners are occasionally tasked by unidentified persons to cut mangroves for sale to fish mongers. Community members perceive district assembly is responsible for engaging prisoners to achieve this task.
- Beaches around the lagoon utilised for funfairs during festive occasions such as Christmas, May Day and Easter holidays
- Beaches used as keep fit premises every morning by keep fit clubs and football associations
- Very poor fish handling conditions by fishermen
- Catches have declined but not alarming according to fishermen. This may be attributable to species that migrate into lagoon from the sea
- Low prices for fish catches due to small sizes of captured fished from the lagoon
- Absence of public toilets and public places of convenience, so lagoon areas serve that purpose
- Release of waste water or sewage from nearby homes into the lagoon
- Churches are established within the wetlands areas. However, some authorities are open for discussion to relocate premises as and when necessary or required to do so
- Use of mangrove areas around the lagoon as ghettos for some resident groups
- Weak data collection and dissemination of scientific information the wetland
- Low networking and capacity building of fisherfolks.

(ii) The Butuah lagoon:

Tenure: Not well defined and may be regarded as mixed tenure between public ownership, customarily owned or Stool lands, and certain areas owned by private individuals.

Protection status: No known managed protection for public lands. However for areas that are privately occupied, protection status is in the hands of individuals. No well-defined protection status for customarily- owned areas. There is also no known enforcement of customary laws regulating the use of the lagoon.

Land use: The land is mostly used for agricultural activities and for human settlement. Land use for industrial purposes should be further investigated. However portions of wetland areas have been prepared for the establishment of an Oil refinery facility adjacent lagoon. The

prospects of this facility are presently undefined due to conflicting interests pertaining to the use of the lagoon and adjacent wetland areas for fishing and other activities.

Drainage: Several open drainages have been constructed from nearby settlements into the lagoon.

Site visits: Free access granted.

Fencing: No fencing.

Key issues and challenges pertaining to the use and development of the wetland include:

- Perceived decline in cultural values associated with the use of the lagoon system. Lagoon sites are used as defecating grounds and disposal of waste by inhabitants.
- Portions of land used for animal husbandry and rearing of large ruminants with its attendant organic matter pollution
- The mouth of the lagoon is a center of intense human activities including use as fish landing sites, fish mongering and trading in household and perishable commodities.
- Declining fish catches as perceived by fishermen and available statistics
- Lack of capital and credit facilities for fishermen to access
- Lack of good fishing gears
- Crude fishing methods as complained by some fishermen including the use of very small mesh-sizes that targets juvenile fish species

(iii) At the Whin estuary:

Tenure: Not well defined status, and may be regarded as mixed tenure between public ownership, Stool lands and certain areas owned by private individuals.

Protection status: No known managed protection including protection of mangroves. Traditionally, fishing activities are closed on Wednesdays.

Land use: Indigenous forest and mangrove cover and development of settlement areas

Drainage: open drains emanating mostly from hotel operations

Artificial construction within wetland area: connecting Bridge for navigation purposes.

Site visits: Free access granted

Fencing: No fencing

Some of the key issues and challenges pertaining to the use and development of the wetland include:

- Landing sites for fishermen virtually non-existent
- No permanent structures for fishermen at landing points and handling facilities
- Lack of credit and loan facilities for fishermen
- Poor or virtually no direct access routes to the estuary
- Development of hotel facilities around the estuary
- Release of untreated sewage by hotel industry into the estuary
- Housing development within the catchments of the estuary with the potential of releasing domestic wastes into the system if not controlled
- Uncoordinated and unregulated fishing activities within the estuary.

b) Mammals, amphibians, reptiles and bird information

Detailed information on this subject may be obtained from the Ghana Wildlife Division. However, according to the interviews, there are no reported cases of marine mammals in the water bodies. However, this is not expected for the lagoons owing to their bathymetric conditions. Generally, the following were noted as mainly present in the wetlands:

(i) **At Essei: A**lligators, birds including vultures and crows, and some species of water snakes.

(ii) **At Butuah:** Water fowls, vultures, migratory bird species, monitor lizards, water snakes, and toads

(iii) **At Whin:** Water snakes and several species of migratory birds, bats, and butterfly species exist in the wetland

Detailed studies should be carried out for further classification.

5 DISCUSSION

5.1 The spatial information and implications for biodiversity

Spatial evaluation of the wetlands has allowed to estimate the present area occupied by the wetlands to allow for proper management interventions. On the whole, the decrease in water extent of the Essei lagoon amounting to about 82% is worrisome. These are attributable to natural and anthropogenic impacts. In terms of land use, built-up area around the Essei lagoon amounts to 8.7% which is comparatively higher than that calculated for Butuah which makes up only 0.77%. This information reveals comparatively serious consequences for Essei than for Butuah in terms of human impacts around the lagoon. There were several human activities observed around the Essei lagoon compared to Butuah lagoon which confirm the spatial information derived from the maps. Anthropogenic impacts at Essei relate to active sand winning practices by local inhabitants, the use of the beaches as places of convenience and disposal of human excreta, use of beaches as car washing bays, disposal of inorganic and organic wastes as well as solid waste materials including polyethene bags. Domestic drainage systems were also apparent.

The use of certain portions of the lagoon as recreational centers and drinking spots were obvious. The release of vehicular oil and chemicals from adjacent mechanic shops into the water body constitutes serious threats to the survival of the flora and fauna species content of Essei. Habitat loss at the Essei lagoon may have contributed to a possible loss in biodiversity to a great extent. In addition, habitat fragmentation of the Essei lagoon through creation of the defense wall in the middle of the wetland targeted towards flood control possibly aggravates the situation. Destruction of fish breeding sites is evident and the degradation of mangrove species is pervasive. However, considerable amount of natural areas land exist as unused (52%) that suggests a potential for ecological restoration planning.

The overall area of the Butuah Lagoon and Whin Estuary had increased in spatial extent by a margin of 17 % and 14. 6 % respectively between the period of 1973-2010. This may be attributed to possible impact of climate variability on those wetlands. What is not apparent is the overall change in biodiversity during the period due to the absence of long-term data on the biodiversity assets of the studied areas. On the contrary, it was revealed that Essei lagoon had decreased in its entire spatial extent by a margin of about 80% over the period of about 30

years (1973-2010). The implications of the spatial change of the wetlands on their biodiversity assets are unclear due to the lack of long-term data on biodiversity information. However, the overall increase in area of the Butuah lagoon and the Whin estuary may have had positive impact on biodiversity assets, possibly through the creation of new breeding and feeding grounds for fisheries productivity and the development of plankton and invertebrate communities.

5.2 Implications of water quality on biodiversity

The water quality parameters provided indications of the changing conditions across the habitats and distribution of fisheries resources and other aquatic flora and fauna. In principle, the Whin estuary recorded fairly stable hydrographic conditions for most parameters measured relative to the survival and proliferation of fish species and aquatic fauna and flora. Indeed, Whin recorded the best water quality standards.

High average water temperature at Butuah estimating to about 33^{o}C should be of great concern. As a matter of fact, aquatic organisms are dependent on certain temperature ranges for optimal health. Temperature affects many other parameters in water, including the amount of dissolved oxygen available, the types of plants and animals present, and the susceptibility of organisms to parasites, pollution and disease. Therefore such extremely high temperatures may not be favourable for aquatic life. These findings calls for further research and long-term data to investigate into the causes of the excessively high temperatures measured in the lagoon. While research would provide in-depth answers, possible reasons could be related to minimal shade and weather conditions or possibly hot water discharges into the water from urban or industrial sources or simply chemical processes or groundwater inflows.

Generally, oxygen concentration amounting to 5 mg/L is generally required for fish survival and growth. Oxygen content of the Essei lagoon was at a critically low levels ranging between 0.1-1.27 mg/L, which may be regarded as near deoxygenation. This may have accounted for the very low fisheries content of the lagoon compared to that of Whin and Butuah which recorded average values of 3.11 mg/L and 3.74 mg/L respectively. Turbidity in the Butuah lagoon showed record high values that may have impacted negatively on the

productivity of the system in general. This may be due to the intense human activities around the lagoon such as agricultural and organic effluent discharge.

A pH test measures the alkalinity or acidity concentration in water. A pH of 7 is neutral, below 7 is acidic, and above 7 is basic or alkaline. Acid rain, from auto exhausts or coal plants, causes a drop in the pH of water. Also, agricultural runoffs and untreated effluent discharge could also change the pH. The recorded pH values between 7 and 8 suggests that the water bodies have a reasonably good buffer range capacities that could imply optimally good pH levels for supporting a range of aquatic life. A pH range between 6.5 and 8.5 is generally suitable. Acidity is highly detrimental to aquatic macroinvertebrates and fish. The pH values derived from the studies imply that Whin provides the most suitable conditions for fisheries development with pH values ranging between 7.98- 8.34. pH ranges recorded for Essei and Butuah amounted to 7.69-7.83 and 7.46-7.81 respectively and may be regarded as fairly optimal.

The Whin estuary recorded the highest average conductivity values amounting to 55.61 μS/cm. This may be due to dissolved inorganic ions such as chloride, sulfate, sodium, calcium, etc. The relatively high conductance of the water body may also be attributed to the geology of the location and soils type. Clay or limestone soils for instance would have high conductance. It may also be indication of inorganic pollution due to detergents or other effluents released from hotel operations. Oil spills generally tends to lower the conductivity of the water since oil does not conduct electrical current very well. However, we can not lay claim at this stage that the generally low conductivity values recorded at Essei and Butuah lagoons was as a result of an oil spill but can be argued that there may be other forms of oily products released into the system including effluents from soap factories or related industries if any at all.

5.3 Plankton and the invertebrate communities

The generally lower richness and diversity of plankton and macroinvertebrate fauna of the Essei and Butuah Lagoons could be implicated in the correspondingly lower richness and diversity of their fish communities since plankton and aquatic macroinvertebrates constitute an important link in the trophic relationships among various communities in aquatic ecosystems.

The diversity, distribution, richness and abundance of macroinvertebrate communities often give important clues of the functional status or ecological health of wetlands. Chironomid larvae, capitellid polychaetes and oligochaetes feed on organic material in water and are common in environments where large amounts of organic material are deposited due to their ability to survive the resultant low oxygen levels and other reducing conditions better than most other species. For this reason, they have been used as indicators of pollution though their mere occurrence might not necessarily imply pollution (Yankson and Kendall, 2001).

It is probable therefore, that, the dominance of these invertebrates in the wetlands is a reflection of high levels of organic matter contents of the water bodies which could be potential source of pollution in the wetlands. In addition, the higher densities of chironomids, capitellid polychaetes and oligochaetes at the upper areas of the wetlands (Stations D & E) than the mouths (Station A) suggests that organic input might be higher at the upper regions of the water bodies than the mouth. It would therefore be necessary to monitor and control sources of organic material inputs such as agricultural activities, effluent discharge and other potential sources.

The extremely lower richness and diversity of littoral invertebrate community at the mouth of the Butuah Lagoon (Station A) relative to the other areas is attributable to the unstable environment of the mouth of the lagoon which is caused by the periodic opening of the lagoon as means of controlling flooding during the rainy season. This possibly disturbs the substratum, enables high sea water intrusion and causes changes in the entire mouth environment, rendering the area unfavourable for development of a diverse invertebrate community. In the Whin Estuary however, it is presumable that the remarkably higher diversity at the mouth (Station A) than the other areas is due to the rocky banks which provide a favourable biotope for the development of a rich and diverse littoral invertebrate community of predominantly gastropods, bivalves, crustaceans and other macrofauna which utilize rock surfaces and crevices.

5.4 The fish communities

Of the three wetlands, the Whin fish community stands the most rich and diverse. It is obvious from the study that more fishes from the marine environment enter the Estuary than the

lagoons. This might be a result of the higher plankton richness of the Estuary, coupled with the fairly stable and favourable hydrographic conditions of the estuarine environment for fish survival and growth.

The size range of most of the commonly encountered and marine fishes such *Liza falcipinnis, Liza dumerilii, Mugil curema,*(Mugilidae) *Lutjanus goreensis* (Lutjanidae) *Sardinella maderensis* (Clupeidae) from the Whin Estuary were clearly smaller than the normal maturity sizes reported in Schneider (1990) and Paugy *et al*. (2003). This suggests that the Whin Estuary is highly utilized by juvenile of commercially important fishes from the sea possibly as nursery and feeding grounds. In view of the prevailing considerable fishing activities in the Estuary, it would be necessary to enforce fisheries management regulations, especially the mesh size regulation to control the exploitation of juvenile fishes in the Estuary.

5.5 The flora community

The riparian vegetation acts as a buffer and may protect the health of the water body. A healthy abundance of plants provides nutrients to the ground and may strengthen the banks, preventing soil erosion and even absorbing harmful runoffs from industries. Indeed, riparian vegetation can help improve and restore the cleanliness of water. Given the area of available vegetation present around the wetlands i.e. about 38% for Essei, 44% for Butuah and 21% for Whin, and the generally high biodiversity of the various grass, herb, sedges and tree species suggests that the vegetated areas may not have contributed to the overall species diversity of the systems, especially for Whin where an overall loss in vegetated area due to increase in the water body over the last 30 year period may not have necessarily decreased biodiversity. In fact, biodiversity was comparatively higher in Whin compared to the lagoons. The majority of the grasses are utilised as feed for livestock while the herbs are use in the communities for feeding ruminants e.g. *Tridax procumbens, Aspilia africana, Euphobia heterophylla, Euphorbia hirta, Phyllantus amarus, Boerhavia diffusa, Ipomoea cairica and Ipomea barbata.* Besides, some of these herbs are used for medicinal purposes e.g. *Physalis angulata* is used for treating palpitation of the heart, *Acanthospermum hispidum* for curing leprosy. The leaves of *Achyranthes aspera* are used for treating itching and for headaches. Whin had the highest diversity in mangrove species namely *Rhizophora mangle, Avicennia*

Africana, Laguncularia racemosa. Essei and Butuah lagoons habour single species mangroves namely *Avicennia portulacastrum and Avicennia africana* respectively.

The observed wide diversity of mangrove species in the Whin estuary relative to the Essei and Butuah lagoons may have contributed to the higher biodiversity in fisheries at Whin. At Whin, the high biodiversity in phytoplankton which forms the basis of marine food web cannot be excluded in these considerations. Generally, the mangroves have been observed to be permanent homes for species such as crab species including Fiddler crab (*Uca tangeri*) at Whin, nursery areas where the young grow before moving out t deeper waters. Mangroves are also important feeding grounds for diverse marine species such as the mullets (*Liza falcipinis*), the lagoon tilapia (*Sarotherodon melanotheron*) and snappers (*Lutjanus goriensis*).

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The data have shown that the wetlands have a vast economic and conservation potential. However, deplorable management, ignorance or conflict of interest on the part of users has led the wetlands onto a path of potentially irreversible destruction. Certainly, a new coastal management thinking and practice are needed taking into account a Ghanaian economic, socio-cultural and environmental perspective. It is argued here that development as a whole can not be the adaptation of external views but should be based on local empirical evidence. This allows to defend an own view placing in the context of global trends. Such a holistic approach would be necessary calling for stronger partnerships including scientists, local and government actors as well as the international community.

At Essei and Butuah, it can be concluded that there would be a need to enhance marine wildlife and biodiversity. Friends of the Nation (FoN) and other stakeholders must be proactive in matters of conservation of the wetlands in these areas in order to keep pace with the human impacts which appear to be on the ascendancy. For instance the setting up of a Marine Protected Area (MPA) at Essei following the removal of the lagoon defense walls would be very necessary if restoration of fisheries is highly desired. Such an action would potentially increase the scope of the wetland corridors at Essei. In addition, activities such as sand winning and the use of the beach for recreation should be minimized or halted. Sanitation must be

improved, and inhabitants around the lagoon should be encouraged to improve sanitation around the lagoon by reducing the use of the lagoon as receptacles for waste.

The initiation of Special Area Management Plan (SAMP) for the Whin estuary for development of ecotourism would be relevant for conservation purposes of the already ―pristine" environment of the estuary which has the potential to also generate some income for the local people. Butuah lagoon and associated vegetation are presently faced with serious human encroachment which could aggravate with time. Mangrove restoration is highly encouraged in adjacent areas of the lagoon. Single species of mangroves were recorded at the lagoon sites, and therefore serious efforts should be made at improving the species composition of mangroves at those lagoon sites through afforestation programmes.

This study also prompts the need to engage in further scientific studies, monitoring and capacity building for measuring and documenting long-term data on hydrological factors. This will be relevant for estimating the potential impacts of sea level rise and climate change on biodiversity assets in those wetlands. For this, a consideration also of large scale physical ocean processes that also address future impacts of climate change and ocean acidification would be necessary.

For the habitats studied, it was of interest to notice that the overall area of the Butuah Lagoon and Whin Estuary had increased in spatial extent by a margin of 17 % and 14. 6 % respectively between the period of 1973-2010. This may be attributed to possible impact of climate variability. What is not clear is the overall change in biodiversity during the period due to the absence of long-term data on the biodiversity assets. On the contrary, it was revealed that Essei lagoon had decreased in its entire spatial extent by a margin of about 80% over the period of about 30 years (1973-2010). The implications of the spatial change of the wetlands on their biodiversity assets are unclear due to the lack of long-term data on biodiversity information. However, the overall increase in area of the Butuah lagoon and the Whin estuary may have had positive impact on biodiversity assets, possibly through the creation of new breeding and feeding grounds for fisheries productivity and the development of plankton and invertebrate communities. Habitat loss at the Essei lagoon may have contributed to a possible loss in biodiversity to a great extent. In addition, habitat fragmentation of the Essei lagoon through creation of the defense wall in the middle of the wetland targeted towards flood control possibly aggravates the situation.

The water quality parameters provided indications of the changing conditions across the habitats and distribution of fisheries resources and other relevant aquatic flora and fauna. In principle, the Whin estuary recorded fairly stable conditions relative to the survival and proliferation of fish species and aquatic fauna and flora. Indeed, Whin recorded the best water quality standards. The low oxygen content of the Essei Lagoon calls for serious management intervention on curbing the organic inputs through control of effluent discharge or run-offs. Optimum levels for fish survival and growth is about 5mg/L. However, oxygen content of the Essei lagoon was at a critically low levels ranging between 0.1-1.27 mg/L, which may be regarded as near deoxygenation. This may have accounted for the very low fisheries content of the lagoon. Turbidity in the Butuah lagoon showed record high values that may have impacted negatively on the productivity of the system in general. This may be due to the intense human activities around the lagoon such as agricultural and organic effluent discharge.

The benthos is one of the most important elements of the continental water ecosystems, which can be used as indicator of water pollution, as it reacts quickly to minor environmental changes. The distribution and density of benthic animals depends on substratum, quantity and composition of organic matter in sediments. The results have shown that the present densities of chironomids, capitellids, polychaetes and oligochaetes are indication of high organic matter input into the water bodies especially at Essei and Butuah lagoons and therefore a strong indication of widespread pollution. This is largely attributed to effluent discharges, agriculture and rampant misuse of lagoon sites as waste disposal sites. Behavioural changes would be necessary. In particular, instituting commitment measures relative to the abolishment of sand winning practices at Essei, and motivating political will at the District Assembly level.

In terms of the flora, majority of the grasses are utilised as feed for livestock while the herbs are use in the communities for feeding ruminants e.g. *Tridax procumbens, Aspilia africana, Euphobia heterophylla, Euphorbia hirta, Phyllantus amarus, Boerhavia diffusa, Ipomoea cairica and Ipomea barbata.* Besides, some of these herbs are used for medicinal purposes e.g. *Physalis angulata* is used for treating palpitation of the heart, *Acanthospermum hispidum* for curing leprosy. The leaves of *Achyranthes aspera* are used for treating itching and for headaches. Whin had the highest diversity in mangrove species namely *Rhizophora mangle, Avicennia Africana, Laguncularia racemosa.* Essei and Butuah lagoons habour single species mangroves namely *Avicennia portulacastrum and Avicennia africana* respectively.

It is highly recommended for an upscaling of efforts to reduce the increasing impacts on these vulnerable ecosystems from pollution, resource depletion and other threats if these water bodies in particular Essei and Butuah are expected to continue to provide their required goods and services for the sustainance of livelihood in the Sekondi-Takoradi Metropolis. Information on species of conservational importance, classified as either threatened or rare could undoubtedly support restoration efforts if appropriately applied and scientifically monitored.

6.2 Recommendations for follow-up studies for graduate and undergraduate students

Halting biodiversity will require undertaking or commissioning studies involving other ecological, socioeconomic and cultural aspects. This could be short-term to long-term studies targeting mainly Bachelor, Master or Doctorate research. Specific research questions could be further developed around the following topics:

- Ecological, Economic and Geographical:

a) Building upon the ecological inventory of the wetlands by looking at stocks of the fishery
b) Designing rehabilitation models for the restoration of the Essei and Butuah lagoons
c) Extended spatial mapping of the three wetlands and the demarcation of wetland corridors dating few decades back
d) Mapping of land use and land cover including the mapping of drainage outlets into wetlands
e) Estimation of biodiversity changes over time due to impacts of land use changes
f) Given the changes in surface area of water in the lagoons within the last 30 years, investigation into possible impacts of sea level rise and climate variability on the biodiversity assets would be necessary especially at Essei lagoon and Whin estuary
g) Development of beach profiles in aid of coastal adaptation measures
h) Economic valuation of wetlands including cultural valuation
i) Monitoring of Biodiversity especially for key and alien species and the estimation of long-term changes over time e.g.
    - Population monitoring of *Oreochromis. niloticus* in the Butuah lagoon
    - *Population monitoring of Thalassoma pavo perceived to be exotic species or ornamental*
j) Exploring the potential for sustainable exploitation of little known species found for poverty reduction and socioeconomic development of the wetland communities
k) Feasibility for aquaculture and commercial production of selected fisheries e.g. the lagoon tilapia *S. melanotheron* or other relevant culturable species.

l) Exploring feasibility of mariculture involving sea weeds production as alternative livelihood as being done in some East African countries e.g. Tanzania.
m) Assessment of heavy metal pollution of the wetlands
n) Mangrove restoration trials including aspects of seedlings regeneration.
o) Detailed study on the demarcation of land use categories and land cover for special area management planning
p) Investigation in to multi-species mangrove restoration trials at Essei and Butuah lagoons
q) Estimation of mangrove forest structure, composition and fragmentation studies
r) Pollution studies including analysis of faecal coliform levels
s) Water quality monitoring and understanding of elevated temperatures of the lagoon in Butuah lagoon
t) Understanding aspects of the biology of invasive species such as *Oreochromis niloticus*
u) Assessing the ecological implications of introduced species *Oreochromis niloticus* in the Butuah lagoon system

- Sociological and cultural studies (for all three wetlands):

a) Collation of user profiles or groups of different organizations or institutions and businesses operating along the wetland areas to facilitate effective stakeholding processes
b) Investigate into challenges faced by NGOs and other civil society groups working on marine conservation issues in the STMA.
c) Identify specific opportunities for working together between CRC/Friends of the Nation and local residents for conservation of the wetlands
d) Assess the effectiveness of closed areas or seasons for local fisheries management by monitoring catches before and after areas have been closed.
e) Assess feasibility for introduction of closed areas or seasons at lagoon sites especially at Essei and Butuah where none presently exists.
f) Investigation into Best Management Practices (BMP) around the Whin estuary.
g) Assessment of the value chain of the fishery, and why there is perceived notion of more sale of fish upcountry than in the coastal belt?

h) Investigate into historical and existing traditional fishing methods, taboos and cultural rules within the fishing communities
i) Investigate into present customary rights to wetlands in the STMA

6.3 Recommendations on other mitigation actions

Table 39: Proposals toward recovery of the wetlands following some suggested steps and considerations

Wetland	Bundling of mitigation actions			
	Physical/ environmental	**Organizational**	**Socio-cultural**	**Economic**
Essei lagoon	***(a) Short term actions (within 12 months):*** - initiate proper land use planning and re-zoning of the wetland in collaboration with district assemblies and interest groups - Engage political lobbying to enforce ban on sand winning activities on the beach - encourage the construction and use of sanitation facilities in homes - Estimating point sources of pollution by developing ~~–~~public maps" that show drainage discharge points into wetlands	***(a) Short term actions (within 12 months):*** - Develop communication tools on sanitation for inhabitants around the lagoon -design and select appropriate mangrove restoration sites - Initiate plans for fisheries management reforms to reduce excessive fishing, restore endangered species such as the lagoon tilapia (*Sarotherodon melanotheon)* - Advocate for the implementation of closed days or seasons presently non-existent.	***(a) Short term actions (within 12 months):*** - awaken the consciousness of the people through knowledge sharing and sensitization seminars -provision of community shelters or leisure gardens such as sitting places on beach for leisure at no fee - encourage local traditional authorities to introduce rules and regulations regarding the use of the lagoon since there are no known defined regulation or laws about the lagoon. E.g. introduce non-fishing to allow for fish recruitment success. - Discourage mangrove cutting through sensitization on the importance of mangroves as fish breeding, spawning and feeding grounds.	***(a) Short term actions (within 12 months):*** - - raise funds from private and donor sources to initiate project - seek sponsorship from companies as part of their Corporate Social Responsibility

Wetland	Bundling of mitigation actions			
	Physical/ environmental	**Organizational**	**Socio-cultural**	**Economic**
	(b) Longer- term actions (within 5 years and beyond) - Support the development of nursery habitats for fisheries through the removal of the groins to expand the lagoon system in order to broaden fish breeding grounds - - Improve upon sanitation for fish handling and quality control measures - Infuse new management and scientific skills -Establishing a Marine Protected Area (MPA) because of the special biodiversity features. This may be considered after groins have been removed	***(b) Longer- term actions (within 5 years and beyond)*** - Introduce access management and expand planning horizon of all beach users e.g. footballers, keep-fit clubs and sand winners because the bank of the lagoon is the only beach in the whole of Sekondi since all other shores have sea defense. - Enhanced awareness creation audio-visual methods e.g. radios, video and TV shows and sensitization rallies - development of the lagoon as an ecotourism destination - Continuous monitoring and apprehension of offenders. ZOIL could be empowered to assist in such policing efforts.	***(b) Longer- term actions (within 5 years and beyond)*** - - establish fisher folk cooperatives and groups for the wetland access management. The local groups should also be tasked to collect and disseminate information about the lagoon - involvement of local people in the management process of ecotourism activity. - Restore confidence in the chieftaincy system through mediation and non-partisan activities	***(b) Longer- term actions (within 5 years and beyond)*** - Introduction of small fees to maintain leisure gardens Fund raise from private sources including hotel operators around wetland e.g. Lagoon side hotel
Butuah lagoon	***(a) Short term actions (within 12 months):*** - Creation of refuse dumps and waste collection points to	***(a) Short term actions (within 12 months):*** - Lobby district assembly to enforce laws to prevent the unlawful	***(a) Short term actions (within 12 months):*** - embark on massive environmental education on the need for proper	***(a) Short term actions (within 12 months):*** - Secure funding through Private-Public Sector Partnerships (PPP)

Wetland	Bundling of mitigation actions			
	Physical/ environmental	**Organizational**	**Socio-cultural**	**Economic**
	discourage disposal of waste into lagoon - monitoring for water quality especially assessing reasons for highly elevated water temperatures of the lagoon system. ***(b) Longer- term actions (within 5 years and beyond)*** - Establish proper land use plan for the area - Need for a permanent structure at landing sites for use by fishermen - Water quality monitoring	disposal of waste into the lagoon - Lot of education and institution of feasible research studies to raise the consciousness of people towards most favourable extraction methods ***(b) Longer- term actions (within 5 years and beyond)*** - Review and generate economic and developmental activities for local people that have the potential to conserve biodiversity. - support district assembly to enforce good sanitation practices. - Education on the importance and relationships of the marine system - Formation or strengthening of school clubs for environmental education.	sanitation to protect the water body. - Promoting dialogue among user groups, addressing disharmonies in rules and regulations pertaining to the exploitation of the resources ***(b) Longer- term actions (within 5 years and beyond)*** - Create the atmosphere for positive interaction among resource stakeholders around Butuah. - embark upon behavioral change towards good sanitation practices - Correct unjustifiable myths - Disseminate scientific findings on the deplorable conditions of the lagoon - Infuse additional information where necessary.	***(b) Longer- term actions (within 5 years and beyond)*** Collaborate and share resources with other NGOs and civil society groups with a common vision.

Wetland	Bundling of mitigation actions			
	Physical/ environmental	**Organizational**	**Socio-cultural**	**Economic**
Whin estuary	***a) Short term actions (within 12 months):*** - monitoring of water quality of the sites, possibly by secondary school students or ~~–~~wetlands" clubs in the STMA. ***(b) Longer-term actions (within 5 years and beyond)*** - maintain water quality Establish special area management over Whin estuary - development of the estuary into an eco-tourism destination	***a) Short term actions (within 12 months):*** - Purchase basic water quality monitoring kits for use by students and secondary school teachers selected for the program. ***(b) Longer-term actions (within 5 years and beyond)*** - Institute training for teachers to supervise students and clubs engaged in water quality monitoring - Purchase land rights where necessary - CRC/FoN should collaborate with the District assembly and local people over the management of the estuary	***a) Short term actions (within 12 months):*** - Sensitize hotel operators (i.e. Takoradi Beach Hotel, and Africa Hotel) on the need to establish or upgrade waste water treatment plants and to minimize release of effluents into the estuary ***(b) Longer-term actions (within 5 years and beyond)*** - Disseminate scientific findings on the implications of degrades systems such as the Essei lagoon to local people and Coordinating council and district assemblies. - Applaud useful beliefs and norms - Reward stakeholders who engage in good management practices e.g. Hoteliers who deploy sewage treatment facilities - Advocate for hoteliers to offer temporary employment or casual jobs to local fishermen as an alternative form of	***a) Short term actions (within 12 months):*** - Seek private and public donor sources. ***(b) Longer-term actions (within 5 years and beyond)*** Income generation from ecotourism for maintenance of ecotourism facilities and support conservation efforts.

Wetland	Bundling of mitigation actions			
	Physical/ environmental	Organizational	Socio-cultural	Economic
			livelihood during lean seasons. - mobilize fishermen to form cohesive group for management of the estuary.	

6.4 Recommendations to develop the Whin estuary into an eco-tourism destination

Given the existing aesthetic conditions and environmental quality of the estuary, the development of the environment of the estuary into an eco-tourism destination should be of paramount importance. Such an activity will not only maintain the biodiversity but would also generate some income for local people, to maintain the estuary and generate employment opportunities for local inhabitants. Within the scope of an eco-tourism activity, the following objectives may be considered or piloted:

1) To promote ecologically sustainable tourism activities that involves the traditional communities living around the estuary
2) To identify suitable partners and suitable cooperation strategy (including the development of Memoranda of Understanding) with identified institutions.
3) To develop a management plan for the Whin estuary, involving also any interested institution.
4) To construct nature trails within the mangrove forests
5) To establish bird watching as an income generating activity to be developed in association with SNV based in Takoradi
6) To create awareness among local communities, educate students and for research activities
7) To use the Whin estuary to drive tourism markets in the Western Region.

6.5 Recommendations to enhance dialogue, partnership and scholarship

1) Development of cordial relations with fishermen and interest groups for wetlands management by:
    - Instituting small scale development projects to improve livelihood of fishermen
    - Any management intervention aimed at reducing over-dependence on fishing by opening up other income generating ventures for fishermen
    - Lobbying for employment of fishermen by hoteliers where possible
    - Provision of better fish landing sites
    - Provision of short-term micro-financing to venture into new areas after capacity have been built to ensure they are able to maintain pay back loans
    - Managers, scientists and fishermen should dialogue and work together towards longer term goals
    - Promotion of trust , understanding and tolerance of opinion among all interest groups
2) Create awareness among school children and students of the importance of wetlands and their relationships to coastal resources through:
    - Education on the relevance of wetlands to basic and secondary school students
    - Strengthen existing environmental clubs in basic and secondary schools in the metropolis by involving them in monitoring water quality and beach profile monitoring.

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8. APPENDICES

Appendix 1: Study schedule (7 weeks: July 14- Sept. 1, 2010).

	Preliminary surveys	Field surveys & assessments		Reporting and submission	
Item	Jul. 14- 16	Jul. 20-25	Jul. 26-31	Aug. 1-12	Aug. 13-Sept. 1
Reconnaissance surveys					
Water quality assessment in estuaries and lagoons					
Collection of water samples					
Analysis of water samples in the lab					
Mangroves survey and other plants					
Identification and assessment of structural development of mangrove stands					
Identification of riparian vegetation					
Analysis or riparian vegetation into tree species, grasses, sedges, herbs and mangroves					
Herbarium and desktop identification work on plant samples					
Phytoplankton & zooplankton survey					
Sampling of phytoplankton and zooplankton					
Laboratory work on identification of samples					
Fisheries survey					
Identification of species from landed catches					
Fish sampling					
Laboratory work of collected and unidentified specimens					
Macro invertebrate survey (Benthos & Epiphytes)					
Collection of benthic and littoral invertebrate samples					
Laboratory work of collected and unidentified specimens					
Compilation of data on reptiles, mammals, amphibians based on oral narratives. Birds data to be obtained from SNV-Takoradi					
Processing of GPS data/ boundary delimitation					
Questionnaire surveys on historical and current status of the ecosystems					
Mapping of wetlands and natural boundaries					
Write-up and submission of draft report for review					
Data analysis and incorporation of review comments					
Final compilation and submission of final report					

Appendix 2: Protocol sheets

Protocol Sheet 1: Site record (habitat characteristics)

Please fill in as much information as possible to help us verify the significance of the site. GPS data are helpful but not essential. Please take digital photo of sites as far as possible.

SITE NAME: _____ WETLAND TYPE: _____ DATE __-___/_____/_____ NAME OF INVESTIGATOR_____GPS REF. NO.:_____/_____GPS ACCURACY: __ __ (M) UTM EAST __ __ __ __ UTM WEST __ __ __ _

DIRECTIONS TO SITE:

SITE DESCRIPTION: (Describe the ecological and landscape setting [landforms, dominant vegetation types and patterns, quality/condition, hydrology, and offsite influences])

KEY ENVIRONMENTAL FACTORS (seasonal flooding/hydrology, herbivory, fires, etc)

LANDUSE HISTORY / COMMENTS (past and current land history including offsite use)

BIOLOGICAL SIGNIFICANCE (Include any relevant references to printed reports or other data)

OTHER VALUES (recreation, aesthetic, etc.)

EXOTIC SPECIES (list species and abundance, write "None" if none are noticed, include any comments)

INFORMATION NEEDS (include the intensity of this survey – amount of area viewed, etc.)

MANAGEMENT NEEDS

SITE PHOTOS (note if any are taken and what they portray)

Item	**Code**		
Tenure	1	Public property	Date of occupancy:
	2	Private property	
	3	Leased	
	4	Customary land	

Protection status	1	No legal - no managed protection	Year protected: Area legally protected (ha): Protection measures:
	2	Reserve - no managed protection	
	3	Reserve- managed protection	
	4	Traditional/ customary protection	
	5	Other	
Land use	1	Animal husbandry e.g.:	Production method: Organic / Conventional Scale: Small/ Commercial
	2	Cropping such e.g.:	
	3	Urban subdivisions	
	4	Indigenous forest / shrub	
	5	Garden; Parkland:	
	6	forestry, planted natives:	
	7	Open space; Bare land; Recreation land	
	8	Coastal Dunes	
	9	Climax forests	
	10	Others (please specify):	
Drainage	1	Open drains	Notes:
	2	Irrigation	
	3	Others:	
Artificial constructions around in-outflow	1	Dams	Notes:
	2	Culverts	
	3	Others:	
Site visits	1	Free access granted	Comments:
	2	Access permit required	
	3	Access denied	

Fencing	1	No fencing	Comments:
	2	Some fencing (one side, large breaks) %	
	3	Secure, intact fencing around entire perimeter %	

Protocol Sheet 2: Sampling methods for the wetland habitats including fauna and flora

Method	Application	Field time per site	Required expertise	Sample collection	Equipment needed
(a) Water quality					
physical probes	pH, O2, electroc conductivity, temperature, BOD	10-30 mins	none	no	water quality checker-Horiba U-10
secchi disc	water transparency	short, 5-10 mins	none	no	secchi disc
visual assessment of water colour	water colour and type (black, white, clear, turbid, etc)	fast, 1-5 mins	none	no	water sampler for deeper waters
visual assessment of sediment	sediment colour and type (organic, sandy, clayish, etc)	fast, 1-5 mins	none	sediment sample	grab sampler
(b) Wetland habitat types:					
Field habitat assessment	bank characteristics, discharge, sedimentation, evidence of disturbance, riparian attributes, water depths	1-3 hours	expert in field methods	no	tape measure, camera, substrate sampler

Method	Application	Field time per site	Required expertise	Sample collection	Equipment needed
Spatial data analysis	land use, vegetation type and distribution, riparian corridor characteristics, size and shape of water bodies, water colour, hydrologic regime and slope	variable depending on data resolution and availability	knowledge of reading data and GIS. Contact with Geological survey Depts.	no	satellite imagery, aerial **photos, DEM. Land cover** maps
(c) Macrophytes (plants)					
Visual search	note visible plants within certain areas i.e.full water mark, high water mark for qualitative analysis	1-5 hours	species identification and random sampling	yes	basic
random sampling	qualitative, unbiased search	1-5 hours	species identification and random sampling	yes	basic
plots	vegetation including mangroves	variable usually 1 hour/ plot	species identification and survey design	yes	basic
grab	good, quantitative method	1-5 hours	random of transect sampling	yes	grab sampler, boat & GPS
(d) Zooplankton (small invertebrates in water)					
plankton sampler	plankton crustaceans and rotifers	1-3 hours	sampling techniques	yes	plankton (box) samplers
(e) Epiphytic macro invertebrates:					

Method	Application	Field time per site	Required expertise	Sample collection	Equipment needed
various samplers depending on vegetation type	Littoral nearshore zone	1-4 hours	sampling techniques	yes	samplers, sieves
(f) Benthic macro invertebrates					
grab sampler	invertebrates inhabiting soft or sandy sediments	I hour/ site	sampling techniques	yes	grab sampler
(g) Fish					
Information on fish species will be sought from fisnermen and identification of fish landed on beaches. Particular note will be taken on types of gears used					
(h) Reptiles and amphibians					
Visual search	location of visible animals	variable	knowledge of microhabitats	no	none
Use of key informants	interviews, ask local people including fishermen about the species they have observed and use/ used	2-4 hours	interviewing techniques and questionnaire design	no	none
(i) Mammals, amphibians and reptiles:					
Sightings	look for mammals to surface	variable	minimal	no	binoculars if necessary, camera

Method	Application	Field time per site	Required expertise	Sample collection	Equipment needed
Use of key informants	interviews, ask local people inclusing fishermen about the species they have observed and use/ used	2 hours	interviewing techniques and questionnaire design	no	none
Tracks	detecting mammal presence on land, riparian	depends on search time, variable	expertise required to identify species if tracks are found	no	camara- take photos

Protocol Sheet 3: Assessment of threats

Activity	Nature of damage/ threat	Seriousness	Area		Current management (Yes/ No) **Nature:**	Description/ comments
			Extent (m^2)	% of total area		
(a) Human uses[1]: -						
(b) Animal uses[2]: -						

Protocol Sheet 4: Estimation of current management measures

[1] earthworks; rubbish dumping; waterways works; clearing; drainage; tramping; shooting; recreational, construction works

[2] Animal grazing, trampling, erosion, trees chopped, destruction of riparian cover, barriers to fish migration, birds disturbed at on nesting sites…

Site management strategy	**Code for estimating priorities**	**Contacts/ comments:**
Environmental education	1	
Fencing (stock-control and regeneration space)	2	
Regeneration (or failure)	3	
Catchment plan (remedying extinction or habitat degradation)	4	
Visitor Management	5	
Monitoring programme (Ecosystem function)	6	
Others (including traditional efforts and policy):	7	

Appendix 3: Statistics on the hydrographic parameters

S/n	Parameter	Essei lagoon	Butuah lagoon	Whin estuary
1	**Temp**			
	Mean	25.98	32.95	25.57
	Min	25.1	29.8	24.6
	Max	27	36.8	26
	SD	0.8	2.19	0.46
2	**pH**			
	Mean	7.76	7.63	8.08
	Min	7.69	7.46	7.98
	Max	7.83	7.81	8.34
	SD	0.06	0.13	0.11
3	**Turbidity**			
	Mean	57.79	180.07	42.29
	Min	37.5	99	20
	Max	76.5	355.5	103.5
	SD	12.32	88.76	30.4
4	**Dissolved Oxygen**			
	Mean	0.65	3.74	3.11
	Min	0.1	0.09	2.85
	Max	1.27	9.51	3.52
	SD	0.36	3.37	0.21
5	**Salinity**			
	Mean	18.78	19.01	37.01
	Min	8.6	13	36.4
	Max	30.8	32	37.7
	SD	3.51	2.76	0.14
6	**Conductivity**			
	Mean	29.26	18.95	55.61
	Min	14.1	2.97	54.8
	Max	48.2	40.6	56.3
	SD	13.72	14.79	0.45

Appendix 4: Phytoplankton occurrence in three wetlands

	WATER BODY		
PHYTOPLANKTON	ESSEI	BUTUAH	WHIN
Blue - green algae			
Oscillatoria spp.	++	++	+
Anabaena spp.	++	+++	++
Lyngbya sp.	++	+++	
Spirulina spp.	+	++	+
Calothrix sp.		++	
Microcystis spp.	+++	+++	++
Chroococcus sp.	++	+++	++
Aphanizomenon sp.	+	+	
Diatoms			
Navicula spp.	+++	++	+++
Nitzschia spp.	++	+	++
Gyrosigma sp.	+		+
Pleurosigma sp.		+	+
Coscinodiscus spp.	+++		+
Stephanodiscus spp.	+++	+	+
Melosira sp.	+		+++
Rhizosolenia spp.	++	++	++
Diatoma spp.	+++	++	+++
Asterionella sp.	+		++
Synedra spp.	+	+	++
Cyclotella sp.			+
Green algae			
Staurastrum spp.	++	+	+++
Pediastrum sp.	+		+++
Spirogyra sp.	+		+
Netrium spp.	+	+	++
Microspora sp.	+	++	+++
Closterium sp.	+		+++
Scenedesmus sp.		+	++
Chaetomorpha sp.	+		++

\+ = occurred sparingly
\+ + = moderately abundant
+++ = highly abundant

Appendix 5: Zooplankton occurrence in three wetlands

	WATER BODY		
ZOOPLANKTON	ESSEI	BUTUAH	WHIN
Copepods			
Calanus sp.	+		+++
Cyclops spp.	++	++	+
Sappharina sp.	+	+	+
Thermocyclops sp.		++	++
Copepodite sp.		+	+++
Rotifers			
Brachionus sp.	+	+	+++
Keratella spp.	+++		+
Kellicottia spp.	++	+++	+++
Trichocera sp.			++
Cladocerans			
Bosmina sp.	++	+	+++

+ = occurred sparingly
+ + = moderately abundant
+++ = highly abundant

Appendix 6: Occurrence of benthic macroinvertebrate community in the three wetlands

			WATERBODY		
CLASS	**ORDER**	**FAMILY**	**ESSEI**	**BUTUAH**	**WHIN**
OLIGOCHAETA			+	+	+
POLYCHAETA		Capitellidae	+	+	+
		Nereidae	+		
		Cirratulidae		+	
		Opheliidae	+		
		Maldanidae	+		
INSECTA	DIPTERA	Chironomidae	+	+	+
		Ceratopogonidae			+

		Aedinae		+	
GASTROPODA		Potamididae		+	
Others					
Echinodermata				+	
Nemertea			+		+

+ = present

Appendix 7: Occurrence of littoral macroinvertebrates in the three water bodies

				WATERBODY		
CLASS	**ORDER**	**FAMILY**	**SPECIES**	ESSEI	BUTUAH	WHIN
OLIGOCHAETA				+	+	+
POLYCHAETA		Capitellidae		+	+	+
		Nereidae		+		
		Cirratulidae		+		
		Onuphidae				+
INSECTA	DIPTERA	Chironomidae		+	+	+
		Ceratopogonidae		+	+	
		Aedinae		+		+
	ODONATA	Coenagriidae		+		
GASTROPODA		Potamididae	*Tympanotonus fuscata*		+	+
		Muricidae	*Thais hemastoma*			+
			Thais forbesi			+
		Neritidae	*Nerita senegalensis*			+
			Littorina punctata			+
		Patellidae	*Patella safiana*			+
BIVALVIA		Mytiliidae	*Perna perna*			+
		Arciidae	*Anadara senelis*			+
		Ostreidae	*Crassotrea tulipa*			+
CRUSTACEA			*Balanus pallidus*			+
			Hermit crab			+

+ = present

Appendix 8: Occurrence of fish species in three water bodies in the Sekondi –Takoradi Metropolis

Family	Species	Water Body		
		Essei	Butuah	Whin
Mugilidae	*Liza dumerilii*		+	+
	Liza falcipinis	+	+	+
	Mugilbananensis		+	+
	Mugilcephalus			+
	Mugilcurema		+	+
Clupeidae	*Odaxothrissamento*	+	+	
	Sardinellamaderensis			+
Cichlidae	*Oreochromisniloticus*		+	
	Sarotherodonmelanotheron	+	+	+
Gobiidae	*Bathygobiussoporator*			+
	Periopthalmusbarbarus	+	+	+
Serranidae	*Serranusaccraensis*	+		
Acanthuridae	*Acanthurusmonroviae*			+
Labridae	*Xyrichthysnovacula*			+
Bothidae	*Scyaciummicrurum*			+
Haemulidae	*Plectorhynhusmediterraneus*			+
Lutjanidae	*Lutjanusgoreensis*			+
Eleotridae	*Eleotrissenegalensis*			+
Gerreidae	*Eucinostomusmelanopterus*			+
Clariidae	*Clariasgariepinus*		+	
	Heterobranchuslongifilis		+	
Portunidae	*Callinectesamnicola**	+	+	+
Gecarcinidae	*Cardiosomaarmatum***	+	+	
Ocypodidae	*Ucatangeri***			+
Grapsidae	*Goniopsiscruentata***	+	+	+
Sesarmidae	*Sesarmaharzudii***		+	+

+ = Present * = Marine crab ** = Land crab

Appendix 9: Riparian vegetation around the wetlands

S/N	Name of Flora	Water Body (Location)		
		B	E	W
	Grasses			
1	*Axonogus compressus*		+	
2	*Cenchorus ciliaris*		+	+
3	*Chloris pilosa*		+	
4	*Dactyloctenium aegyptium*		+	+
5	*Elensine indica*		+	+
6	*Mariscus alteternifolia*	+	+	
7	*Panicum maximum*	+*		+
8	*Paspalum vaginatum*	+*	+	
9	*Setaria barbata*			+
10	*Sporobolus pyramidalis*	+	+	
	Herbs			
1	*Acanthospermum hispidum*		+	+
2	*Achyranthesaspera species*		+*	
3	*Acligta alba*		+	
4	*Alternanthera pungus*		+	
5	*Aspilia africana*	+		
6	*Asystasia gigantica*		+	+
7	*Boerhavia diffusa*		+	+
8	*Calapogonium mucohoides*	+		
9	*Caloponium mucuniodes*			+
10	*Canavalia reseus*			+
11	*Capraria biflora*	+	+	
12	*Cassia nigricans*	+		
13	*Centrosema pubescens*	+		
14	*Cesuvium portulacastrum*		+*	
15	*Chromolaena odoraata*	+		
16	*Commelina bengalensis*			+
17	*Corchotus aestuans*	+		+
18	*Croton lobatus*			+
19	*Desmodium adescendens*		+	

20	*Eughorbia hirta*		+	
21	*Euphorbia heterophylla*			+
22	*Fleura aestuans*		+	
23	*Gomyhrena celosoides*		+	
24	*Hyptis lanceolata*	+		
25	*Indiglofera arrecta*		+	
26	*Indigofera hirsuta*			+
27	*Ipomea pre-caprae*		+ *	
28	*Ipomoea involucrata*	+		
29	*Iponea barbata*	+		
30	*Iponea carica*	+		
31	*Kallastroemia pubsceus*		+	
32	*Ludigia decurrens*		+	
33	*Malvastrum coromandeliamum*		+	
34	*Mimosa pudica*	+ *	+	
35	*Oldelandia corymbosa*		+	+
36	*Passiflora foetida*	+	+	+
37	*Phyllanthus amarus*		+	+
38	*Physalis angulata*	+	+	+
39	*Portulaca oleracea*	+		
40	*Ruellia tuberosa*		+	
41	*Sanseviria liberica*	+		
42	*Schwenkia americana*	+		
43	*Sesamum indicum*			+
44	*Sesuvium portulacastrum*	+		+
45	*Sida acuta*	+	+ *	
46	*Slanum nigrum*	+		
47	*Solanum nigrum*		+	
48	*Spigelia anthelmia*	+		
49	*Stachytarpheta indica*	+	+	
50	*Synedrella nodiflora*		+	
51	*Talinum triangulare*			+
52	*Trianthema portulacastrum*	+	+	
53	*Tridax procumbens*			+
54	*Vernonia cineria*	+	+	
	Sedges			
1	*Cynodon dactylon*		+ *	+
2	*Cyperus rotundus*		+	+

3	*Cyperus umbellata*	+		
	Shrubs			
1	*Abutilon mauritianum*		+	
2	*Acacia nolitica*	+		
3	*Agave sisalana*			+
4	*Alchornia Cordifolia*	+		
5	*Avicennia africana*	+*		+*
6	*Avicennia portulacastrum*		+	
7	*Baphia nitida*	+		+
8	*Calutropis procera*		+	
9	*Cassia occidentalis*	+	+	
10	*Cassia tora*	+		
11	*Crotalasia retusa*		+	
12	*Fagara xanthoxyloides*	+		
13	*Flagellaria daemae*	+*		
14	*Flaucortia flavescens*	+		
15	*Grewia Carpinifolia*	+		
16	*Grifforia simplcifolia*	+		
17	*Hoslundia opposita*	+		
18	*Iponea asarifolia*		+	
19	*Jatropha gossipifolia*	+		
20	*Laguncularia racemosa*			+*
21	*Lantana camara*	+	+	
22	*Leucaena glauca*	+*		+
23	*Mallotus oppositifolius*	+		
24	*Manihot esculentus*	+		
25	*Naudea latifolia*	+		
26	*Paulinia pinnata*	+		
27	*Phoenix redinata*	+		
28	*Rhizophora mangle*			+*
29	*Securinega virosa*	+	+	+
30	*Thespesia populnea*		+	+
31	*Thevetia peruviana (Milk bush)*		+	
32	*Tridisia subcordata*	+		
33	*Waltheria indica*	+		
	Trees			
1	*Antiaris africana*	+		

2	Azadirachta indica (Nim tree)	┼		
3	Baghia nitida		┼	
4	Coco nucifera	┼		
5	Psidium guajava	┼		
6	Terminalia catappa		┼	┼
7	Elaeis guineansis	┼	┼	┼

Key

┼ Species present around the water body.
*┼ Species present and dominant around the water body
B Butuah Lagoon
E Essei Lagoon
W Whin Estuary

Appendix 10: National wetland policies

National policies on the protection, management and development of the marine and coastal environment revolve around the following areas:

- Integrated Coastal Zone Management and sustainable development
- Marine environmental protection, both from land-based activities and from sea-based activities; and
- Sustainable use and conservation of marine living resources (both of the high seas and under national jurisdiction).

Plans pursued to achieve the implementation of the above are as follows:

- Coastal Zone management Indicative Plan (1990)
- National Environmental Action Plan (1994)
- Draft Integrated Coastal Zone Plan (1998)
- Coastal Zone Profile of Ghana (1998)
- National Oil Spill Contingency Plan with specific reference to the marine environment (2002)
- Environmental sensitivity map of the coastal areas of Ghana (1999 and 2004).

Legislations relating to coastal protection and sustainable development include:

- Beaches Obstruction Ordinance, 1897 (Cap 240)
- The Mineral and Mining Law, 1986 (PNDC 153)
- Rivers Ordinance, 1903 (Cap 226)

- Land Planning and Soil Conservation Ordinance No 32 of 1953 as Amended by the Land Planning and Soil Conservation (Amendment) Act, 1957 (No. 35 of 1957)
- Maritime Zones (Delimitation) Law 1986 (PNDC 159) urban planning and Development
- Town and Country Planning Ordinance (Cap 84)
- Wild Animals Preservation Act, Act 235 (1964)
- The Towns Ordinance (Cap 86)
- National Building Development Act (1961)
- Fisheries Act 2002, Act 625
- Fisheries (Amended) Regulations (1977 and 1984)

The legal framework for coastal zone issues and management in Ghana are contained in the following documents:

- The 1992 constitution
- EPA Act, 1994 (Act 490)
- Environmental Assessment Regulations, 1999 (LI 1652)
- Local Government Act, 1993 (Act 462)
- Environmental Standards and Guidelines

In addition, specific legal frameworks exist:

(a) The legal framework for Ecosystem Protection, which are:

- Wildlife Animals Preservation Act 1961 (Act 43)
- Wildlife Conservation Regulations 1971 (LI 685)
- Wildlife Reserves Regulations 1971 (LI 740)
- The Wetland Management (Ramsar sites) Regulation (1999)
- Oil in Navigable Waters Act, 1964 (Act 235)

(b) The legal framework for Fisheries resources, which are:

- Fisheries Law 1971 (PNDCL 256)
- Fisheries Act 2000

(c) The legal framework for Oil and Gas Industry

- Petroleum (Exploration and production) Law 1984 (PNDCL 84)
- Mineral (Offshore) regulations, 1963 (LI 257)
- Mineral (Oil and Gas) regulations, 1963 (LI 256)
- Oil and Mining Regulations, 1957 (LI 221)

(d) The legal framework for Tourism Promotion (including coastal tourism)

- Ghana Investment Promotion Centre Act 1994 (Act 478)
- Companies Code 1963 (Act 179)
- Free Zone Act 1995 (Act 504)
- Ghana Tourist Board
- Ghana Commission on Culture

Ghana has a working document on wetlands: _National Wetlands Conservation Strategy' since 1999 - facilitated as a result of being a signatory to the Ramsar Convention of 1971. Seven (7) wetlands have been demarcated as Ramsar sites http://www.ramsar.org/wurc_policy_ghana.htm). Traditional management practices comprise customary laws or taboos also exist. These determine the rights to land and wetland resource use. They include the enforcement of sanctions for violation by the responsible authority.

2.5 Relevant Programmes to Coastal Wetlands Management

In Ghana, a number of programmes related to wetlands have since been implemented. These include:

- The development of University courses on Coastal Zone Management at the University of Cape Coast and the University of Ghana
- The Ghana Coastal Wetlands Management Project (CWMP): This project aimed at establishing and managing five Ramsar sites along the coast- funded by GEF and implemented by the Wildlife Department as a component of the Ghana Environmental Resource Management Project (GERMP).
- The Lower Volta Mangrove Project (LVMP) investigated the problems related to excessive exploitation of mangroves in the south-eastern part of the country and recommended an operational framework within the public and private sectors for sustainable and participatory management of natural resources- Funded by the DFID.

- The GLOWA Volta Project aimed at an interdisciplinary approach for a sustainable water resource management in the Volta Basin and to develop a Decision Support System (DSS), funded by BMBF.
- The rehabilitation and community management of mangrove forests in some respective locations by some local environmental NGOs with funding support from the Ramsar Convention's Small Grants Fund.
- Ghana Environmental Resource Management Project in coastal wetlands Management Component.
- Ecological baseline studies of the Korle Lagoon (1990-2000), carried out as an EIA requirement, and as result the pollution status of the lagoon was established.
- Save the Seashore Birds Project (1985-1995). This was to protect the seashore birds.
- Darwin Marine Biodiversity of West Africa Project that served as a training project in marine biodiversity assessment.
- Climate, Vulnerability and Adaptation assessment on water resources, agriculture and the coastal zone projects (1997-1999), assessed the vulnerability of the coastal zone to climate change.
- Coastal area management plan for Princess Town (1998-2000), which aimed at providing a plan for the management of Princess Town.
- Keta Sea Defence Project Work (2000-2004), which aimed at protecting the Keta and its environs from rampant erosion and to ensure improvement in the environmental and socio-economic conditions at Keta and neighbouring towns.

Other projects include:

- Ghana Environmental Resources Management Project in the Coastal Wetlands management Component
- Fisheries sub-sector Capacity Building Project
- Establishment of a Protected Wetland Ecosystem on the Coast
- Combating Living Resource Depletion and Coastal Area Degradation in the Guinea Current LME through Ecosystem-based Regional Actions
- Amansuri Conservation and Integrated Development Project (ACID)
- Danida Water and Sanitation Sector Programme II: Support to Integrated Water Resources Management (IWRM) Component (2004-2008).

- Reduction of Environmental Impact from coastal tourism.
- Gulf of Guinea Large Marine Ecosystem Project
- Fisheries Sub-sector Capacity Building Project
- Establishment of a Protected Wetland Ecosystem on the coast
- Development and Implementation of Oil Spill Contigency Plan
- Monitoring of fish stocks levels and associated oceanographic parameters
- Institution of a programme of Monitoring, Compliance and Surveillance of the marine environment
- Development of industrial pollution standards
- Public education on sound coastal and marine environmental practices
- Scientific information and research on wetlands include works on shorebirds, sea turtles, mangroves and fish resources.
- Presently the USAID supported Integrated Coastal and Fisheries Governance (ICFG) Initiative implemented in collaboration with the Friends of the Nation in the Western Region.