

**INFLUENCE OF HUMAN ACTIVITIES ON INSECT DIVERSITY
AND ABUNDANCE IN THE WETLAND ENVIRONMENT**

BY

**BEATRICE AYORKOR MENSAH
10357994**



**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA,
LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE AWARD OF MPhil ENVIRONMENTAL SCIENCE
DEGREE**

JUNE, 2013

DECLARATION

I hereby declare that except for references to other people's work, which I have duly acknowledged, this dissertation is the result of my own research work under the supervision of Dr Rosina Kyerematen and Dr. Ted Annang. This work has neither in part nor wholly been presented elsewhere for another degree or for any other purpose.

.....
BEATRICE AYORKOR MENSAH
(STUDENT)

.....
DATE



.....
DR. ROSINA KYEREMATEN
(SUPERVISOR)

.....
DATE

.....
DR. TED ANNANG
(CO- SUPERVISOR)

.....
DATE

DEDICATION

This work is dedicated to God almighty and my dear father Mr. JOSEPH Mensah Mensah and my children.



ACKNOWLEDGEMENT

My foremost appreciation goes to the Lord Almighty for sustaining me throughout the course of this research.

I would first like to express my gratitude to my supervisors, Dr. Rosina Kyerematen and Dr. Ted Annang under whose diligent supervision this study has been successfully completed.

I would like to acknowledge the Health Division CSIR Institute Ecological Laboratory, Department of Geography and Resource Development and the Centre for African Wetlands for the use of their laboratory facilities.

I also feel a deep sense of gratitude to Mr. Henry Ekow Davis, Mr. Roger Sigismond whose selfless and valued contribution and support by way of identification of insect in the laboratory contributed immensely to the successful completion of this study.

I am also thankful to Mr. Daniel Acquah-Lampsey and Mr. Jones Dartey whose selfless and valued contribution and support on the field contributed immensely to the successful completion of this work.

I am also grateful to Mr. Francis Doe for his help with data analysis.

Lastly, my profound thanks go to my husband, Mr. Abraham Laryea Okorley for his support, understanding and encouragement and for his immense contribution in diverse ways during my MPhil. Programme

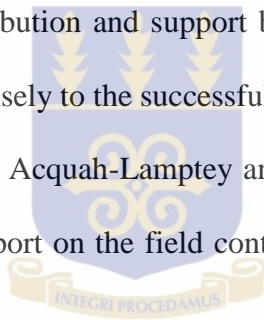


TABLE OF CONTENT

DECLARATION	i
DEDICATION	ii
ACKNOWLEDGEMENT	iii
TABLE OF CONTENT	iv
LIST OF TABLES	xii
LIST OF PLATES	xiii
ABSTRACT	xiv
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background	1
1.2 Justification	3
1.3 Objectives.....	5
1.4 Hypothesis.....	5
CHAPTER TWO	7
LITERATURE REVIEW.....	7
2.1 Definition of Wetlands.....	7
2.2 Biodiversity.....	8
2.3 Types of Wetlands.....	9
2.4 Ghana’s Wetland Resources	9
2.4.1 Marine/Coastal Wetland.....	9
2.4.2 Inland Wetlands	10
2.4.3 Man-Made Wetlands.....	10
2.5 “Wise Use” of Wetlands	10
2.6 Ramsar Wetlands	11
2.7 Wetland Services.....	11



2.8 Threats to Ghana's Wetlands.	12
2.9 Insects.....	13
2.9.1 Evolution of Insects	13
2.9.2 Wetland Insects	14
2.9.3 Subclasses of Insects	14
2.9.4 Suborder Exopterygota.....	15
2.9.5 Suborder Endopterygota.....	15
2.9.6 Importance of Insects in the Aquatic Environment.....	16
2.9.7 Factors influencing Insect Abundance and Diversity	16
2.9.7.1 Density-Dependent Factors	16
2.9.8 Density-Independent Factors	18
2.10 Pollution	20
2.10.1 Definition	20
2.10.2 Types of Pollution	20
2.10.2.1 Water Pollution	21
2.11 Water Quality	24
2.11.1 Physical Characteristics	24
2.11.2 Chemical Characteristics.....	24
2.11.3 Biological Characteristics	25
2.11.4 Suspended Solids	25
2.11.5 Turbidity.....	25
2.11.6 Colour.....	26
2.11.7 Temperature	26
2.11.8 pH.....	26
2.11.9 Conductivity and Salinity.....	27
2.11.10 Dissolved Oxygen (DO).....	27
2.11.11 Biochemical Oxygen Demand (BOD)	28

2.11.12 Trace metals	28
2.11.13 Cadmium	28
2.11.14 Copper	28
2.11.15 Lead	29
CHAPTER THREE.....	30
MATERIALS AND METHODS	30
3.1 Study Areas	30
3.1.1 Winneba	30
3.1.2 Sakumo Lagoon	32
3.1.3 Kpeshie Lagoon	34
3.2 Methods.....	35
3.2.1 Sampling Points	35
3.2.2 Sampling Design and Technique	35
3.2.3 Malaise Trap.....	35
3.2.4 Pitfall Trap	36
3.2.5 Yellow Pan Trap	37
3.2.6 Flight Interception Trap	38
3.2.7 Charaxes Trap	39
3.2.8 Sweep Net	40
3.2.9 Aerial Net.....	41
3.2.10 Visual Observation and Direct Counts.....	42
3.3 Sampling and Analysis of Water.....	42
3.3.1 On Site Measurements	43
3.3.2 Water.....	43
3.3.3 Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO)	43
3.3.4 Heavy Metals	43
3.3.5 Bacteriological Sampling	44

3.4 Laboratory Analyses of Water	44
3.4.1 Physico-Chemical Methods for Water Analyses	44
3.4.2 True Colour	44
3.4.3 Turbidity.....	45
3.4.4 Dissolved oxygen	45
3.4.5 BOD	46
3.4.6 Analysis of Trace Metals	46
3.4.7 Suspended Solids	47
3.4.8 Lead, Iron and Copper	47
3.5 Bacteriological Analyses: Faecal and Total Coliform.....	48
3.6 Social Survey	50
3.6.1 Sampling Technique.....	50
3.6.2 Questionnaire Administration	50
3.6.3 Interview	50
3.6.4 Non Participatory Observations	50
3.6.5 Sorting and Species Identification	51
3.7 Statistical Analyses	51
CHAPTER FOUR.....	53
RESULTS	53
4.1 Relative Abundance of Insects.....	53
4.2 Species Richness and Diversity Indices	58
4.2.1 Estimated Species Richness	58
4.2.2 Observed Species Richness.....	59
4.3 Water Analyses	61
4.3.2 Temperature	61
4.3.3 pH.....	62
4.3.4 Salinity	63

4.3.5 Conductivity.....	64
4.3.6 Turbidity.....	64
4.3.7 Suspended Solids	66
4.3.8 Colour.....	67
4.4 Chemical Analysis	68
4.4.2 Biochemical Oxygen Demand (BOD)	69
4.5 Bacteriological Analysis	70
4.5.1 Total Coliform.....	70
4.5.2 Faecal Coliform.....	71
4.6 Trace Metals.....	72
4.7 Social Survey	74
4.7.1 Respondent Information.....	74
4.7.2 Sex.....	74
4.7.3 Educational Level.....	74
4.7.4 Income Level.....	75
CHAPTER FIVE.....	79
DISCUSSION	79
5.1 Insect Abundance	79
5.2. Observed Species Richness.....	81
5.3. Estimated Species Richness among Sites	83
5.4. Water Quality Analysis.....	84
5.4.1. Temperature	84
5.4.2 pH.....	85
5.4.3 Salinity	85
5.4.4 Conductivity.....	86
5.4.5 Turbidity.....	86
5.4.6 Suspended solids	87

5.4.7 Colour.....	88
5.4.8 Dissolved Oxygen	88
5.4.9 BOD	89
5.4.10 Total Coliform.....	89
5.4.11 Faecal Coliform.....	89
5.4.12 Trace Metals.....	90
5.4.13 Concentration of Iron/Fe and Lead (Pb)	91
5.4.14 Concentration of Cadmium and Calcium.....	91
5.4.15 Magnesium Mg/ Zinc Zn	91
5.5. Social Survey	92
5.5.1 Sex of respondents	92
5.5.2. Educational level.....	92
5.5.3 Income Level.....	92
5.5.4. Occupational Status.....	93
5.5.5 Waste Disposal and Sanitation.....	93
CHAPTER SIX	95
CONCLUSION AND RECOMMENDATIONS.....	95
6.1 Conclusion	95
6.2 Recommendation.....	96
REFERENCES.....	98
APPENDICES	110

LIST OF FIGURES

Figure 1: Map showing the study area within the Muni-Pomadze lagoon.....	31
Figure 2: Map showing the study area within the Sakumono lagoon.....	33
Figure 3: Map showing the study area within the Kpeshie lagoon.....	34
Figure 4: Relative abundance of insects order at all the sites.....	54
Figure 5: Relative abundance of insects order between wet and dry season at Sakumono.....	55
Figure 6: Relative abundance of insects order between wet and dry season at Kpeshie.....	56
Figure 7: Relative abundance of insects order between wet and dry season at MuniPomadze.....	57
Figure 8 to10: Shows the Randomized species accumulation curves. Number of observed and estimated species at each site as a function of increasing number of samples. ACE, Chao1 and Jack1= non parametric estimates of species richness, Sobs= actual species observed in samples.....	60
Figure 11 a-c: Monthly variations in Temperature at the various sites in the study area.....	61
Figure 12 a-c: Monthly variations in pH at the various sites in the study area.....	62
Figure 13 a-c: Monthly variations in Salinity at the various sites in the study area.....	63
Figure 14 a-c: Monthly variations in Turbidity at the various sites in the study area.....	65
Figure 15 a-c: Monthly variations in Suspended solids at the various sites in the study area.....	66

Figure 16 a-c: Monthly variations in Colour at the various sites in the study area.....	67
Figure 17 a-c: Monthly variations in Dissolved Oxygen (DO) at the various sites in the study area.....	68
Figure 18 a-c: Monthly variations in Biochemical Oxygen Demand (BOD) at the various sites in the study area.....	69
Figure 19 a-c: Monthly variations in Total coliform at the various sites in the study area.....	70
Figure 20 a-c: Monthly variations in Faecal coliform at the various sites in the study area.....	71
Figure 21: Occupational status of the respondents in the study area.....	76
Figure 22: Proportion of respondents who said they had access to private toilet facility to those who don't have.....	77
Figure 23: Mode of disposal of refuse in the study area.....	78

LIST OF TABLES

Table1: Diversity and richness indices for each season in and around each lagoon.....	58
Table 2: Values of species richness estimates at all the site.....	59
Table3: Value for conductivity($\mu\text{s}/\text{cm}$) for sites and seasons.....	64
Table 4: Titrimetric Analysis.....	72
Table 5: means and standard deviation values of Trace Metals of the Sakumono, Kpeshie and Muni-Pomdze Lagoons.....	73
Table 6: Educational Level Breakdown.....	75
Table 7: Income Level/Month Breakdown by category and Percentage (%).....	76

LIST OF PLATES

Plate 1: Malaise trap with a collecting apparatus set at the fringe of a lagoon.....	36
Plate 2: A pitfall trap.....	37
Plate 3: A Yellow Pan Trap.....	38
Plate 4: A flight interception trap.....	39
Plate 5: A charaxes trap.....	40
Plate 6: A Sweep net.....	41
Plate 7: Aerial Net.....	42
Plate 8: Heavily polluted sites in Kpeshie, Sakumono and Muni-Pomazde lagoons.....	49

ABSTRACT

The Wetland environment is a unique with unique biota, including insects. Insects serve as indicators of environmental health. However, the recent spate of human encroachment on wetlands would affect this unique biota structure. This phenomenon could pose a threat to the wetland environment. The physical and chemical quality of these habitats would provide background information for comparison against established quality standard of the wetland environment. Information gathered could help manage threatened wetlands better. The study involved reconnaissance surveys, trapping of insects, physico-chemical and bacteriological assessment of water and social surveys to determine how human activities influence insect diversity and abundance in and around the wetland environment. Of the 5541 individual insects recorded, a total of 22 orders belonging to 112 families were collected and identified from different sites along the Sakumono, Kpeshie and Muni – Pomadze Wetlands. The distribution of species was significantly different among the various locations with the most diverse site being Kpeshie where 2128 individuals were collected. Principal component analysis indicated that species assemblage on sampled site were related to some environmental and water quality parameters. In the case of Kpeshie the water was badly polluted but still had a positive correlation with insect diversity and abundance. The social survey of the selected communities showed that majority of the residents had low level of education and this has affected their appreciation of issues involved in environmental pollution. Majority of the communities also lack proper toilet facilities and publicly demarcated waste disposal sites and there was no coordinated and concerted effort to manage the three lagoons. Activities such as the establishment of farms, improper fishing practices, discharge of domestic garbage, industrial and human waste into the lagoon are creating very serious problems for the lagoons.

CHAPTER ONE

INTRODUCTION

1.1 Background

Wetlands are highly diverse habitats and for that reason there was, for a long time, no agreed universal definition of a wetland. However, since the Ramsar Convention of 1971, wetlands have been defined as: areas of marsh or fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters (Ramsar Convention, 1971).

Wetlands are believed to be among the earth's most productive ecosystems (Barbier *et al*, 1997). They can be categorized based on their (i) components (i.e. their biotic and abiotic features which include plants and animals, and soil and water, respectively), (ii) functions (i.e., the interactions between the components such as nutrient cycling), and (iii) attributes such as the diversity of species. These characteristics of wetlands permit the existence of economic activities for humans. The activities may be categorized into two based on wetland resources and wetland services (Emerton *et al.*, 1999). 'Wetlands' is an elastic term including a great variety of landforms. Certain wetlands that appear in temperate or cold climates (e.g. tundras) have no tropical equivalent, and vice versa for tropical forms (e.g. mangroves).

Wetland resources include the water, land, soils, plants and animals, which may be exploited for subsistence, income and employment. While wetland services such as

maintenance of hydrological and biogeochemical cycles, act as traps for silt and other materials and erosion control which play a major role in maintaining the general ecological balance. The importance of rivers and wetlands as natural “purifiers” of inflows into Lake Victoria for example, cannot be understated (Scheren *et al.* 2000). Other than supplying local communities with resources for subsistence, wetlands support distant communities with ecological services such as flood impact reduction, flow regulation and drought alleviation, ground-water recharge, water quality protection and purification, drinking water supply and storage, erosion and sediment control, wastewater treatment, carbon retention, climate modification, among others. (Seyam *et al.*, 2001).

In Africa, the New Partnership for Africa’s Development (NEPAD) has identified six sectoral priorities, including the Environment Initiative. Wetland conservation was highlighted as one of the eight sub-themes for priority intervention (Anon, 2001).

Many people regard insects with horror as either pests or revolting creepy-crawly creatures to be avoided or worse still, squashed without mercy. Insects are invertebrates significantly vital to the functioning of every ecosystem. They colonize virtually all conceivable habitats from the equator to the poles and fill all trophic niches above the level of primary producers (Resh and Carde, 2003). They are the most abundant and diverse organisms present in most environments. Because of their short life cycles and sensitivity to perturbations, insects may be useful as indicators of environmental quality. In most terrestrial environments, insects are the dominant herbivores. They may greatly influence the plant community as well as reflect the quality of plant resources available to them (Barbour *et al.*, 1998; Groves, 2002). There are also lots of insects in wetlands

because wetlands are too shallow for a lot of fish to live in, and insects can lay their eggs in wetlands without fear of them being eaten.

Insects are in for the large part responsible for the breakdown of organic material such as plant, animal and human remains, the elimination of animal waste, the aeration of the soil and the vastly important task of plant pollination. They are an essential food source to many birds, fish, reptiles and amphibians, while in some parts of the world they also constitute a significant part of the human diet. The plight of endangered mammals is often given considerable exposure, but insects and related species, which are endangered, receive little attention despite their importance in the overall balance of nature (Constanza *et al.* 1997).

1.2 Justification

The basic human life-support systems of the biological environment have always been characterised by change, an inevitable consequence of all human land use throughout history (Mather, 1986; IGBP/HDP, 1993). Seemingly “natural” or pristine ecosystems have been altered significantly by humans at some point in the past (Turner *et al.*, 1990). In recent times, biodiversity has become easy targets for human over-exploitation due to burgeoning human populations and the quest for a “better life” through improvements in science and technology. Biodiversity, therefore, is being exploited at much faster rates than ever before with negative implications for sustainable human livelihood (Turner *et al.*, 1990). Wilson (1992) has stated that biodiversity is facing a decline of crisis proportions which could ultimately lead to mass extinctions in the very near future. In Ghana, increasing evidence indicates that the rate of environmental degradation has increased in recent times (Gyasi *et al.*, 1995).

Wetlands have been historically considered “wastelands” (Williams, 1993; Ryan & Ntiamoa-Baidu, 2000) and, therefore, subjected to degradation through dredging, flooding, filling and excavation for various agricultural and industrial uses. In recent times, however, the attraction and value of wetlands as important wildlife habitats, among other uses (such as provision of fin and shell fish, salt, thatch, wood, etc.) (Sather & Smith, 1984; Ryan & Ntiamoa-Baidu, 2000) have been increasingly recognised. Coastal wetlands are especially important as nutrient-rich habitats for fish spawning and nursery (Ntiamoa-Baidu & Gordon, 1991).

Since wetlands were, for a long time, regarded as wastelands whose productivity could only be improved by conversion into agriculture and other uses (Kamugisha, 1993; MNR, 1995), there was apparently no interest in conducting socio-economic research on such habitats. Wetland research has emerged following the realization of their values, services and functions. The socio-economic research that has been undertaken has been highly variable. Gordon and Cobblah (2000) for instance, assessed the diversity of insects at the Muni-Pomadze Ramsar site to provide baseline information on the ecological health and integrity of this wetland before sound management decisions can be made.

Studies on perceptions and attitudes generally showed that communities recognize the importance of wetlands as a natural resource (Musali, 1994). The presence of insects, their diversity and abundance in and around wetlands provide a lot of bases for determining water quality, the level of degradation and pollution. The theoretical foundations of insect population and community regulation in wetlands remain in the initial stages of development. One finds little mention of the important insect fauna in general reviews of wetland ecology or in standardized field procedures to evaluate the biotic integrity of

wetland habitats. Those efforts are the major focus of the research, and it will be contended that many commonly held beliefs about wetland insect ecology require significant reevaluation. The study will begin by reviewing the characteristics of insect communities found in diverse wetland types, notably the Muni-Pomadze, Kpeshie and Sakumo wetlands. It will then discuss the population and community ecology of wetland insects, including patterns of colonization and interactions with the physical environment, plants, predators, and competitors. The high diversity of insects and their reliance on freshwater systems for breeding, make them good indicators for the quality of such habitats. Insects contribute largely to the total invertebrate biomass of freshwater littoral communities (Corbet, 2004).

1.3 Objectives

The main objective of this study is to determine how human activities influence insect diversity and abundance in and around the wetland environment. The specific objectives were to determine the:

- insect diversity of the three wetland environments
- relative abundance of insects of the three wetlands
- human activities of the three wetlands and how they influence insect diversity and abundance
- Physico-chemical state of the water of the three wetlands

1.4 Hypothesis

(a) Null hypothesis: that human activity has had no impact on insect abundance and diversity around wetlands.

(b) Alternative hypothesis: that human activity has had significant impact on insect abundance and diversity around wetlands.

CHAPTER TWO

LITERATURE REVIEW

2.1 Definition of Wetlands

In general terms, wetlands are lands on which water covers the soil or is present either at or near the surface of the soil or within the root zone, all year or for varying periods of time during the year, including during the growing season (Mitsch and Gosselink, 1993; NAS, 1995). The recurrent or prolonged presence of water (hydrology) at or near the soil surface is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. Wetlands can be identified by the presence of those plants (hydrophytes) that are adapted to life in the soils that form under flooded or saturated conditions (hydric soils) characteristic of wetlands (Mitsch and Gosselink, 1993; NAS 1995). There are also wetlands that lack hydric soils and hydrophytic vegetation, but support other organisms indicative of recurrent saturation (NAS, 1995). Wetlands are also lands transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface, or the land is covered by shallow water (Turner, 1988). Wetlands can thus be permanent, temporary or seasonal, with static or flowing water, which may be fresh, brackish or salt. Wetland ecosystems can be marine, estuarine, riverine, and lacustrine or marsh, bog, or swamp (Maltby, 1986; Turner, 1988).

In developing countries three forms of wetlands are of particular economic importance; mangroves, seasonal wetlands in dry areas (e.g. along rivers) and deltaic environments. Wetlands have also been defined as areas of marsh or fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh,

brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters (Ramsar Convention, 1971)

2.2 Biodiversity

Streams and their associated wetlands are recognized as valuable, yet environmentally-sensitive, habitats in the landscape. Streams and wetlands form complex biotic communities dominated by species of invertebrates (Morse *et al.* 1993). Macro invertebrates, which are defined as those invertebrates greater than 0.5 mm and typically, include such groups as insects (mayflies, stoneflies, caddis flies, and true flies), crustaceans, segmented worms, and molluscs, play an integral role in the food web, often directly impacting the health of an aquatic ecosystem. Biodiversity includes genetic diversity, species richness and ecosystem diversity, and assumes that these are interdependent (Groombridge and Jenkins, 2002) and quantified through taxonomic inventories within specified areas (Fox and Rowntree, 2000). The number of different species within a geographical area depends on migration and adaptation to environmental conditions and how they in turn modify the environment (Barbour *et al.*, 1998; Groves, 2002).

A range of species may have no direct value to people, but may provide important ecological service to the wider community through an ecosystem that is more sustainable. Species diversity is the primary indicator of ecological health of an area. For example, the diversity and size of herbivorous insect populations often indicates the diversity and size of the plant population (Price, 1983), however, it is difficult if not impossible to locate and identify all species of all classes of organisms in a natural area of any size. Interactions among a large number of species, studies at the community level may be unmanageable.

Ecologists have often chosen to focus their attention on particular groups of organisms, generally those that are easiest to study such as plants or birds, as indicators of environmental quality.

2.3 Types of Wetlands

The main characteristics of a wetland are determined by the combination of the salinity of the water in the wetland, the soil type and the plants and animals living in the wetland. Due to the high variability of the conditions, and because of the different needs for distinguishing among different types of wetlands, so far, there is no single wetland classification system that would account for the manifold aspects of a specific ecosystem type. Tidal and non tidal marshes are the most common form of wetlands. They are either fresh- or saltwater, depending on the body of water they border. Marshes are known for rich soils, a variety of wildlife and soft vegetation. Swamps maintain a water level several feet deep and are characterized by woody plants and trees.

2.4 Ghana's Wetland Resources

Wetland ecosystems in Ghana constitute about 10% of the country's total land surface. Based on the criteria of the Ramsar Convention, three main types of wetlands are identified in Ghana. These are, marine/coastal, inland and man-made (NWCS Ministry of Lands and Forestry, 1999).

2.4.1 Marine/Coastal Wetland

The wetlands within the coastal zone of Ghana are mainly saltwater ecosystems. They are primarily associated with flood plains of estuaries of large rivers and watercourses. The major coastal wetlands or salt-water ecosystems are rocky marine shores (Senya Breku), estuarine waters (Mouth of Volta, Pra) mangroves/tidal forest (Lower reaches of Volta and Ankobra) and brackish/saline lagoons (Open Korle and Amisa), (Ministry of Lands and Forestry, 1999).

2.4.2 Inland Wetlands

Inland waters are mainly freshwater ecosystems. They occur wherever groundwater, surface springs, streams or run-off cause saturated soils, frequent flooding or create temporary and/or permanently shallow water bodies. Included are the following: permanent river/stream (Densu), permanent freshwater lakes (Bosumtwi) freshwater swamp forest (Amansuri) and freshwater marshes (Black, Red and White Volta), (NWCS Ministry of Lands and Forestry, 1999).

2.4.3 Man-Made Wetlands

The Ramsar Convention also recognises four categories of man-made or artificial wetlands. These are wetlands constructed for aquaculture, agriculture, salt exploitation, water storage and urban/industrial purposes. In Ghana, these are exemplified as follows: irrigated land (Tono and Veve), salt pans (Elmina Salt Pans), reservoirs (Kpong Head Pond and Brimsu Reservoir) and Urban /Industrial (Tema Sewerage Treatment Plant) (NWCS Ministry of Lands and Forestry, 1999).

2.5 “Wise Use” of Wetlands

“Wise use of wetlands is the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development.” (Ramsar Convention, 1987). The “wise use” concept implies that wetland conservation need not exclude the human element but rather make human use a promoting factor for the sustainable management of wetlands. The concept applies to all wetlands and water resources, not only to those sites designated as Wetlands of International Importance. The concept’s application is crucial to ensuring that wetlands can continue to

fully deliver their vital role in supporting maintenance of biological diversity and human well-being (Mediterranean Wetlands Initiative, 2013).

2.6 Ramsar Wetlands

Ramsar wetlands are wetlands of international importance listed under the Convention on Wetlands (Ramsar Convention). The Convention was signed in 1971 at a meeting in the town of Ramsar in Iran. The aim of the Convention is to halt the worldwide loss of wetlands and to conserve those that remain (Ramsar Convention 1971).

2.7 Wetland Services

The National Wetlands Conservation and Management Programme of Ghana identified wetland services/functions as flood impact reduction, flow regulation and drought alleviation, ground- water recharge, water quality protection and purification, drinking water supply and storage, erosion and sediment control, wastewater treatment, carbon retention, climate modification, wildlife and habitat function, biomass export, recreation, eco-tourism and transport (NWCMP, 2000). Other functions such as nutrient cycling are also important. Despite their obvious importance, wetlands have continued to be assaulted because of increasing economic and population growth. They have been converted into agricultural land, urban and industrial areas because their loss was perceived as a minor cost, compared to the expected benefits from development projects. Expansion of farmlands, natural resources discharge of industrial waste and agro-chemicals into water systems, for instance, threaten wetlands ecosystems. The consequences are immense, including loss of livelihood, loss of biodiversity and degradation of water systems (Seyam *et al.*, 2001).

2.8 Threats to Ghana's Wetlands.

In recent times, biodiversity has become easy targets for human over-exploitation due to burgeoning human populations and the quest for a “better life” through improvements in science and technology. Biodiversity, therefore, is being exploited at much faster rates than ever before with negative implications for sustainable human livelihood (Turner *et al.*, 1990). Wilson (1992) has stated that biodiversity is facing a decline of crisis proportions which could ultimately lead to environmental degradation (Gyasi *et al.*, 1995). Prof Yaa Ntiamoah-Baidu, Chairperson for the Centre for African Wetlands, disclosed this in an interview in Accra in June, 2010 (Ghana News Agency), that, apart from Sakumo Ramsar site, Keta, Songor, Densu and Muni Pomadze were out of the reach of government. She noted that for lack of full ownership of the wetlands it was very difficult to enforce the laws on people who encroach on such lands for settlement and industrial development, citing Densu Delta and Sakumono which were under siege from encroachers. According to her wetlands which she said could boost Ghana's tourism in an immense measure were rather used as dumping grounds for domestic and industrial wastes (Ghana News Agency, 2010).

Wetlands were critical for flood and storm control, recharging of groundwater and water purification. According to Prof. Ntiamoah-Baidu, the perennial floods in Accra, especially Dansoman, a suburb of Accra was as result of the encroachment on the wetland. Wetlands served as natural habitat for lagoon fisheries and fish nurseries for marine fish species. (Ghana News Agency, 2010). Nana Kofi Adu-Nsiah, Executive Director of the Forestry Commission (Wildlife Division), explained that, inadequate funding for wetland conservation, lack of adequately qualified staff and limited awareness, deficient appreciation of the Ghanaian public for wetland functions and values were some of the

challenges facing the division. Lack of co-ordination between relevant sector agencies and poverty in the communities living within and around the Ramsar sites was also a problem (Ghana News Agency, 2010).

2.9 Insects

2.9.1 Evolution of Insects

Insects are a very old group of animals on earth, probably developing about 450 million years ago. The first trilobites, primitive arthropods now extinct, appeared in the fossil record about 500 million years ago; and by 300 million years ago insects were already well-developed. By the time the dinosaurs appeared some 225 million years ago, most of the insect groups we know today were already present. Important exceptions are the butterflies, moths, bees and wasps, (all those dependent on flowering plants) which they only developed after flowering plants appeared 130 million years ago. The fact is that for the last 100 million years, long before mammals became the dominant species, insects have remained relatively unchanged (Van Wyk, 2013).

Insects have thus been hugely successful in colonising the earth, and are found in just about every single available habitat. They have also proved extremely adaptable, adapting to changing conditions much faster than other organisms; thus enabling them to flourish under conditions that have caused the extinction of many other animals or plants (Van Wyk, 2013). Insects are the most abundant and diverse organisms present in most environments. Due to their short life cycles and sensitivity to perturbations, insects may be useful as indicators of environmental quality. In most terrestrial environments, insects are the dominant herbivores (Van Wyk, 2013).

2.9.2 Wetland Insects

Insects developed on land and the vast majority live in the terrestrial environment, less than 2,000 of the more than 1 million insect species inhabit the aquatic environment. Most of these live in freshwater. Only a small handful of species are found in the marine environment – these live only in the intertidal zone. Insects occur in running water, lakes, stagnant waters, brine, hot springs, cold glacial streams, and even in tar pits. The shallow waters of ponds and lakes however offer the most favourable balance of water temperature, sunlight, dissolved oxygen, food and living space for insects. Most species are thus found in shallow waters with none inhabiting deep water in lakes or the deep sea. As air breathers, they have developed a variety of devices to survive under water. Larvae and nymphs extract oxygen from the water through their skin and/or filamentous gills. Larger larvae and nymphs, and all adults living under water, have to breathe surface air and to do this they use a variety of mechanisms which are prototypes of snorkels, aqualungs and diving bells (Van Wyk, 2013).

2.9.3 Subclasses of Insects

Insects are divided into two subclasses based on the absence or presence of wings and are termed Apterygota and Pterygota respectively. The pterygotes contain the vast majority of insects about (99.9%) (Gullan and Cranston, 2005). Apterygota are primitive wingless insects and commonly includes four groups of primitive insects: proturans, collembolans, diplurans, and thysanurans (Keith Arthur John, 2013).

The subclass Pterygota includes most of the world's insect species. Pterygota means “wings,” and describes insects that have wings, or once had wings in their evolutionary history. These insects also undergo metamorphosis. The subclass is further divided into

two groups – the Exopterygota and the Endopterygota. Insects in this group undergo a simple or incomplete metamorphosis. The life cycle includes just three stages – egg, nymph, and adult. During the nymph stage, gradual change occurs until the nymph resembles the adult. Only the final molt stage has functional wings (Van Wyk, 2013).

2.9.4 Suborder Exopterygota

A large number of familiar insects fall within the superorder Exopterygota. Orders in this subdivision include: Ephemeroptera (Mayflies), Odonata (Dragonflies and Damselflies), Orthoptera (Grasshoppers and Crickets), Phasmida (Walking sticks), Grylloblattodea (Rock crawlers), Dermaptera (Earwigs), Plecoptera (Stoneflies), Zoraptera, Isoptera (Termites), Dictyoptera (Cockroaches), Hemiptera (Bugs, Aphids, and Whiteflies), Thysanoptera (Thrips), Psocoptera (Booklice), Embioptera (Web spinners and Foot spinners), Phthiraptera (Chewing and Sucking lice), Mantodea (Praying mantis) and Mantophasmatodea (Heel walkers) (Richids and Davies, 1978).

2.9.5 Suborder Endopterygota

These insects undergo a complete metamorphosis with four stages – egg, larva, pupa, and adult. The pupal stage is inactive (a rest period). When the adult emerges from the pupal stage, it has functional wings (Hadley, 2013). Orders in this subdivision include: Coleoptera (Beetles), Neuroptera (Alderflies, Doseonflies and Fishflies), Hymenoptera (Ants, Bees, Wasps and Sawflies), Trichoptera (Caddisflies), Lepidoptera (Butterflies and Moths), Siphonaptera (Fleas) Mecoptera (Scorpionflies), Strepsiptera (Twisted winged parasites) and Diptera (Trueflies).

2.9.6 Importance of Insects in the Aquatic Environment

Aquatic insects are very important in the food chain. While only a few insect species have adapted to the aquatic environment, those that have done so are present in very large numbers – that means a huge biomass of animal matter available in the food chain in these systems. They are found in just about every conceivable aquatic habitat, often being the only link between the lowest and highest trophic levels in that ecosystem. Many species are nutrient or energy exporters from one ecosystem to another – the juvenile stages may live in a water body where they grow and accumulate energy, but this energy is transferred to the terrestrial adult where it is now available in a different ecosystem. Aquatic insects are also good indicators of water quality. Some groups like stoneflies and caddis-flies live only in clear unpolluted water, while some chironomids prefer polluted waters. The presence or absence of certain groups or species can thus be an indication of the health of an ecosystem. (Van Wyk, 2013).

2.9.7 Factors influencing Insect Abundance and Diversity

2.9.7.1 Density-Dependent Factors

Density-dependent factors are common regulators of insect abundance, as up to 80 % of the regulation can be density-dependent (Woiwod & Hanski, 1992; Brook & Bradshaw, 2006). One of the most obvious factors influencing herbivore abundance is their food resources, such as leaves, flowers, and fruits. The phenology of host trees can also drive changes in herbivore abundance, especially in the abundance of resource specialists (Basset, 1991a; 1991b; van Schaik *et al.*, 1993; Novotny & Basset, 1998). Herbivores prefer young leaves that have higher nitrogen content and weaker chemical defenses than old leaves (Coley, 1980; Mattson, 1980; Basset 1991b; Coley & Barone, 1996), and are therefore, more abundant during the leaf flush than at other times (Basset, 1991a; Aide

1993). Similarly, a high production of flowers can increase abundance of herbivores with flower-feeding larvae (Intachat *et al.*, 2001). The effects of host trees are more pronounced in seasonal tropical forests with a distinct dry season than in tropical forests where rainfall occurs throughout the year (Hopkins & Memmott, 2003), although host trees can also influence insect abundance in the latter (Basset, 1991b). Annual resources have also been associated with increased species diversity. High flowering in the previous month leads to an increase in the number of moth species caught during the following month (Intachat *et al.*, 2001). Similarly, the quantity of young leaves correlates with the number of leaf chewing insect species (Basset, 1996). This is due to two factors: firstly, increased amount of leaves means more resources in terms of food and oviposition sites and secondly, palatable young leaves with high water content offer a high quality food source for both specialist and generalist species. Another density-dependent factor is predation. Ants have been identified as one of the key predators in tropical forests (Novotny *et al.*, 1999; Floren & Linsenmair 2002, Loiselle & Farji-Brener, 2002), and other animals, such as birds, lizards and bats, exert predation pressure on herbivorous insects (Gradwohl & Greenberg 1982, Dial & Roughdarden, 1995; Van Bael & Brawn, 2005; Kalka *et al.*, 2008).

Insects are also vulnerable to predation by parasitoids (Memmott *et al.*, 1994, Walker *et al.* 2008). Predation is not uniform temporally or across habitats (Novotny *et al.*, 1999; Loiselle & Farji-Brener, 2002; Van Bael & Brawn, 2005) and the importance of predation as a regulator of insect abundance in tropical forests varies from non-existent to significant (Hopkins & Memmott, 2003; Richards & Coley, 2007). A study by Van Bael & Brawn (2005) revealed that predation by birds decreased arthropod densities in the drier forest sites but not in the wetter site with lower leaf production and less seasonality in insect abundance. Richards and Coley (2007) showed significantly higher predation rates in gaps

than in under storey that had lower food availability for herbivores. Predation pressure can also differ due to prey size (Dial and Roughdarden, 1995).

In any community competition can potentially affect insects and can either be intraspecific or interspecific, but interspecific competition does not exist without intraspecific competition (Hanski *et al.*, 1998). Competition can also be asymmetric influencing only one of the species that co-occur (Karban 1986). Although the importance of interspecific competition among herbivores has been questioned (Lawton & Hassell, 1981; Lawton & Strong, 1981), competition can also affect species indirectly through shared natural enemies, hence causing seasonality in insect abundance (Morris *et al.*, 2004).

2.9.8 Density-Independent Factors

Density-independent factors are usually weather factors of which temperature is one of the most important (Price, 1997). Most insects are poikilothermic (organisms having body temperature that varies with the temperature of its surroundings) and even small temperature changes can influence growth and reproductive activity of insects (Wolda & Glomset 1988). In the tropics, temperatures seldom drop below a developmental threshold level but changes in temperature can still cause seasonality (Denlinger, 1986; Wolda & Glomset 1988) Minimum air temperatures have been shown to influence seasonality in arthropod abundance (Basset, 1991a) and increased daily minimum temperatures have been associated with increased moth abundance (Intachat *et al.*, 2001). Temperature has also been associated with species diversity. For example low minimum temperature in the previous month increased moth diversity in the following month (Intachat *et al.*, 2001). Water (rainfall, humidity, moisture content) availability is another important regulatory factor in tropical forests (Didham & Springate, 2003). Insects are very sensitive to

desiccation because of their small bodies and high metabolic rates (Wiggelsworth, 1972). Desiccation is especially a problem in the upper canopy where daily fluctuations in temperature and moisture deficit are the most extreme (Parker, 1995). Rainfall has been linked to seasonality in insect abundance in many studies (Denlinger, 1980; Tanaka & Tanaka, 1982; Basset, 1991a; Nummelin, 1996; Intachat, *et al.*, 2001). In areas with pronounced dry seasons the influence of rainfall can be extreme limiting species existence to the wet season (Janzen, 1993). The effect of rainfall on seasonality of insect diversity is however less studied.

Low rainfall in a given month and high rainfall two months prior to this has been associated with high moth diversity (Intachat *et al.*, 2001). Similarly, butterflies had higher species diversity in Bornean rain forest during dry seasons (Hamer *et al.*, 2005), however, rainfall only influenced species diversity in primary forest and not in logged forest where it was found that species diversity did not experience seasonal variation. Rainfall can also have an indirect influence on herbivorous insects through their host plants. Herbivores are dependent on their host plants and thus, the phenology of their host plants has consequences for their reproduction (Van Asch & Visser, 2007). In seasonal forests it is advantageous for herbivores to synchronise with host plant leaf production as young leaves are often more palatable than mature leaves for insect herbivores (Novotny *et al.*, 2003).

Increased food intake relates positively to the fitness of herbivores and can cause changes in population density (Van Asch & Visser, 2007). Some weather factors operate indirectly or are used as cues for development (Didham & Springate, 2003). For example, many insects use photoperiod as a cue for initiation or termination of diapause to avoid

unfavourable conditions (Wolda & Glomset 1988), whereas solar radiation and wind can influence development and growth of insects by altering temperature and moisture regimes. Increased wind and solar radiation can lead to desiccation, and hence affect population densities. It is also important to bear in mind that often, multiple weather factors influence insect abundance and diversity simultaneously and their significance varies for different insect groups. (Didham & Springate 2003).

2.10 Pollution

2.10.1 Definition

The World Commission on Environment and Development (1987) defined water pollution as “the introduction by man of substances or energy, directly or indirectly into the environment which causes harm to living organisms and hazards to human health, hindrance to aquatic activities including fishing impairment of water quality for aesthetic value and for recreational use” (Hannawi and Hash, 1987).

2.10.2 Types of Pollution

There are different types of pollution. When gaseous, particulate, liquid and solid waste are introduced into the environment at such a rate that the environment is not able to regenerate itself or undergo self purification and recovery then the environment is said to be polluted. Pollutants can be of two different forms: man made and natural, Man made pollutants may originate from agricultural, domestic or industrial activities which may end up in the air, water bodies and land causing environmental problems. Man made pollutants are as varied as the human or the anthropogenic activities that produce them (Hynes, 1971; Hannawi and Hash, 1987). In the villages or rural areas, pollution is mainly from garbage and excreta as a result of lack of sanitary safeguards (Hynes, 1971),

whereas in the urban areas, pollution is as a result of industrial waste in addition to sewage from domestic sources. Natural pollutants may originate from natural phenomena such as sea spray and the transport of dust by wind. Some of the natural pollutants include minerals, decaying bodies of animals and other disease –causing organisms (Hynes, 1971).

2.10.2.1 Water Pollution

Water pollution is the introduction by man, directly or indirectly, of substances or energy, which result in such deleterious effects as, harm to living resources, hazards to human health, hindrance to aquatic activities including fishing, impairment of water quality with respect to its use in agricultural, industrial and often economic activities (GESAMP,1988)

There are different forms of water pollution namely:

- i. Pathogenic Organisms
- ii. Oxygen Demanding Pollutions
- iii. Nutrients and Eutrophication
- iv. Toxic Pollution
- v. Industrial Pollution
- vi. Sediments and Suspended Solids

Pollution of water bodies could lead to contamination of aquatic life and subsequent loss of aquatic fauna and flora (Alloway, 1990; Kirkwood and Longley, 1995). Trace and other metals are of importance to the body and these include silver (Ag.), arsenic (As), cadmium (Cd), chromium (cr.) cooper (Cu.), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb)and zinc (Zn). These are classified as macro, essential, non essential and toxic, depending on the physiological changes they bring about in the body. Some trace metals bioaccumulate through the food chain or web in both aquatic and terrestrial environments. These trace metals have toxic effects at the upper tropic levels of the food chains or webs on the

organisms (Kirkwood and Longley, 1995). Analysis of feathers collected from fish-eating birds off Peru revealed average concentrations of 2.0 ppm in Inca tern (*Larosterna inca*) and 1.0 ppm in red –legged cormorant (*Phalacrocorax bougainvillii*) (Gochfeld, 1980).

The effects of trace metal pollution at higher trophic levels include stunted growth, and malfunction of tissues and organs of adult fish, crustaceans and mollusks and also delayed embryonic development (Curry – Lindahl, 1972). Trace metals such as Fe, Mn, Zn and Cu are essential for metabolism at reasonably low concentrations but become toxic at higher concentrations in organisms including man (Kirkwood and Longley, 1995). Many trace metals also inhibit phytoplankton growth and photosynthesis even at very low concentrations. Some of the trace metals such as Pb, Ag and Hg in industrial wastewater effluents when ingested by humans and other animals can also react with proteins, DNA and RNA affecting metabolic processes and reacting with other substances causing undesirable physiological changes. Some of these metals are carcinogenic and can also cause enzyme inhibition by competing for the active site on the substrates, thus affect the rate of catalytic decomposition of metabolites (FAO, 1991).

Water contaminated with microorganisms is responsible for 40% of medical diseases. About 30 years ago in Ghana the Korle Lagoon was well stocked with tilapia and other useful aquatic organisms and some edible crabs crawled on its banks,(FAO, 1991) The destruction of important lagoons like the Korle and Chemu has been attributed to the discharge of untreated wastewater into the water bodies. Currently the water is without any tilapia, the edible crabs are gone and the lagoon has lost its economic value and aesthetic beauty because of pollution.(FAO, 1991) The Chemu Lagoon has been reported as being the most polluted coastal lagoon in Ghana now.

There are several different types of natural and synthetic organic chemicals used in the industry to make pesticides, plastics, pharmaceuticals, pigments, and other products that are used in everyday life. Many of these are toxic even at very low concentrations. Examples are DDT and other chlorinated hydrocarbons. Sediments and suspended solids carried into surface waters are other types of pollution in surface waters. Rivers always carry sediments to the oceans; erosion and runoff from croplands also contribute a lot to the volume of suspended solids found in surface water. Forest, grazing lands, urban construction sites, and other sources of erosion also contribute to sediments in surface water.

The ever-increasing population of the world has led to expansion in socialization and the development of very large communities which has also led to increased and diverse needs of people, hence the need to find ways and means to meet these needs and wants of humans apart from the natural provision, and this has led to the setting up of industries. The major areas of water use in industry in Ghana are food processing, material processing, cooling and mining (Sam and Ayibotele, 1987). The main pollutants in the country are derived from these industries. The breweries and beverage industry also produce a lot of liquid waste which is usually discharged into lakes and rivers. These liquid effluents which contain a lot of fruit and vegetable juice pulp, mineral acid, sugar, dirty washings and slops containing yeast and residue from alcoholic fermentation, and these are often discharged into surface water bodies (Sam and Ayibotele, 1987) which cause nutrient imbalance in the water (Akuffo, 1998).

2.11 Water Quality

Water is often ranked by its quality and there are many different measures of water quality. The quality of water often depends upon its use. Water quality, especially freshwater quality, is often classified by its uses: recreational, drinking, fishing, and recharge. It is important to understand how the water upstream and downstream is being used because the downstream use will often dictate the overall water quality and that will affect the discharge criteria for water. (Russell, 2006).

2.11.1 Physical Characteristics

The physical constituents of water include temperature, turbidity, colour, suspended solids, conductivity, settleable solids, total chemical solids, etc. These characteristics are used to assess the reuse potential of contaminated water and to determine the most suitable types of operations and processes for its treatment (Metcalf and Eddy, 2003).

2.11.2 Chemical Characteristics

The chemical constituents of polluted water include nutrients such as free ammonia, nitrates, nitrites, total phosphorus, etc. These parameters are used to measure the nutrients present and the degree of decomposition in the contaminated water. Alkalinity, pH, chloride, sulfates and metals (cadmium, copper, lead, arsenic, etc.) are all chemical constituents of polluted water. To assess the suitability of polluter water reuse and for toxicity effects in treatment and also to measure the acidity or basicity of the polluted water, these characteristics are considered; Chemical Oxygen Demand, Biochemical Oxygen Demand, Total Organic Carbon are also chemical parameters used to measure the amount of oxygen needed to stabilize polluted water biologically and chemically (Metcalf and Eddy, 2003).

2.11.3 Biological Characteristics

Biological constituents of polluted water include coliform organisms, specific microorganisms and toxicity. These characteristics are used to assess the presence of pathogenic bacteria, specific organisms present and to detect level of toxicity, whether acute toxic unit or chronic toxic unit.

2.11.4 Suspended Solids

All polluted water has some suspended solids, which are a collection of organic and inorganic materials of various sizes and density. The size and density ranges from 0.001mm to 3.5 mm, and from 0.8-2.65 gm/cm³ and higher (Metcalf and Eddy, 2003).

2.11.5 Turbidity

Turbidity is a measure of light transmitting properties of water, and is another test used to indicate water of polluted water discharges and natural waters with respect to colloidal and residual suspended matter. The measurement of turbidity is based on comparison of intensity of light scattered by a reference suspension under the same conditions (Standard Methods, 2005). Turbidity measurements are reported as nephelometric turbidity units (NTU). Colloidal matter would scatter or absorb light and thus prevent its transmission (Metcalf and Eddy, 2003). Suspended solids that cause turbidity are natural materials resulting from the erosive activity of water as it flows over surfaces. Domestic and industrial effluents contribute large amounts of suspended solids. Soaps, detergents and emulsifying agents also produce stable colloids that result in turbidity (Annang, 2000).

2.11.6 Colour

The colour of water is the result of the different wavelengths that are not absorbed by the water itself, or the result of particulate and dissolved substances present (Chapman and Kimstach, 1992). Colour is measured by the Lovibond Nesslerizer disc.

2.11.7 Temperature

The temperature of water is a most important parameter because of its effect on chemical reactions and reaction rates, aquatic life and the suitability of the water for beneficial uses. Temperature varies with climatic fluctuations and responds to factors such as season, time of day, air circulation, cloud cover and depth and flow of water in the natural system (Annang, 2000). Increased temperature, for example, could cause a change in the species of fish that could exist in the receiving water body. In addition, oxygen is less soluble in warm water than in cold water and this could result in serious depletion of dissolved oxygen in the dry season or summer months. It should be realized that a sudden change in temperature could result in high rates of mortality of aquatic life and the abnormal growth of undesirable water plants. Temperature is measured using a thermometer or read from a portable pH – meter.

2.11.8 pH

pH, also a potential of hydrogen is defined as the negative logarithm of hydrogen-ion concentration (Pankratz, 2000). The hydrogen-ion concentration is an important quality parameter of both natural and polluted water. The usual means of expressing the hydrogen-ion concentration is pH. On a 0 to 14 pH scale, a value of 7 at 25°C represents a neutral condition. Decreasing values indicate increasing hydrogen ion concentration (acidity) and increasing values indicate decreasing hydrogen ion concentration (alkalinity). Metacalf and Eddy (2003) observed that the concentration range suitable for

the existence of most biological life is quite narrow and critical, from 6 to 9 pH. This is measured using a portable pH meter in the field. Most organisms have adapted to life in water of a specific pH and may die if it changes even slightly

2.11.9 Conductivity and Salinity

Conductivity is the ability of water to conduct electrical current. Since the electrical current is transported by ions in solution, the conductivity increases as the concentration of ions increases. Conductivity could be used as a measure of total dissolved solids. Conductivity is also a good measure of salinity in water. The measurement detects chloride ions from the salt. Salinity affects the potential dissolved oxygen levels in the water. The greater the salinity level, the lower the saturation point. Salinity is the total amount in grams of inorganic materials dissolved in 1kg water when all the carbonate has been converted to oxide, all the bromide and iodine have been replaced by chlorine and all organic matter has been completely oxidized (Annang, 2000).

2.11.10 Dissolved Oxygen (DO)

Oxygen is very essential to all aquatic life. The oxygen concentration of natural water bodies varies with temperature, atmospheric pressure, salinity turbulence and photosynthetic activity of algae and plants. The solubility of oxygen decreases as temperature and salinity increases and as pressure decreases (Annang, 2000). Waste discharges high organic matter and nutrients, and this could cause a decrease in DO due to respiration during breakdown of organic matter. Determination of DO is very important in water quality assessment as it influences most chemical and biological processes in the aquatic environment. Concentrations below 5mg/L may affect the functioning and survival of biological communities and below 2mg/L may lead to death of most fishes (Chapman and Kimstach, 1992).

2.11.11 Biochemical Oxygen Demand (BOD)

This is a measure of the quantity of dissolved oxygen used by microorganisms in the oxidation of organic matter. Micro-organisms utilize dissolved oxygen in water to oxidize polluting biodegradable organic matter, thereby giving an indication of the pollution load present. By measuring the initial concentration of a sample and the concentration after five days of incubation at 20⁰C, the BOD can be determined (Standard Methods, 1998).

2.11.12 Trace metals

Heavy metals are important because they are often toxic and they impede or interfere with the biological treatment process of water when in excessive quantities. Depending upon the metal and the species, all the reactions are pH dependent (Russell, 2006).

2.11.13 Cadmium

In Ghana, cadmium is introduced into the aquatic environment through waste streams from mining activities, refuse and sewage sludge disposal in urban areas and manufacturing industries such as steel and iron. Cadmium is a contaminant in many chemical fertilizers (Moore *et al.*, 1995). Phosphate fertilizers contain 5-100 mg Cd kg⁻¹ (O'Neil, 1994). Storm water run offs carry these fertilizers in receiving water bodies. Maximum cadmium concentration recommended for irrigation is 0.01mg/L. Concentrations as low as 0.1mg/L and potential for accumulation in plants and soils to concentrations that may be harmful to humans (Metcalf and Eddy, 2003).

2.11.14 Copper

Copper is an essential micronutrient, but at high doses it has been shown to cause stomach and intestinal distress, liver and kidney damage, and anemia. Copper is a reddish-brown metal, often used in plumbing of residential and commercial structures that are connected

to water distribution systems. Copper contaminating water occurs as a result of the corrosion of copper pipes that remain in contact with water for a prolonged period (Shelton *et al.*, 2005). Copper is toxic to a number of plants at 0.1 to 1.0mg/l in nutrient solutions. Recommended maximum concentration for irrigation is 0.2mg/l (Metcalf and Eddy, 2003).

2.11.15 Lead

Lead is one of the commonest metals that are used in industry for a wide variety of purposes, including pipes, paint pigment, alkyl compounds for gasoline, lead acid accumulators, brass and bronze fixtures and cable sheathing. Lead is a heavy metal that can cause a variety of adverse health effects in humans. At relatively low levels of exposure, these effects may include interference in red blood cell chemistry, delays in normal physical and mental development in babies and young children, deficits in attention span, hearing, and learning abilities of children, and increases in blood pressure of some adults (Shelton *et al.*, 2005). Plants growing near highways often absorb this lead as do some grasses that grow near abandoned lead mines (Moore *et al.*, 1995). Concentration of water above 5mg/l lead can inhibit plant growth. Materials that contain lead have frequently been used in the construction of water supply distribution systems and plumbing systems in private homes and other buildings. Lead in these materials can contaminate water and natural water as a result of the corrosion that takes place when water comes into contact with those materials.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Areas

3.1.1 Winneba

Winneba, traditionally known as Simpa and also informally known as the “Land of the Ghartheys” because its royals and many of its inhabitants bear this name, is an historic fishing town in Ghana. It is located on the south coast, (56 km west of Accra and 140 km east of Cape Coast). Its inhabitants are known as “Simpafos” or “Effutufo”. It is the capital of the Effutu Municipal in Central Region of Ghana. The main industries in Winneba are fishing and pottery (Collar *et al.*, 1994). The Muni- Pomadze wetland in Winneba in the Central Region of Ghana, (Fig.1) is one of five internationally-recognized coastal wetlands (Ramsar sites) worldwide under the Convention on Wetlands of International Importance (Ramsar Convention), because of its importance as a breeding and nesting site for migratory and resident waterbirds, insects, and terrestrial vertebrates (Collar *et al.*, 1994; Ryan & Attuquayefio, 2000).

The wetland is particularly important to the local Effutu people, serving as their traditional hunting grounds, especially during their annual “Aboakyer” Festival. The wetland falls within the Coastal Savanna Vegetation Zone of Ghana, with a bimodal rainfall distribution and a low mean annual rainfall of about 854mm. According to Gordon & Cobbla (2000) the major rainy season occurs from March /April to July/August with a peak in June, while the minor season runs from September to November. The major dry season runs from December to March, and the minor dry season from August to September. Mean annual temperature ranges from 24°C in August to 29°C in March with a relative humidity range

of 75-80% (Gordon & Cobblah, 2000). The site chosen for the survey lies within the boundaries of the proposed Muni-Pomadze Ramsar site. The principal site was located near Mankoadze, a fishing village west of Winneba.

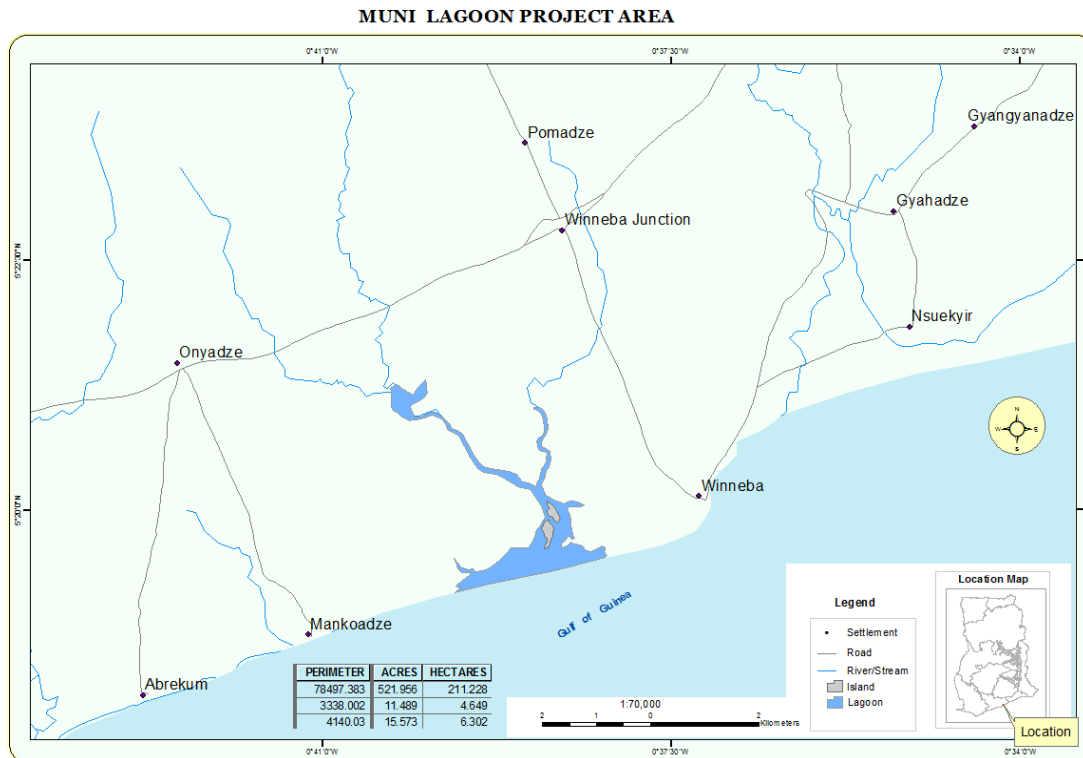


Figure 1: Map of the Study Area

In recent times, the previously diverse fauna including mongooses, of the area has dwindled, with some of the animals presumed locally extinct or existing in very low numbers (Ryan & Attuquayefio, 2000). Current evidence indicates that the degradation of the wetland could be largely attributable to neglect and unsustainable human activities like bushfire setting, hunting, farming, fuelwood harvesting and estate development, over the years (Ntiamo-Baidu & Gordon, 1991; Ryan & Ntiamo-Baidu, 1998) This is against the background of the wetland being particularly vulnerable to degradation because of its more extensive (98%) dry land coverage (Amatekpor, 1994) than the other coastal wetlands in Ghana.

3.1.2 Sakumo Lagoon

Sakumo was originally a small fishing village on a lagoon, but by 2008 had been literally swallowed up by the twin cities of Accra and Tema. The Sakumo Lagoon is located on the eastern part of Accra along the Accra-Tema coastal road 3 km west of Tema. It is situated within latitudes ($5^{\circ} 36.5'$ N and $5^{\circ} 38.5'$ N and between the longitudes $1^{\circ} 30'$ W and $2^{\circ} 30'$ W). It has a surface area of 2.7 km^2 (Tumbulto and Bannerman, 1995), and its catchment area covers a total area of 350 km^2 although the effective catchment area is 127 km^2 because of damming of the streams leading towards the lagoon (Tumbulto and Bannerman, 1995). The area stretches from Madina to Oyarifa on the west and to the Aburi highlands in the north. On the east, it is bounded by an approximate north–south line which also marks the western boundary of Tema (Biney, 1995b). Before it was designated as a Ramsar Site, it was under the jurisdiction of the Tema Development Cooperation. The whole catchment area is situated in the Tema Metropolis of the Greater Accra Region (National Wetlands Strategy for Ghana, 1998, as cited in van Stiphout, 2002).

There are two rainy seasons, a major season which starts in March and peaks in mid-July and a minor season which begins in mid-August and ends in October. The mean annual rainfall is about 753 mm, and Relative Humidity varies from an average of 65% in mid afternoon to 95% at night. Mean monthly temperatures range from a minimum of 24.7°C in August to a maximum of 28.1°C in March. The lagoon and its surrounding wetlands have been designated as one of the five coastal Ramsar sites in Ghana (Kwei, 1974).

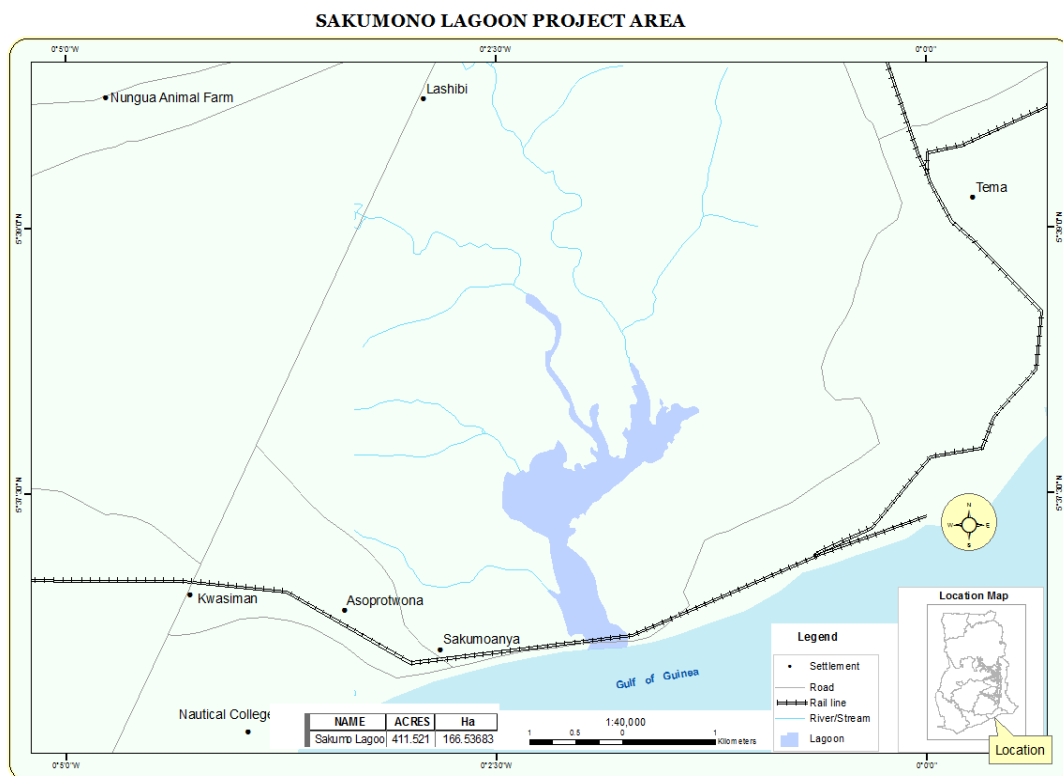


Figure 2: Map of the Study Area

Sakumo Lagoon is still a great birding destination despite its position in the heart of a sprawling metropolis. Lying about 20 km east of Accra and covering up to 350 ha, Sakumo Lagoon is perfectly situated for birding from the city in either the morning or afternoon. The main attraction at Sakumo is the open shallow estuary and flooded reedbeds which between September and April can support thousands of waders and an impressive list of estuarine birds. The surrounding savanna also hosts a number of dry country species and birds of prey. A few hours birding in the morning or afternoon at

Sakumo between October and April should produce upwards of 80 species (Ryan 2005, Ntiamoa- Baidu, & Gordon 1991). It was designated as a Ramsar site on the 14th of August 1992 and it is managed by the Wildlife Division of the Forestry Commission on behalf of the state.

3.1.3 Kpeshie Lagoon

The La Dadekotopon Municipality has a population of 81,684 with about 5,543 homes according to Ghana Statistical Service data with an annual population growth of 3.1% (Kpanja, 2006). The Kpeshie lagoon catchment area lies between latitude 5° 33'0" N and 5° 36'20" N, and stretches between longitude 0° 9'30" W and 0° 7'10" W. (fig. 3). The catchment area occupies approximately 47.391551 ha. The water bodies in this Municipality are the Africa Lake and the Kpeshie Lagoon. The Kpeshie lagoon is less than 1km² in surface area and it is located at the outskirts of La, a peri-urban township. The Municipal Assembly shares boundaries with the following Sub Metros: Osu Clottery towards the east, Ayawaso towards the north and Teshie to the west (Kpanja, 2006).

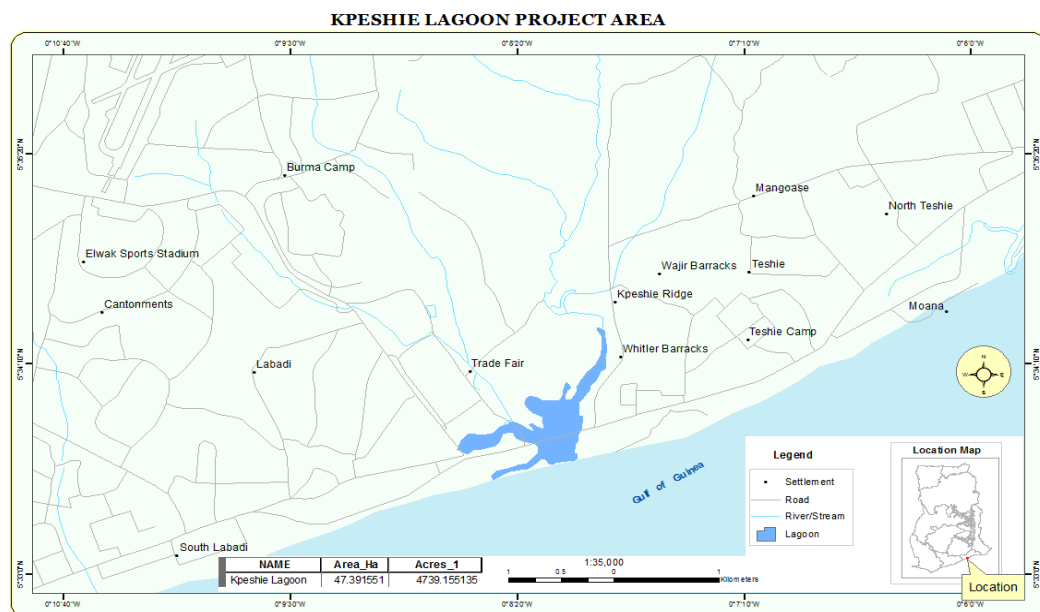


Figure 3: Map showing the study area

3.2 Methods

3.2.1 Sampling Points

Sampling points were selected to capture the major activities carried out along the stretch of the lagoons which would affect the water quality and insect diversity

3.2.2 Sampling Design and Technique

The following trapping techniques were used to collect insects malaise trap, yellow pan traps, light trap, fruit-baited charaxes traps, pitfall traps, flight interception traps, sweep net and aerial net. A systematic, perpendicular walk was undertaken from pre- determined sites to all the selected locations along the lagoons. In order to ensure that the traps were adequately spaced, a meter tape was used to measure the distance between them. Where necessary a hoe and machet were used to cut through grass or mangrove to gain access. Sampling was undertaken monthly during the rainy season (April, to June) and the dry season (December, to February) and temperature was recorded during these seasons.

3.2.3 Malaise Trap

This trap has been designed to collect flying insects. This rectangular trap looked like a tent made of black nylon netting and erected by being supported with at least five poles at various ends (Plate1). The flying insects enter the net through the opened sides and due to the shape of the net they are directed into the collecting bottle containing 70% alcohol placed by the sloping net. Insects were collected after 3-5 days for subsequent identification.



Plate 1: Malaise trap with a collecting apparatus set at the fringe of a lagoon.

3.2.4 Pitfall Trap

This is used for trapping ground inhabiting insects and is a straight sided container that is sunk level with the surface of the surrounding substratum (Plate 2). The container could be baited or without bait. It is a passive form of sampling which relies on the insects rather than the observer initiating the action that leads to capture (Southwood, 1978). Ten traps were set at 20m intervals along the 200m transect in each area. Each trap contained a soapy solution in order to break the surface tension so that trapped insects would not be able to fly out. Trapped insects were collected after 3-5 days and emptied into a container containing 70% alcohol for subsequent identification.



Plate 2: A pitfall trap

3.2.5 Yellow Pan Trap

Yellow pan traps collect insects that are attracted to the yellow colour. It is made up of a shallow, yellow coloured tray filled with soapy water (Plate 3). The trays are particularly attractive to these insects and the detergent is mainly to break the surface tension thus preventing the insects from escaping. The bowls usually have steep edges to prevent the insects from escaping. Ten traps were set at 20m intervals along the 200m transect in each area. Trapped insects were collected after 3-5 days and emptied into plastic containing 70% alcohol for subsequent identification.



Plate 3: A Yellow Pan Trap

3.2.6 Flight Interception Trap

This trap is mainly used to collect flying insects which are not likely to be attracted to baits or light and is made up of brightly coloured netting. Part of the trap is suspended at 90° to the ground using supporting poles and ropes (Plate 4). This is done in a way that the net never touches the ground, ensuring that space is left beneath it for the trays that contain a killing agent made of water and detergent to reduce surface tension. One trap was set in each area. Trapped insects were collected after 3-5 days and emptied into bags containing 70% alcohol for subsequent identification.



Plate 4: A flight interception trap

3.2.7 Charaxes Trap

The charaxes trap is made up of a net with a rectangular cross-section and a string attached to the four corners at the closed top and a flat wooden board attached at the open end (Plate 5). The strings are attached to nearby tree branches. Bait made up of mashed rotten banana mixed with palm wine was placed on the board. Alcohol-loving insects are mostly trapped by this method. Individual traps within areas were separated from each other by at least 50m and by no more than 250m (Oduro and Aduse-Poku, 2005). Standard field handling of specimens captured from charaxes traps consisted of firmly squeezing the thorax to disable the specimen (Oduro and Aduse-Poku, 2005).



Plate 5: A charaxes trap

3.2.8 Sweep Net

The sweep net was used to collect insects around vegetation. It consists of a circular metallic rim with a cloth attached to form a sac with the rim as the opening with a wooden handle attached to the rim (Plate 6). It was swung through the vegetation with alternating forehand and backhand strokes for about 20 times and the content carefully emptied into a killing jar. The catches were later poured into a bag containing 70% alcohol for subsequent identification.



Plate 6: A Sweep net

3.2.9 Aerial Net

The aerial net consisted of a metallic rim with a wooden handle and a fine mesh forming a sack (Plate 7). Swarming butterflies, dragonflies and moths were spotted and collected. The butterflies caught were killed by squeezing their thorax, and placed in glassine envelopes with wings folded together. This technique prevented the insects from losing their scales, a feature very vital for identification. The other insects were transferred into killing jars containing ethyl acetate and kept in glassine envelopes for later identification.



Plate 7: Aerial Net

3.2.10 Visual Observation and Direct Counts

Visual counts were done whenever an insect was spotted that was out of reach to be collected or trapped. At each site, random walk sampling was used for a minimum of two hours to sample each site twice each day. This was done under sunny conditions mostly between the hours of 8:00 hours GMT and 16:00 hours GMT. The butterflies were identified by their wing patterns and colours as well as flight patterns.

3.3 Sampling and Analysis of Water

Sampling was done between April to June 2012 (wet season) and December 2012 to February 2013 (Dry season). In each season, two consecutive samples were made from each of the three sites on weekly basis. At all the stations, water samples were collected by dipping sampling bottles directly into the water body against the direction of flow .

3.3.1 On Site Measurements

A bucket of water was fetched at each site for on site analysis. Temperature, pH, and salinity were measured with a Horiba Digital Water Quality Checker (Model V.10) in $^{\circ}\text{C}$, pH units, and $^{\circ}/_{00}$ respectively. Total dissolved solids (TDS) were measured with a TDS meter in mg/l.

3.3.2 Water

A two-liter polyethylene gallon was filled with water at each site. This was subsequently used in the laboratory for off site analysis. Water samples that were not analyzed immediately were stored in a refrigerator below 4°C .

3.3.3 Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO)

Two types of bottles, one plain and the other dark (painted with bitumen to prevent possibility of photosynthetic production of oxygen) were used for sampling. The plain bottles were used for dissolved oxygen sampling and the dark bottles were used for BOD sampling. The bottles were filled with water to overflowing in order to avoid any air bubbles from getting trapped in the bottles. The dissolved oxygen samples were fixed on site with 2 ml each of Winkler 1 (Manganous chloride) and Winkler 2 (alkaline-iodide-azide reagent). Samples, which were not analyzed within two hours of collection, were kept at or below 4°C but brought to 20°C before analysis in the laboratory.

3.3.4 Heavy Metals

Water samples for trace metal analysis (calcium, magnisium, zinc, cadnum, Lead, Iron and copper) were collected in plastic containers and fixed on the field with nitric acid.

3.3.5 Bacteriological Sampling

One water sample for bacteriological analysis was taken at each site, using glass bottles with metal caps. These bottles were sterilized before use and the mouths covered with aluminum foil to avoid contamination during sample collection. Upon collection, the samples were stored on ice to avoid multiplication of bacteria.

3.4 Laboratory Analyses of Water

Laboratory analyses were carried out in two laboratories. Biochemical oxygen demand (BOD), dissolved oxygen (DO) analyses were carried out at the Water Research Institute, CSIR and Bacteriological analysis was undertaken at the Microbiology Laboratory of the Water Research Institute, CSIR. Suspended solids, turbidity and colour determination were carried out at the Ecological Laboratory, University of Ghana. Conductivity, Magnesium, Calcium, Lead, Zinc, Copper and Iron analyses were carried out at the Ecological Laboratory, Department of Geography and Resource Development, University of Ghana.

3.4.1 Physico-Chemical Methods for Water Analyses

Turbidity, true colour and suspended solids were determined using the HACH DREL 2000 spectrophotometer. Conductivity was measured with the Metrohm Herisau E587 Conductometer. Analyses of metals were undertaken by Atomic Absorption Spectrometry using the Perkin Elmer 3110 model. BOD and DO were determined by titrimetric methods.

3.4.2 True Colour

The Platinum-Cobalt Standard method was used. 50 ml of demineralised water was

filtered and 25 ml poured into a sample cell. The stored programme number, 120, was entered on the spectrophotometer and the 455 nm wavelength used. 50 ml of the sample was filtered and 25 ml poured into a sample cell. The blank was placed into the cell holder and standardised. The prepared sample was placed into the cell holder and the result was displayed in platinum-cobalt units.

3.4.3 Turbidity

The Portable Turbidimeter (Model 2100P) was used for turbidity measurements. A sample cell was filled with about 15 ml of sample and the cell was capped. The and wiped with a soft, line-free cloth to remove water spots and fingerprints. A thin film of silicone oil was applied and wiped with the soft cloth to obtain an even film over the entire surface. This was placed in the cell holder and the reading taken in a Nephelometric turbidity unit.

3.4.4 Dissolved oxygen

The Azide modification of the Winkler method was used for this test. 2.0 ml concentrated H_2SO_4 was added to the samples which had already been fixed on the field with 2 ml each of Winkler 1 (Manganous chloride) and Winkler 2 (alkaline-iodide-azide) reagent. 100ml of the sample was titrated with 0.025 M $Na_2S_2O_3$ to a pale straw colour and 2 ml of starch solution was added and titration was continued to first disappearance of the blue colour.

Calculation: (APHA, 1995).

For titration of a 100ml sample, $mg/l O_2 = \frac{Vol. of M/80 thiosulphate used}{Vol. of sample used} \times 101.6$

Vol. of sample used(1)

3.4.5 BOD

The 5-day BOD test was used. This method consists of filling with sample an airtight bottle of the specified size and incubating it at the specified temperature for five days. Dissolved oxygen was measured initially and after incubation, and the BOD was computed from the difference between the initial and final DO. For this study all samples taken from the field for BOD analysis were diluted, because BOD concentration in most waters exceeds the concentration of DO available in an air-saturated sample. Because the initial DO is determined immediately after the dilution is made, all oxygen uptake, including that occurring during the first 15 minutes, is included in the BOD measurement. The dilution water was prepared by 1 ml each of phosphate buffer, MgSO₄, CaCl₂, and FeCl₃ solutions /l of water.

$$\text{Calculation: BOD}_5 \text{ mg/l} = \frac{D_1 - D_2}{P} \dots\dots\dots(2)$$

Where;

D₁= DO of diluted sample immediately after preparation, mg/l

D₂= DO of diluted sample after 5 day incubation at 20 °C, mg/l

P=Decimal Volumetric fraction of sample used (APHA, 1995).

3.4.6 Analysis of Trace Metals

The measurement of the trace metals Fe, Zn, Pd, Mn, Cd, Ca, and Mg containers was done by aspirating the acidified, filtered samples directly into the atomic spectrophotometer, using the individual hollow cathode lamps for each trace metal. The concentration of the metal is equal to the concentration as measured by the equipment multiplied by the dilution factor where applicable. Before the measurements were done, the atomic analytical spectrophotometer was calibrated using a standard solution of known

concentrations of the various trace metals. The instrumental parameters of the various elements were dependent on the manufacturer specification. The appropriate matrix modifiers and ionization buffers were added to both the samples and standards where applicable to suppress interference from other elements, ionization and at times to increase the sensitivity. The flame used was air-acetylene gas.

3.4.7 Suspended Solids

The photometric (Non filterable residue) method was used. 500 ml of the sample was blended at high speed for two minutes and poured into a 600ml beaker. The sample was stirred and 25 ml immediately poured into a sample cell. The stored programme number for suspended solids (630) was entered and the wavelength was set to 810 nm. A sample cell was filled with 25 ml demineralised water (blank) and placed into the cell holder and standardised. The sample was then placed into the cell holder and the reading taken in mg/l suspended solids.

3.4.8 Lead, Iron and Copper

The total Phosphorus extract before colour development in the above was used for the determination of Lead, Iron and Copper, using the Atomic Absorption Spectrometer (AAS). The formula used in calculating the concentrations in $\mu\text{g/g}$ is as follows:

$$\text{Concentration in } \mu\text{g/g} = \frac{\text{Reading on AAS} \times \text{Vol. of extract (ml)}}{1000 \text{ ml}} \dots\dots\dots(3)$$

Vol. of extract in this case is 100 ml

3.5 Bacteriological Analyses: Faecal and Total Coliform

Total and faecal coliform were determined using the membrane filtration (MF) technique.

The technique uses a filter with uniformly-sized pores small enough to prevent bacteria from entering the filter. A measured volume of sample was drawn through the filter by applying a partial vacuum. The pad retains the bacteria on its surface while allowing the water to pass through. The membrane filtration technique uses an enriched lactose medium and incubation temperature of $44.5 \pm 0.20^\circ\text{C}$ for selectivity, and gives 93 % accuracy in differentiating between coliforms found in the faeces of warm-blooded animals and those from other environmental sources (Spellman and Drinan, 2000). 50 g of McConkey agar was dissolved in 1L of water. This was then heated to boil and then sterilized by autoclaving. Upon cooling, this was poured into petri dishes in a sterile chamber and allowed to solidify (APHA, 1995). A filter was selected and aseptically separated from the sterile package. This was placed on the support plate with the grid side up. The funnel assembly was placed on the support and secured in place. 100 ml of sample or serial dilution was poured on to the filter and vacuum was applied. The liquid was allowed to pass through the filter and the funnel and filter were rinsed with three portions (20-30 ml) of sterile, buffered dilution water. The filter funnel was removed and the filter was aseptically transferred using sterile forceps, grid side up, onto the prepared media (Spellman and Drinan, 2000). This setup was then incubated. Samples for faecal coliform analyses were incubated for $24 \pm 2\text{h}$ at $44.5 \pm 0.2^\circ\text{C}$ and $35 \pm 0.5^\circ\text{C}$ for total coliform samples (APHA, 1995). Upon completion of the incubation period, the surface of the filter paper had growths of both faecal coliform and non-faecal bacterial colonies. The faecal coliform density was calculated using the following formula:

$$\text{Colonies /100 ml} = \frac{\text{colonies counted}}{\text{Sample volume, ml}} \times 100 \text{ ml} \dots\dots\dots(4)$$

(Spellman and Drinan, 2000).

For this study volume of sample used in the determination of total coliform ranged from 0.02-10 ml and 0.05-20 ml for faecal coliform.



(a) Kpeshie lagoon



(b) Sakumo Lagoon



(c) Muni-Pomadze lagoon

Plate 8: Heavily polluted sites in (a) Kpeshie, (b) Sakumono and (c) Muni-Pomadze lagoons

3.6 Social Survey

3.6.1 Sampling Technique

Purposive sampling, which is a non-probability sampling technique, was used. The researcher, adhering to the objectives of the study, selects respondents who can answer her research questions. Using calculations and a relevant research strategy, the researcher can pick the respondents he/she wants to be included in his/her sample. He/she selects cases that are judged to typify the views of the group. The purposive sample is used in impressionistic studies, in pilot and pretesting procedures and when one wishes to gain a quick insight into a social phenomenon (Twumasi, 2001).

3.6.2 Questionnaire Administration

Questionnaires were administered in the major towns where water samples were taken. In all, 280 questionnaires were administered at Winneba, Sakumono and Kpeshie. An effort was made to interview as many women as men in each locality.

3.6.3 Interview

Interviews were conducted by interacting with some of the locals in sensitive areas such as the lagoon sites and small scale industries.

3.6.4 Non Participatory Observations

Non-participatory observations were also undertaken to enable the interviewer generate primary information to complement the information obtained from respondents.

3.6.5 Sorting and Species Identification

Insects trapped with the yellow pan traps, flight interception trap and pitfall traps were sieved and rinsed with water. They were placed in containers containing 70% alcohol and labeled for later identification. Insects collected from the malaise trap were also emptied into labeled containers for later classification. Butterflies caught with the butterfly net and charaxes traps were killed with ethyl acetate in a killing jar. Insects caught with the sweeping net were protected by tightly covering the opening of the net with the hand. Insects were then carefully placed in a bucket containing cotton wool and ethyl acetate to kill them. The insects were then put into jars for later identification. Using a stereomicroscope, preserved insects collected in the field were first separated into their various orders based on morphological characters. All insects were identified to the species level Scholtz and Holm (2005), Carter *et al.*, (1992), Gullan and Craston (2005), Mantheson (1951), Richards and Davies (1978) and Boorman (1981). Difficult to identify specimens were identified in consultation with Mr. Henry Ekow Davis and Mr. Rogger Sigismund (both of the African Regional Post Graduate Programme in Insect Science, ARPPIS). Voucher specimens of species collected during the study have been deposited at the laboratory at the African Regional Post Graduate Programme in Insect Science (ARPPIS), University of Ghana, Legon.

3.7 Statistical Analyses

Many environmental factors can contribute to differences in aquatic insect diversity in the study areas, (Collinson *et al.*, 1995; Gee *et al.*, 1997; DeSzalay and Resh, 2000; Alcocer *et al.*, 2001; Oertli *et al.*, 2002). Several statistical analyses were conducted using SPSS (Vol.16.0) to determine if some of these environmental factors affected insect diversity within the wetlands. Trap data obtained at a given site on a specific date were pooled to

generate a single sample for each site-data combination. Data from all the traps were pooled to obtain total insect diversity per study site and per sampling period. A number of different measures of species diversity were used. Simpson's Index (D) Shannon-Weiner Index (H), Margalef index and the Pielou's Evenness index ('J') (See Appendix 1)

A one-way between groups ANOVA was performed to test whether there was a difference in insect diversity among the three sites (Muni-Pomadze, Sakomo lagoon and Kpeshie lagoon). Simpson/Shannon diversity indices and Margalef richness index were calculated. Singletons and Doubletons are the number of species represented by one or two individuals, respectively. Uniques and duplicates are the number of species occurring in only one or two samples, respectively. Nonparametric richness estimators were used to estimate total species richness at a site: ACE (Abundance-based coverage estimator), ICE (Incidence-based coverage estimator), Chao1 (Abundance-based coverage estimator), Chao2 (Incidence-based coverage estimator), Jack1 (First-order jackknife estimator) and jack2 (Second-order jackknife estimator).

CHAPTER FOUR

RESULTS

4.1 Relative Abundance of Insects

A total of 5,541 individual insects were recorded from all the three sites combined. Muni- Pomadze recorded 1,883, Sakomo wetlands recorded 1,530 and Kpeshie recorded 2,128. Four hundred and twenty nine species of insects, belonging to 22 orders and 112 families were collected from all three sites. Insects belonging to the orders Hymenoptera, Diptera, Hemiptera and Coleoptera were the most abundant and diverse in all three areas (Fig. 4. Table 4). Their relative abundances were 27%, 20%, 15% and 12% respectively, with an aggregate relative abundance of 74% of the total number of insects collected for the study. Hymenoptera and Diptera had the highest relative abundances of 34% and 30% respectively during the dry season while Hymenoptera and Hemiptera were dominant with relative abundances of 25% and 19% respectively for the wet season.

The total insects sampled at the three centers were subjected to one way ANOVA at $p > 0.05$ and there was no significant difference between Kpeshie and Sakumo sites but Muni-Pomadze was significantly different from the two. The mean of at least two groups of the analysis differed significantly ($p > 0.05$). The abundance of insects did not vary much between Kpeshie and Sakumo but that of Muni –Pomadze was relatively less in both Kpeshie and Sakumo. However, there was significant difference in the relative abundance of insects sampled during the dry season and the wet season. For all the three sites, the number of individual insects collected in the wet season was more abundant than the dry season (Figs 5, 6, 7). Hymenoptera was the most abundant order in both seasons at Sakumono with a relative abundance of 29.9% and 9.0% for wet and dry seasons

respectively (Appendix 2). Kpeshie recorded an overall relative abundance of 88% in the wet season and 12% in the dry season with Muni-Pomadze recording an overall relative abundance of 84% in the wet season and 15.6% in the dry season (Appendix 2).

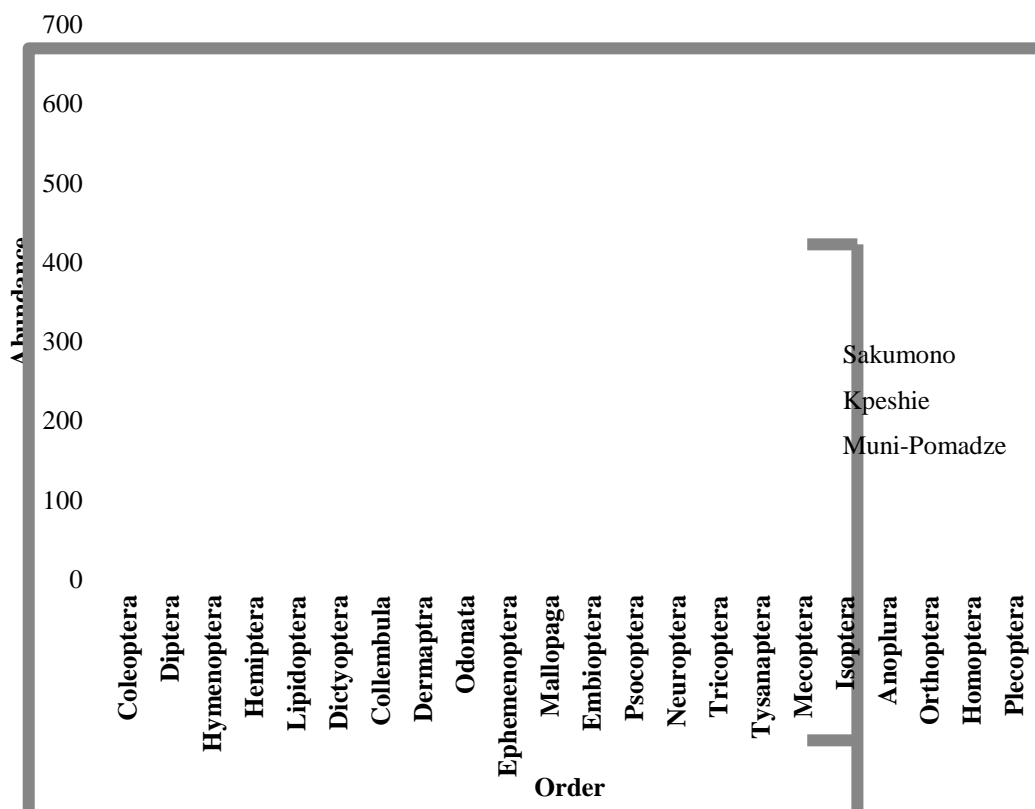


Figure 4: Relative abundance of insect order at all the sites

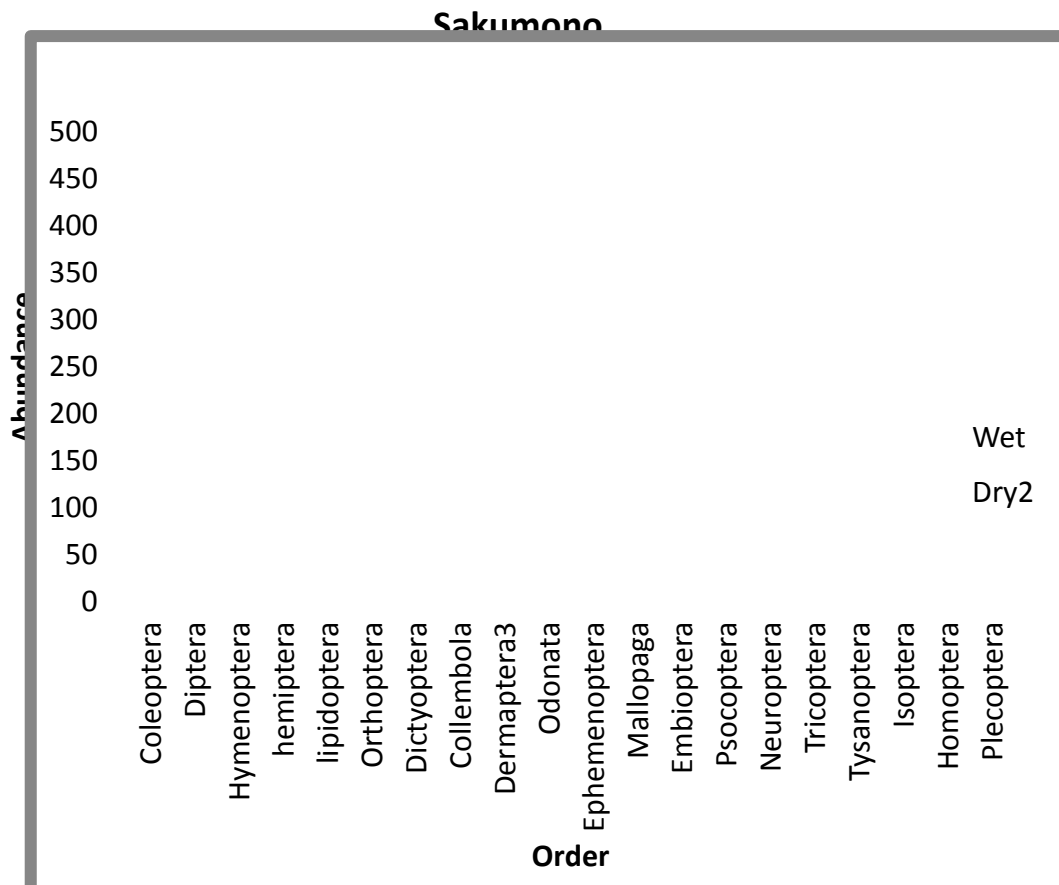


Figure 5: Relative abundance of insect orders between wet and dry season at Sakumono.

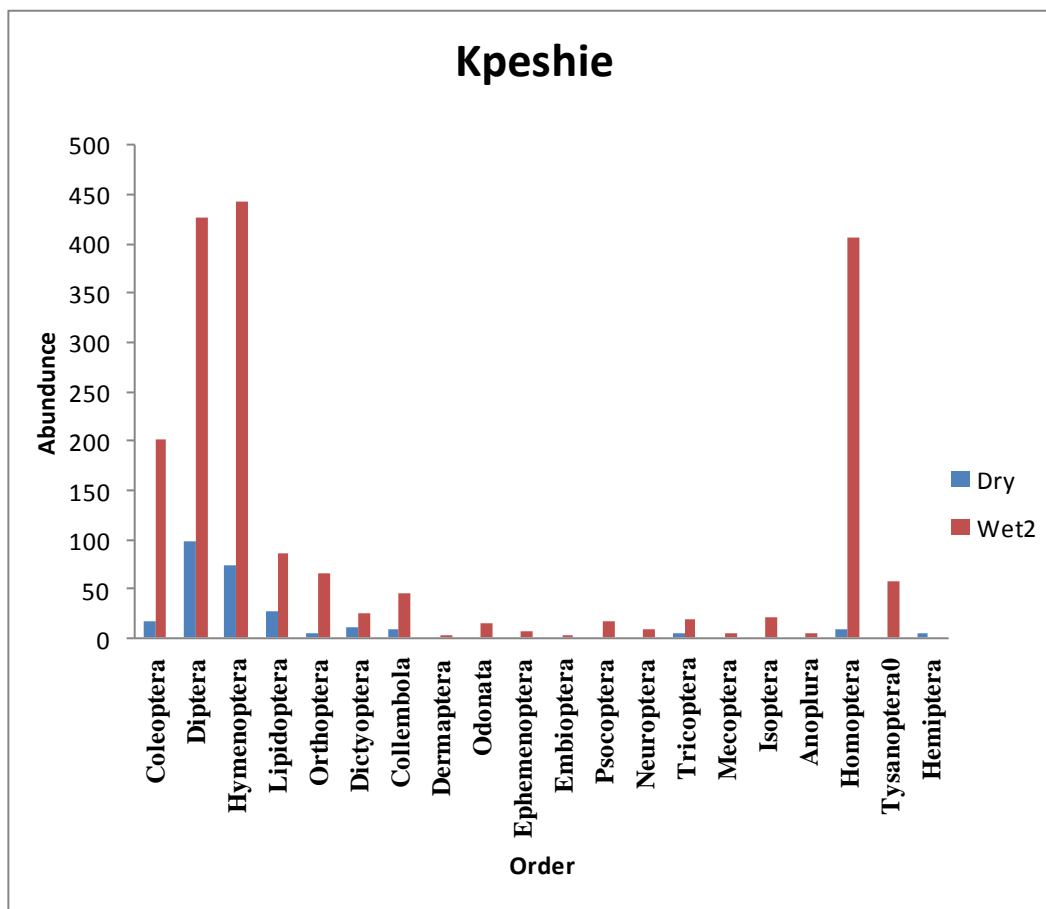


Figure 6: Relative abundance of insect orders between wet and dry seasons at kpeshie

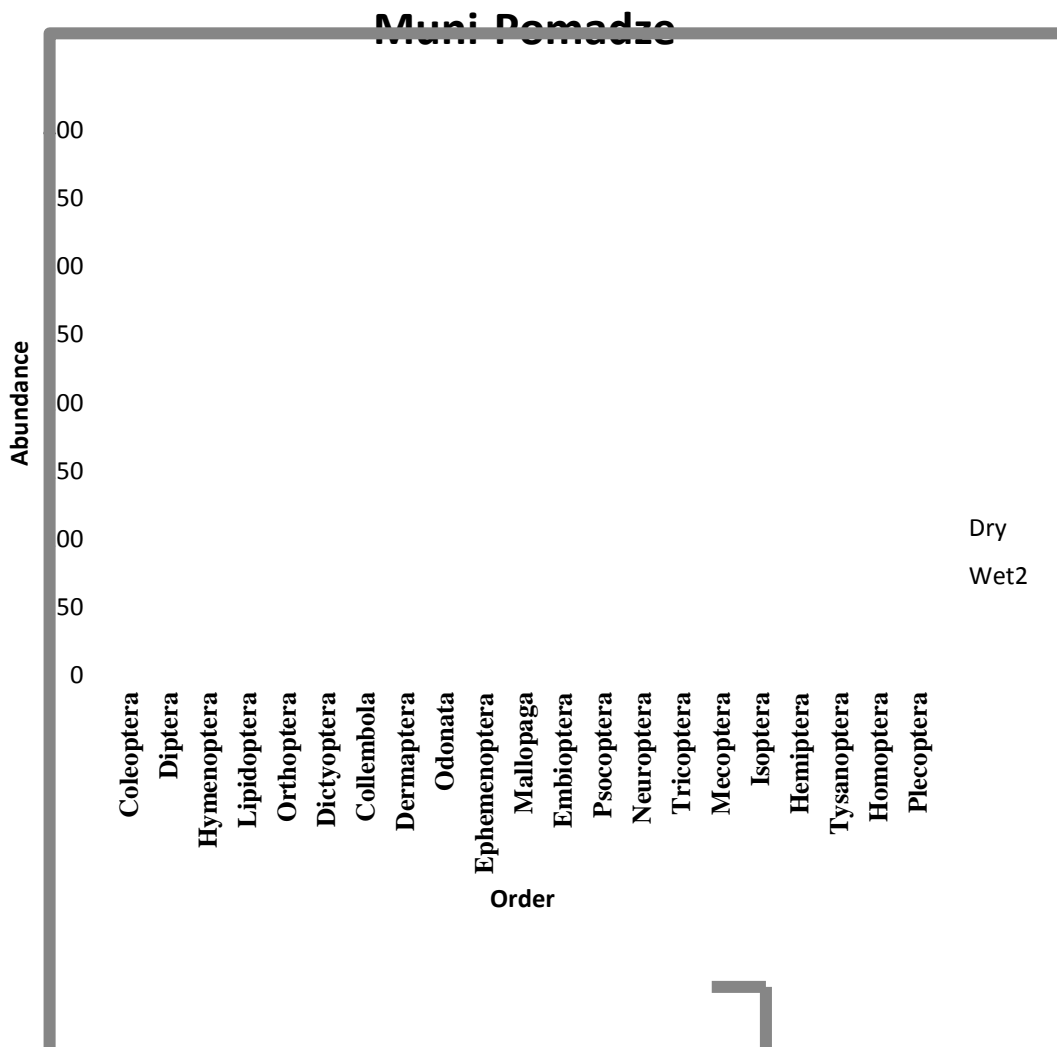


Figure 7: Relative abundance of insect orders between wet and dry seasons at Muni-Pomadze

Table 1 Diversity and richness indices for each season in and around each lagoon

Sites	Indices							
	Simpson (I/D)		Shannon-Weiner (H)		Margalef (D)		Pielou (J)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Sakumono	10.8	13.10	4.15	3.57	131.9	58.8	0.8	0.87
Kpeshie	21.32	51.19	4.87	4.33	152.9	60.8	0.97	1.05
Muni-Pomadze	4.84	14.94	2.55	3.65	139.9	55.8	0.52	0.9
Data Analysis								

4.2 Species Richness and Diversity Indices

The Margalef and Pielou richness were higher in the wet seasons at all three sites than the dry seasons. However, the Sannon Weiner and Simpsons diversity indices were rather higher in the dry season than the wet season (Table 1).

4.2.1 Estimated Species Richness

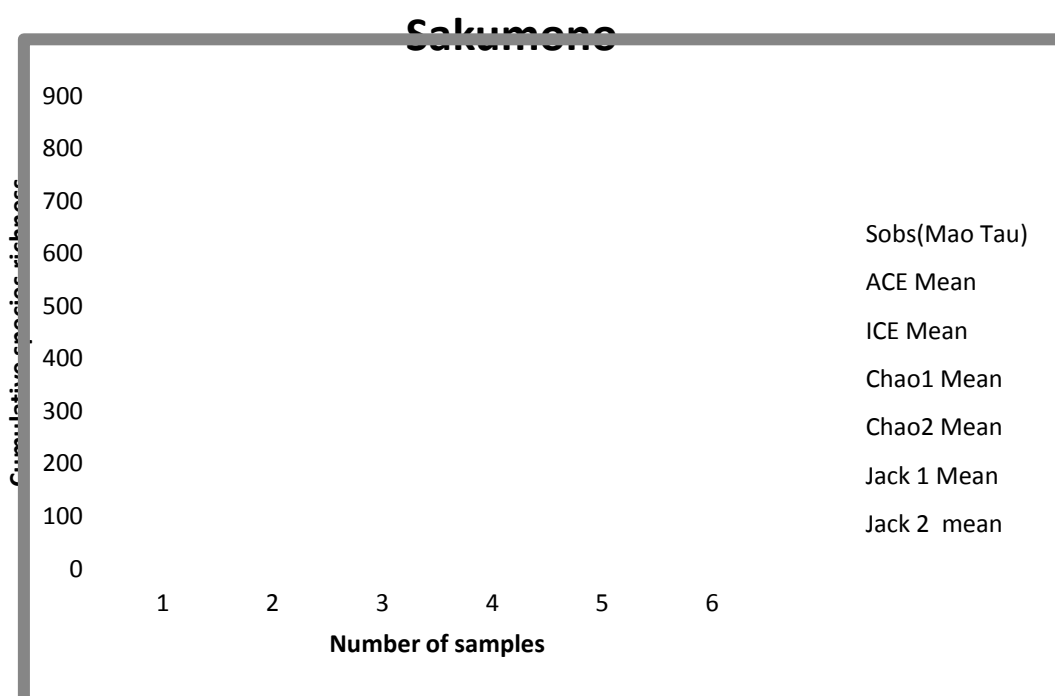
A summary of estimates of species richness as well as the observed species richness is depicted in Table 2. Species accumulation curves (Figure 8) for the three major areas also complement the estimate of observed species richness in the habitats. The total species richness estimated from the sites varied at all the sites and depended on the richness estimator used. At all the sites, the ICE (Incidence-base) coverage estimator was 785, 814, 598 for Sakumono, Kpeshie and Muni-Pomadze respectively and Chao2 produced stable and broadly accurate estimates at small numbers of 204, 219, 199 samples for Sakumono, Kpeshie and Muni-Pomadze respectively (Table 2). The Jack 2 produced lower estimates at small number of 202, 212, 183 samples for Sakumo, Kpeshie and Muni-Pomadze respectively and stable estimates at large number of samples. These estimates emphasize the representativeness of sampling effort in this study and the occurrence of rare species is the essence for this (Colwell *et al.*, 2004).

Table: 2 Species Richness Estimates at all Three Sites

Sites	Total Species Trapped (Sobs)	Singleton/ Doubleton	Unique/ Duplicates	ACE/ ICE	Chao 1/ Chao 2	Jack 1/ Jack 2
Sakumono	199	79/48	19/35	246/785	264/204	218/202
Keshie	214	94/51	25/56	268/814	231/219	239/212
Muni-Pomadze	196	81/67	19/51	192/598	244/199	215/183

4.2.2 Observed Species Richness

The observed species richness (Sobs) was higher at Kpeshie than the rest of the sites (Table: 2). It is very obvious that the species accumulation curves were approaching an asymptote, indicating that species saturation had been reached and sampling effort was adequate (Figs 8-10).

Figure 8:

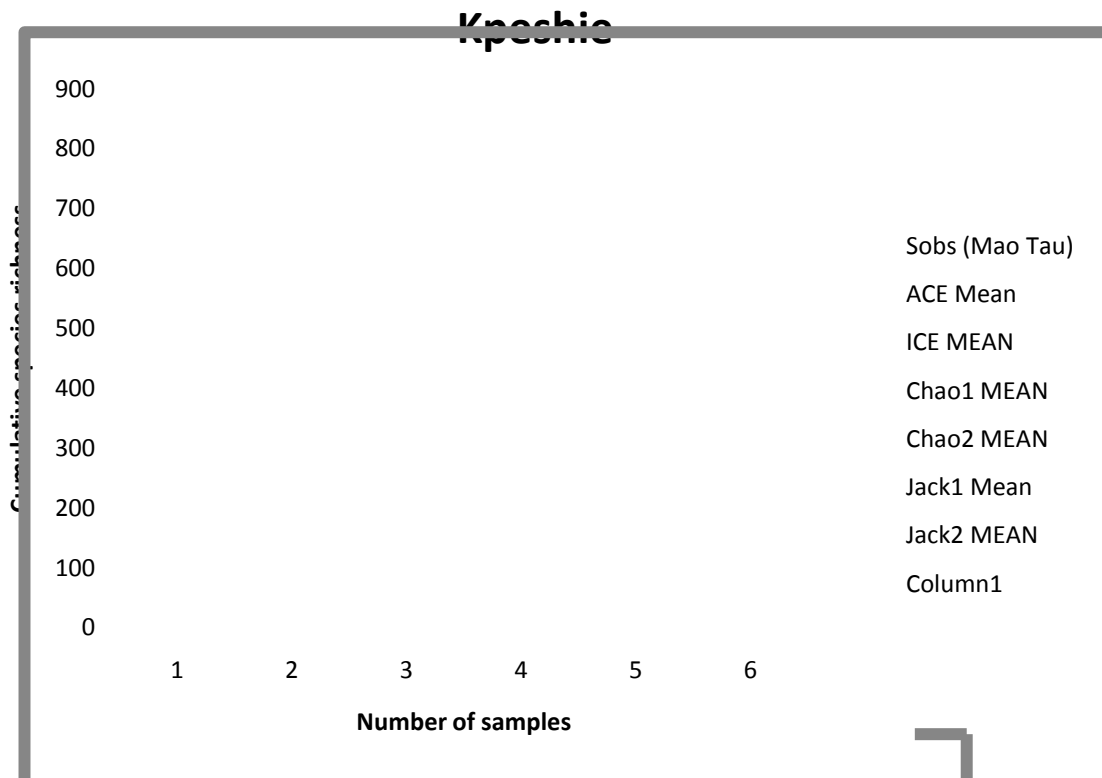


Figure 9:

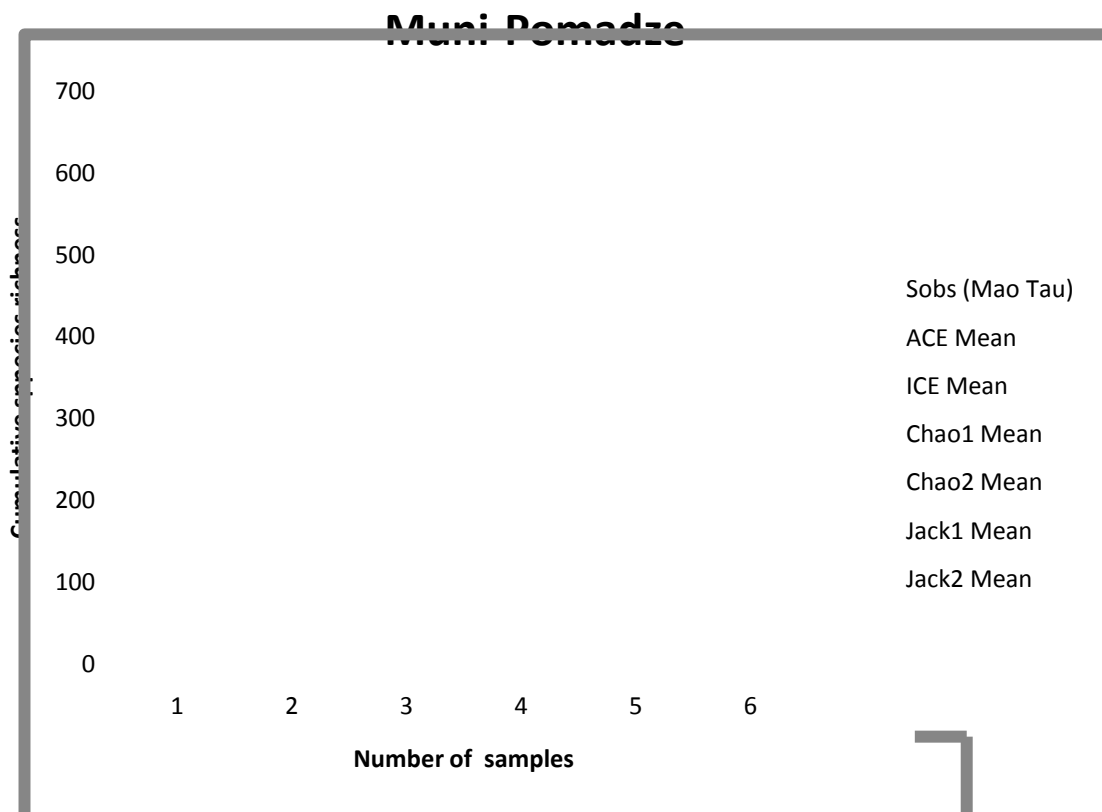


Figure 10:

Figures 8-10 Randomized Species Accumulation curves. (Number of observed and estimated

species at each site as a function of increasing number of samples. ACE, Chao1 and Jack1= non parametric estimates of species richness, Sobs= actual species observed in samples.

4.3 Water Analyses

4.3.1 Physical Characteristics of Water

4.3.2 Temperature

The readings of temperature were higher at Sakumo reaching a maximum of 35°C and this was followed by Muni-Pomadze, but it must be explained that, this is because the measurement at Kpeshie was mostly taken in the mornings due to location's proximity to the researcher's hence the low temperature readings. (Fig. 11 a-c)

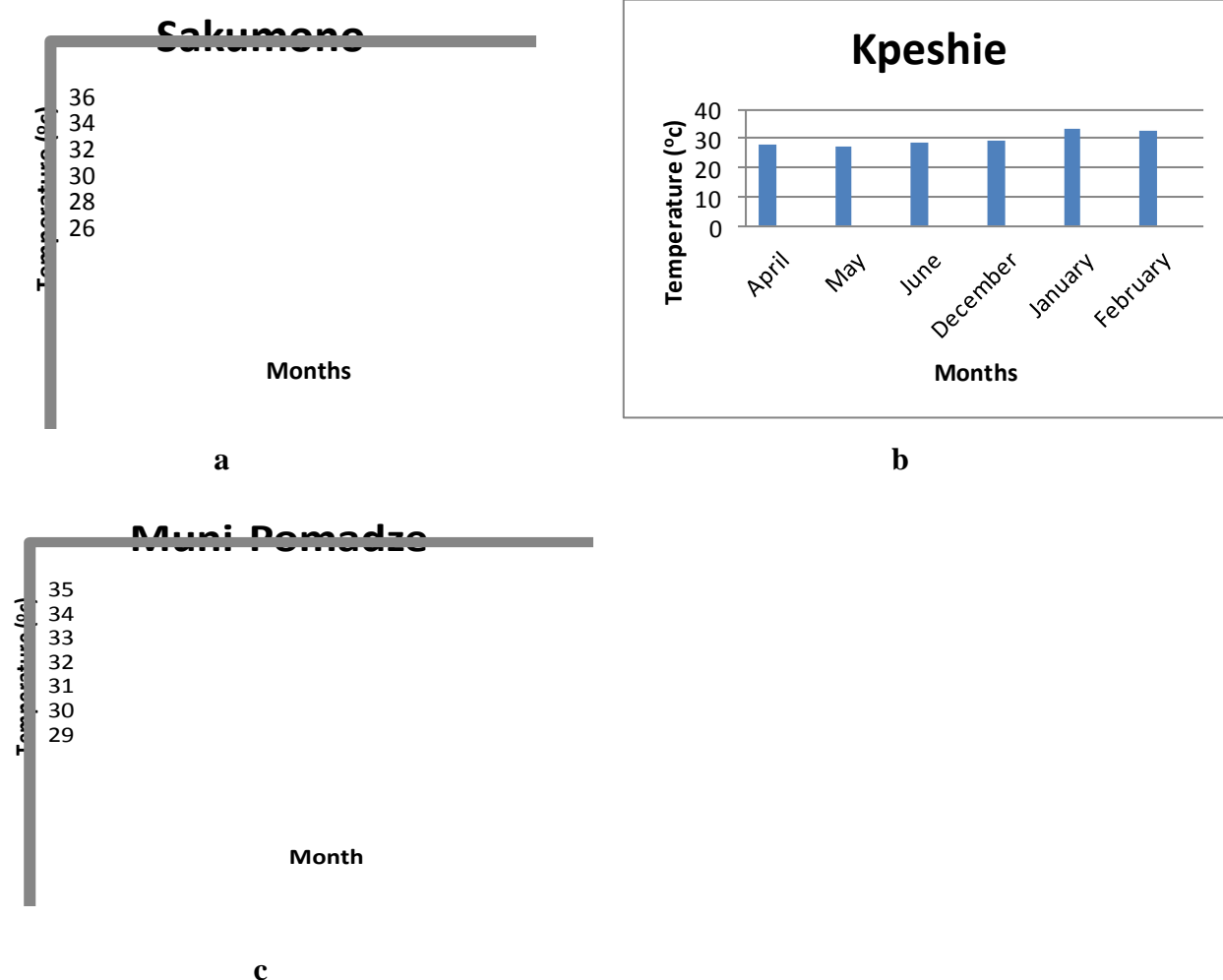


Fig.11a-c Monthly Variations in Temperature

4.3.3 pH

pH values ranged from a minimum of 7.5 at Sakumono in April, June and February to a maximum of 9.2 in February (Fig.12) at Kpeshie, which had the highest mean pH of 9.2 while the lowest mean pH at 7.5 was recorded at Sakumo and Muni-Pomadze.

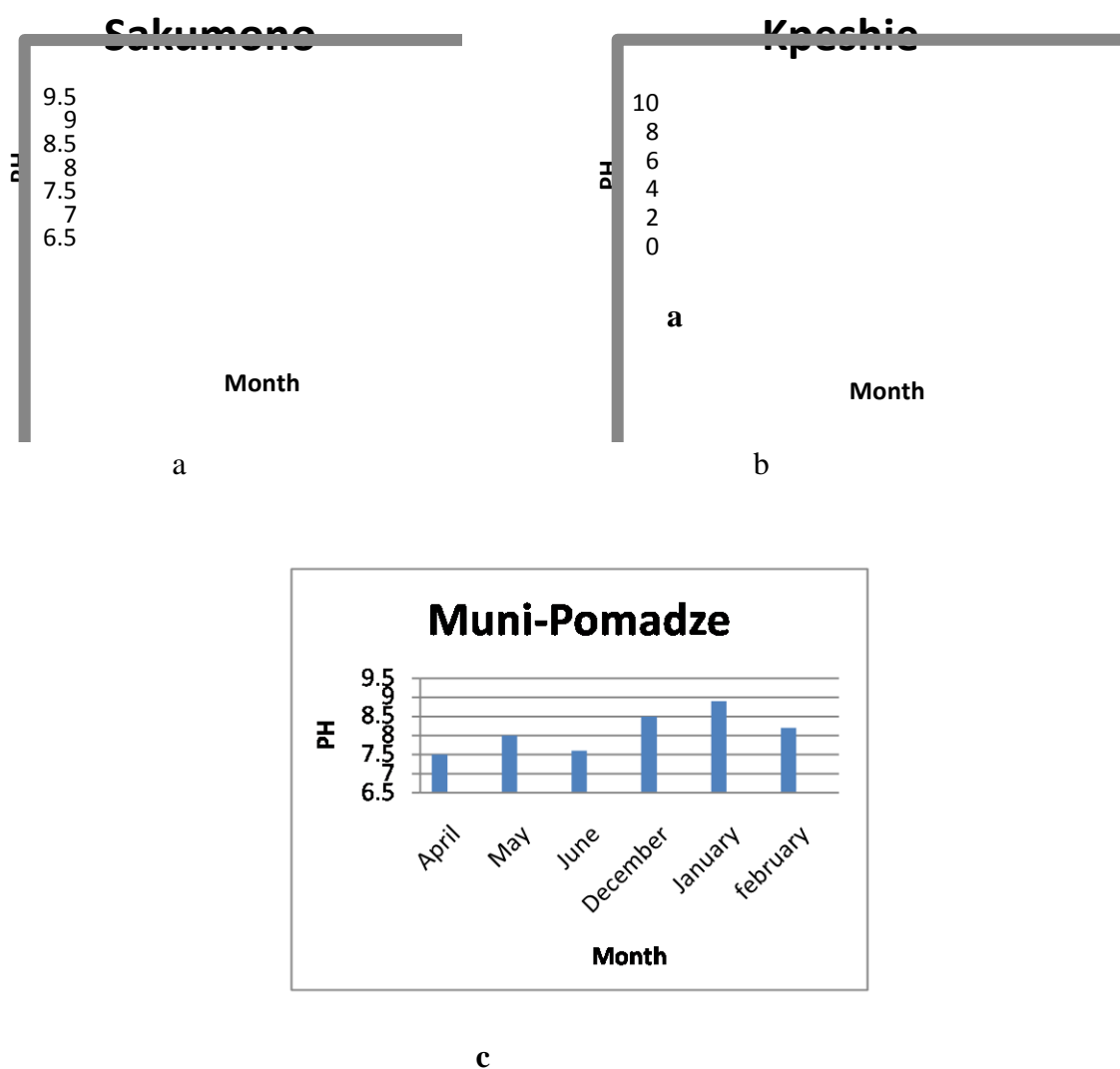
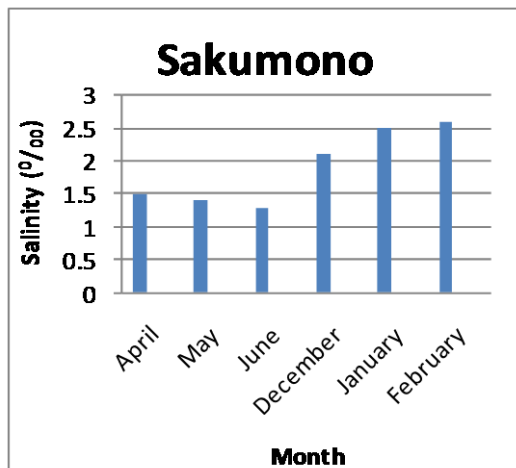


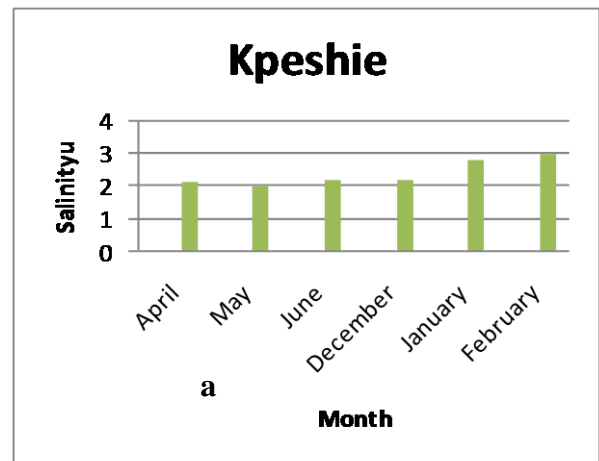
Fig. 12 a-c Monthly Variations in pH

4.3.4 Salinity

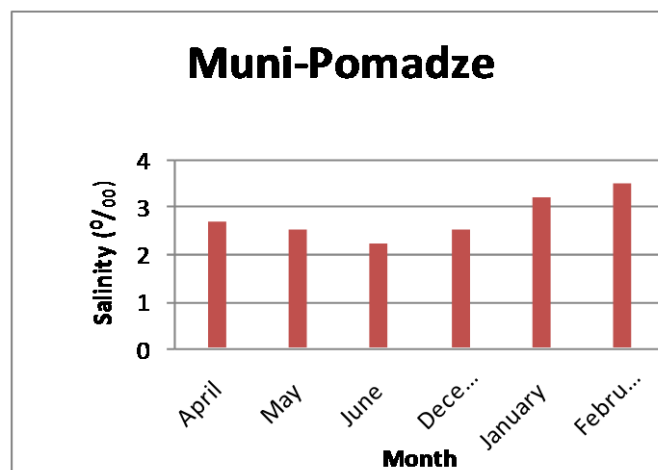
The salinity recorded from the sites ranged from a minimum mean value of 1.5‰ in June to a maximum mean value of 3.5‰ in February. Again, the highest mean value was recorded at Muni-Pomadze and the lowest at Sakumo Lagoon.



a



b



c

Fig.13 a-c Monthly Variations in Salinity

4.3.5 Conductivity

Conductivity values measured in the study are presented in Table 3. Variation in conductivity at different sites was much greater than for pH and temperature. The Mean conductivity value recorded at Kpeshie was the highest, and significantly higher than all the sampling sites. Values ranged from a minimum of 156 μ S/cm at Muni-Pomadze in June to a maximum of 22368 μ S/cm at Kpeshie in December. Kpeshie had the highest mean conductivity of 7077.3 μ S/cm while Muni-Pomadze had the lowest mean value at 432.5 μ S/cm.

Table 3 Value for conductivity (μ S/cm) for sites and seasons

Month/Season	Skumono	Kpeshie	Muni-Pomadze
April	1254	1785	532
May	987	1524	230
June	852	1230	156
December	19328	22368	456
January	14848	14312	523
February	1358	1245	698
<i>Mean (Pooled)</i>	6437.8	7077.3	432.5

4.3.6 Turbidity

Turbidity values ranged from a minimum of 15 mg/l at Muni-Pomadze in April to a maximum of 221 NTU at Sakumo in February (Fig 14). The lowest mean value of 52.8 NTU over the study period was recorded at Muni-Pomadzer while the highest mean value of 93.5 was recorded at Sakumo. The value range shows that there was a significant ($p < 0.05$) variation. The turbidity of the lagoons fluctuated between the wet and dry seasons with the highest values recorded in the dry season and the lowest in the wet season for all three sites.

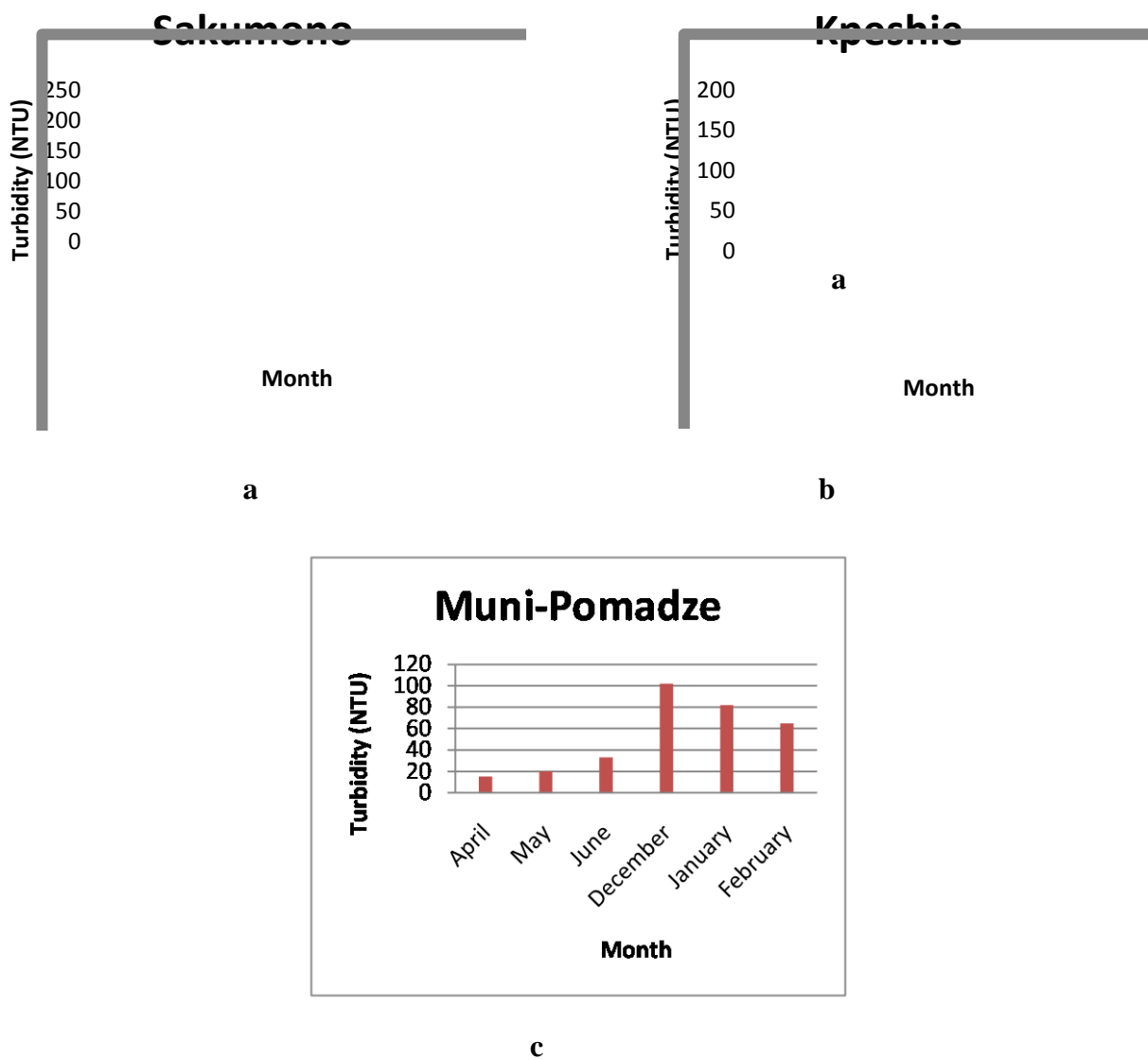
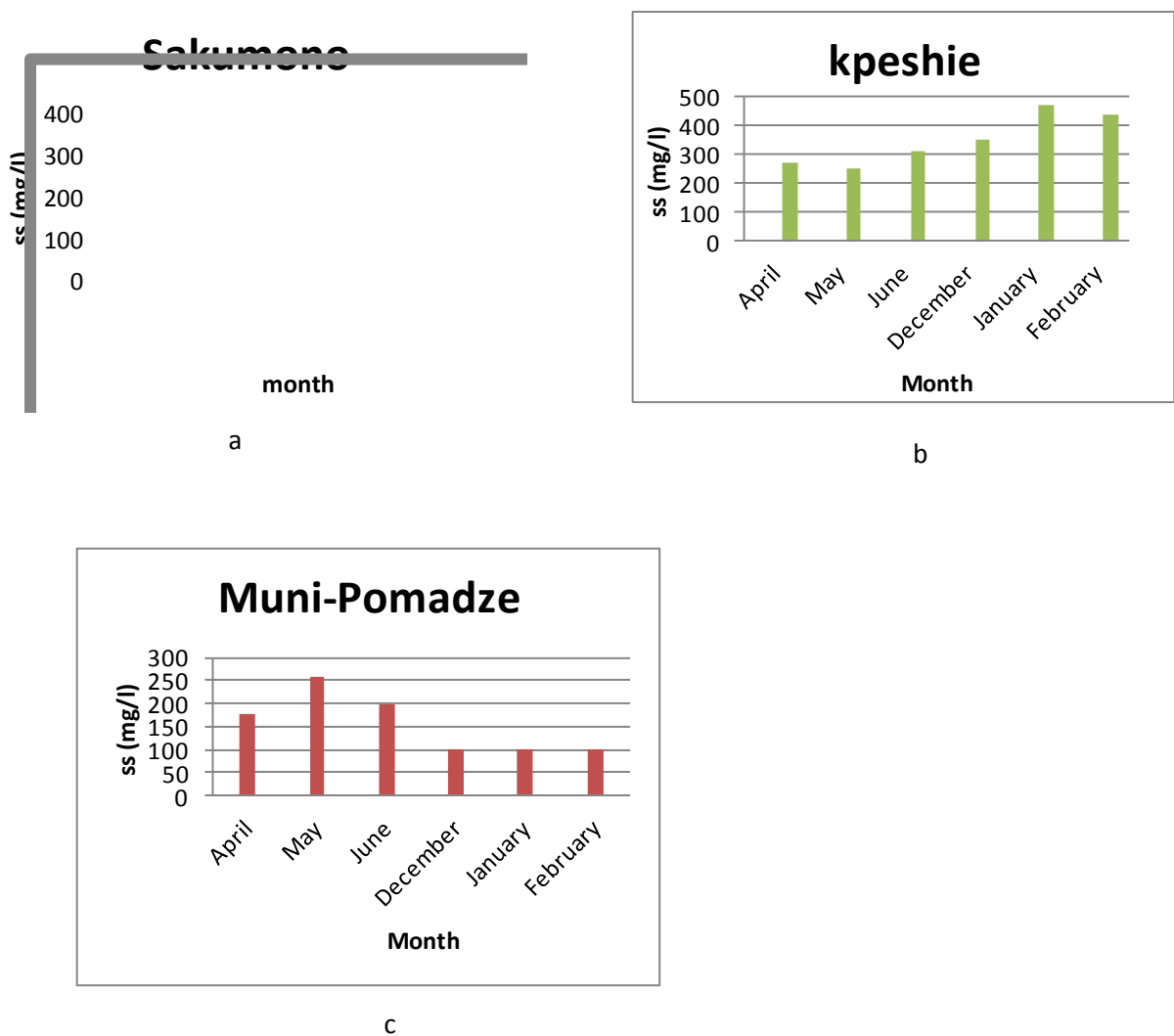


Figure 14 a-c Monthly Variations in Turbidity

4.3.7 Suspended Solids

The Values ranged from a minimum of 100 mg/l at Muni-Pomadze in December to a maximum of 468 mg/l at Kpeshie in January (Fig. 15). Mean values ranged from a minimum of 183.3 mg/l at Muni-Pomadze to a maximum of 348.2 mg/l at Kpeshie. mg/l.



15 a-c Monthly Variations in Suspended Solids

4.3.8 Colour

Colour values ranged from a minimum of 20 PtCo at Muni-Pomadze in April to a maximum of 1066 PtCo at Kpeshie in February (Fig. 16). Sakumono recorded the lowest mean value of 191.7 PtCo while Kpeshie recorded the highest mean value of 695 PtCo.

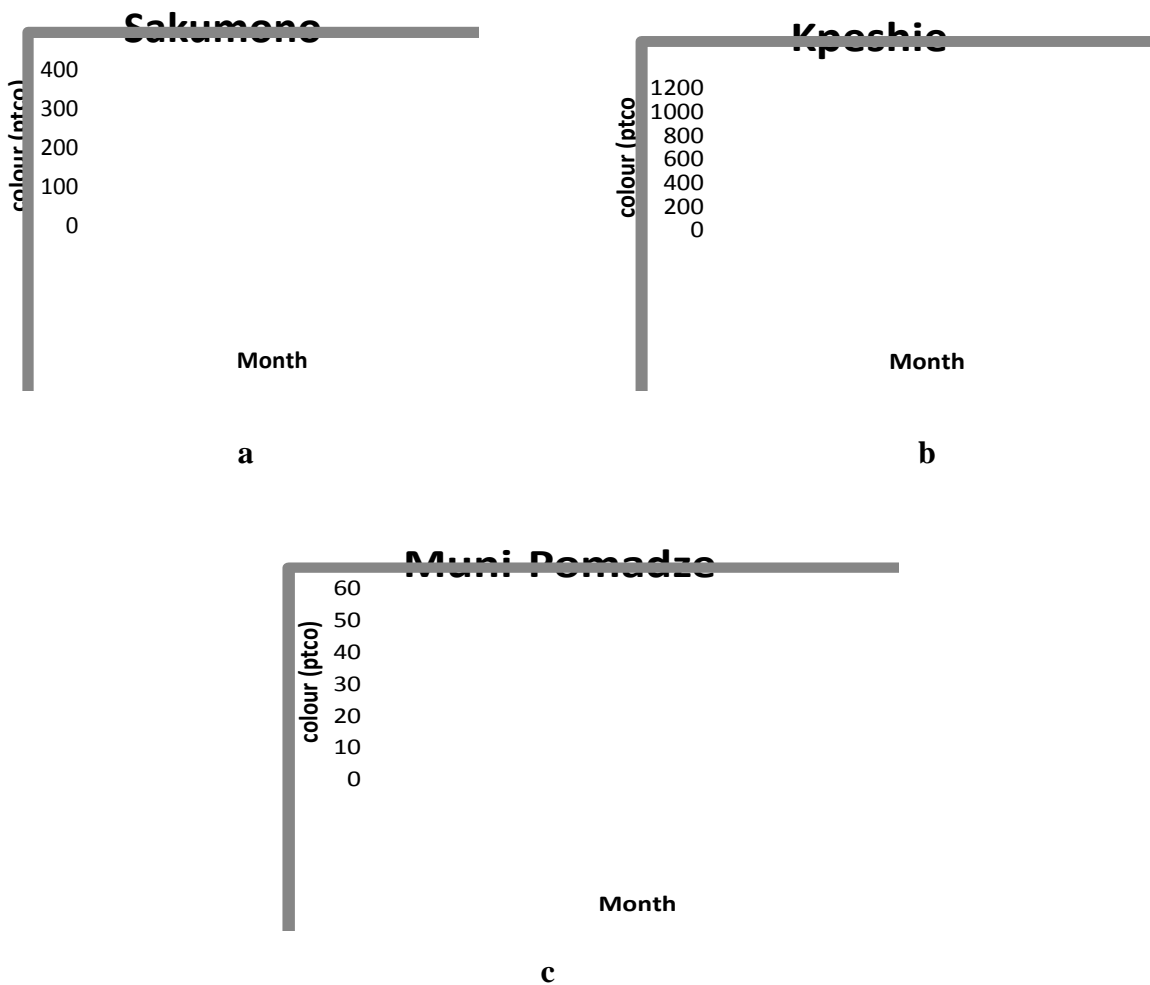


Figure: 16 a-c Monthly Variations in Colour

4.4 Chemical Analysis

4.4.1 Dissolved Oxygen (DO)

Dissolved oxygen values ranged from a minimum of 10 mg/l to a maximum of 22. mg/l at Muni-Pomadze in June (Fig. 17). Muni-Pomadze had the highest mean value of 25.14 mg/l while Kpeshie had the lowest mean value of 5.7 mg/l. One-way ANOVA at $P>0.05$ showed no significant difference between the sites.

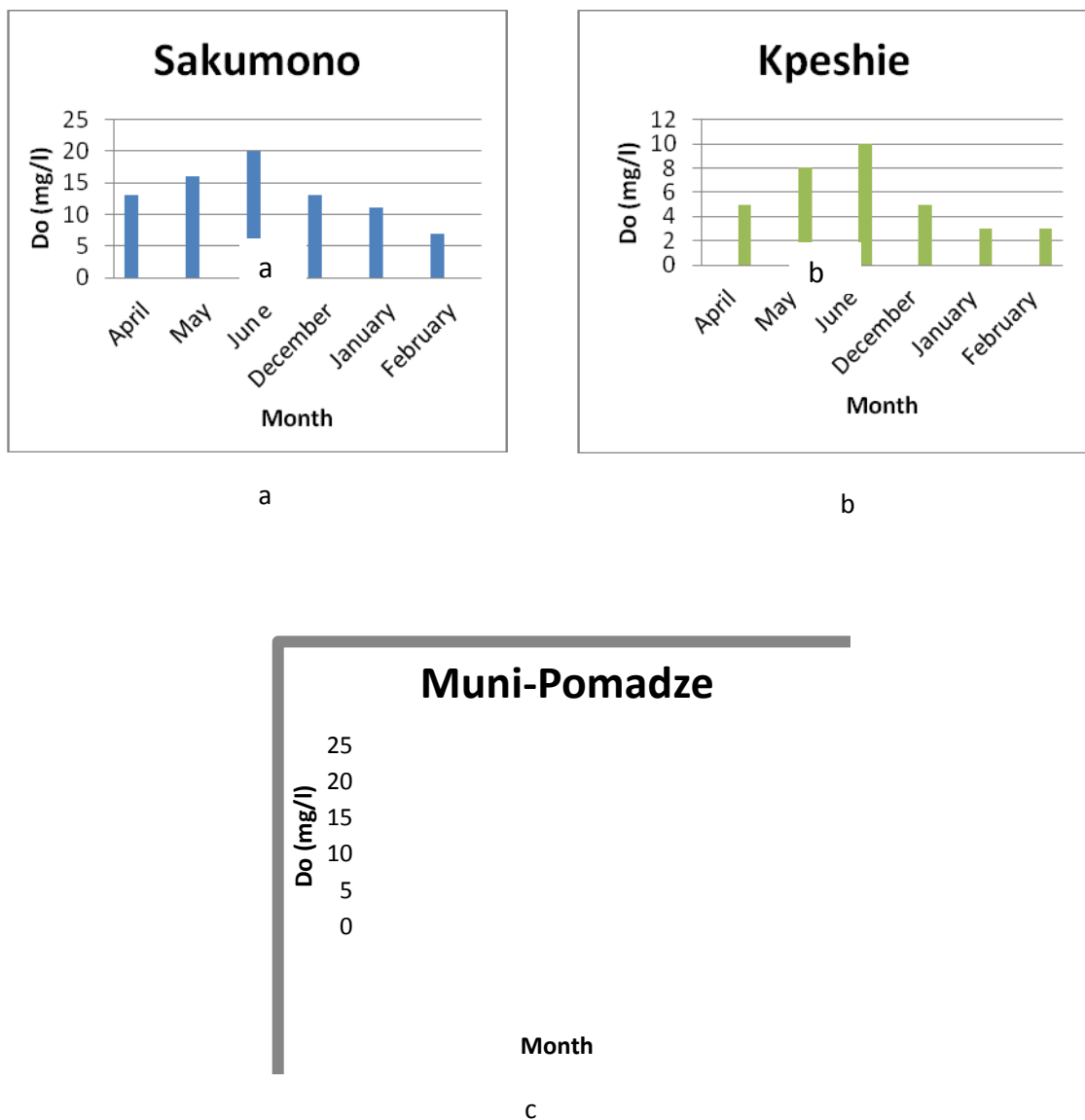


Figure: 17 a-c Monthly Variations in DO

4.4.2 Biochemical Oxygen Demand (BOD)

BOD values ranged from a minimum of 6 mg/l at Muni-Pomadze in April to a maximum of 72 mg/l Kpeshie in (Fig 18). Mean values for the sites ranged from a minimum of 9.8 mg/l at Muni-Pomadze to a maximum of 52.8 mg/l at Kpeshie.

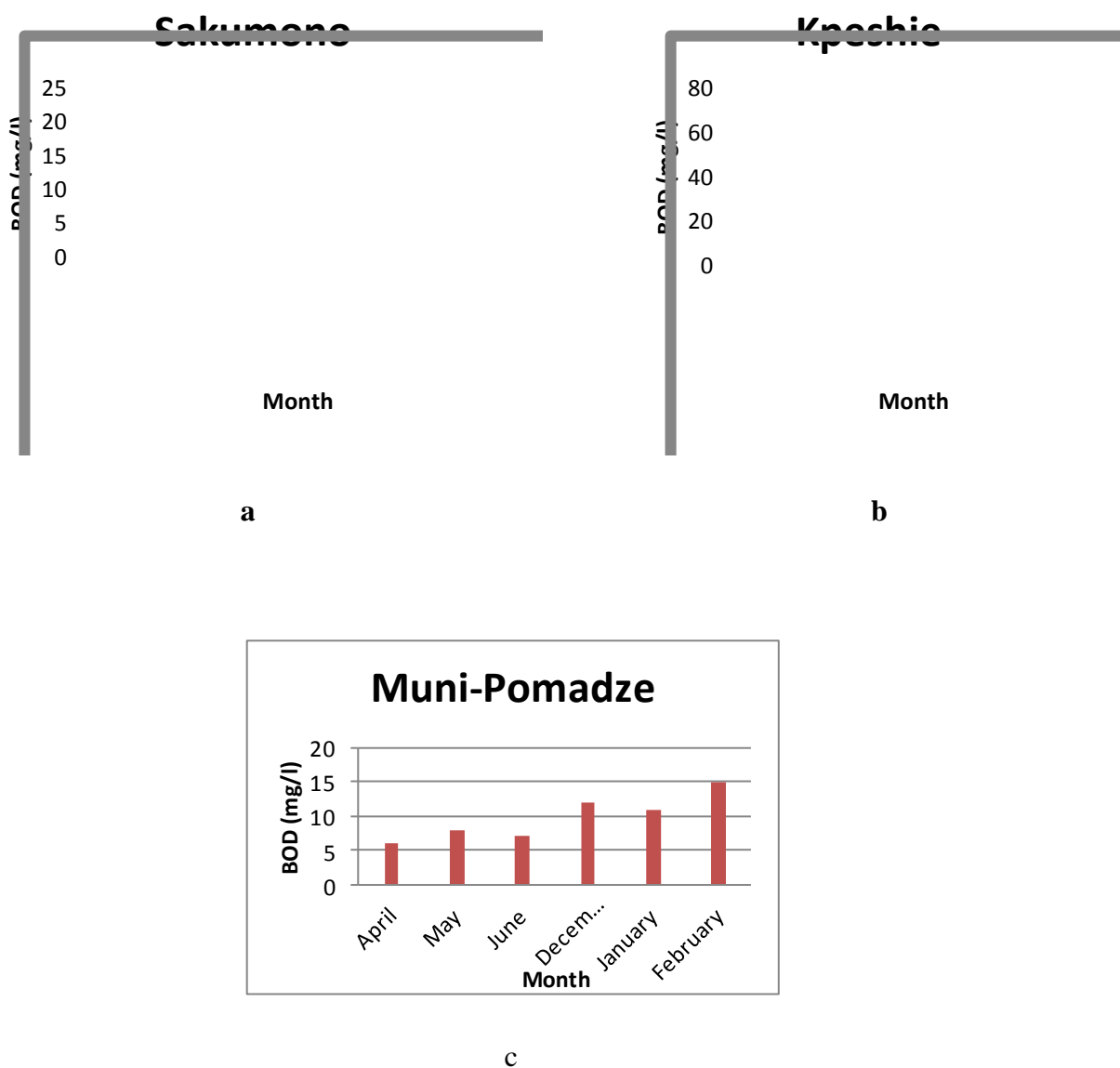


Figure: 18 a-c Monthly Variation in BOD

4.5 Bacteriological Analysis

4.5.1 Total Coliform

Total coliform counts /100 ml ranged from a minimum of 100 at MuniPomadze in April, to a maximum of 110754 in Kpeshie in February (Fig. 19). Mean values for the sites ranged from a minimum of 1,967.7 at Muni-Pomadze to a maximum of 3, 9657.7 Kpeshie.

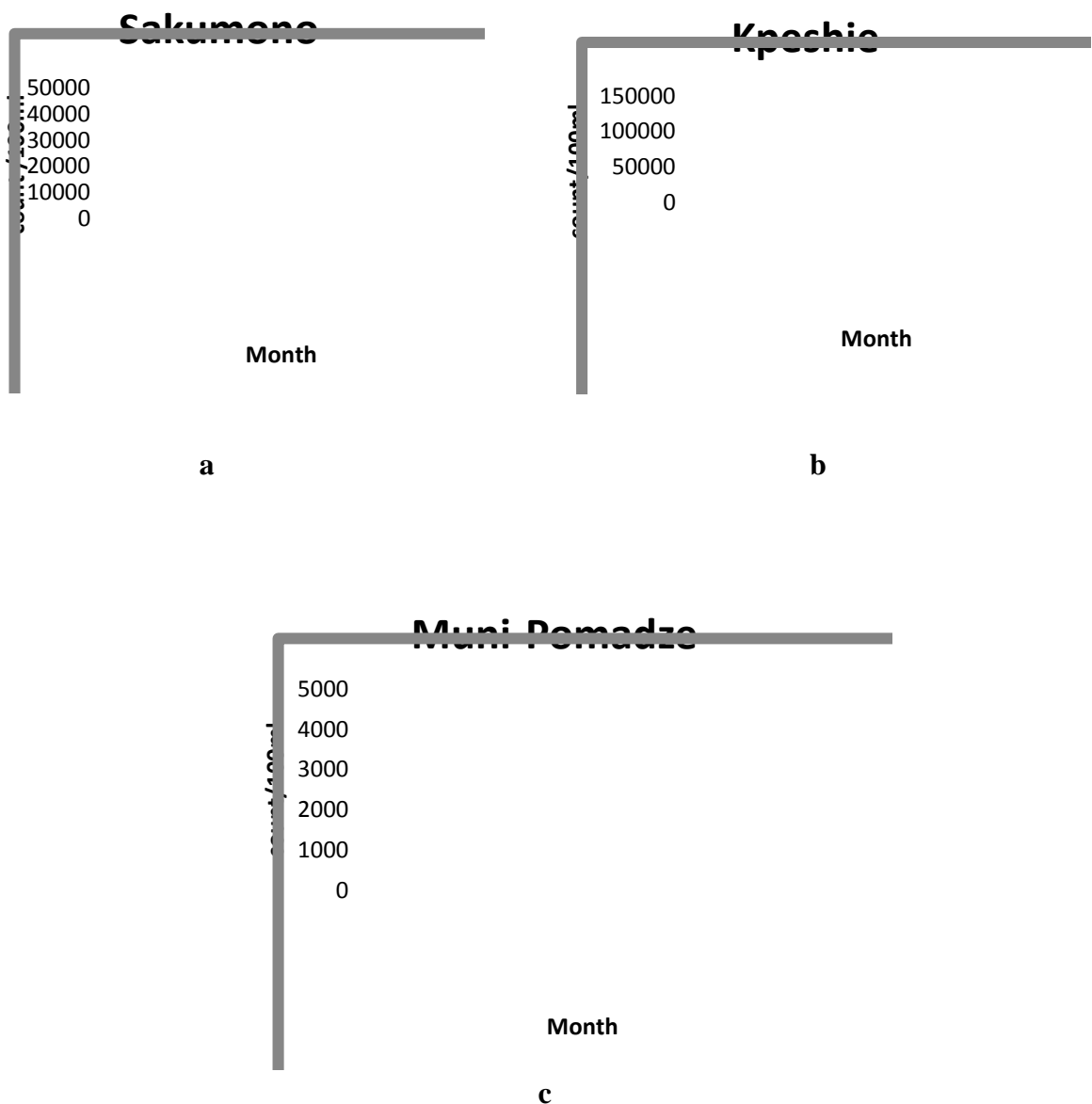


Figure: 19 a-c Monthly Variations in Total Coliform

4.5.2 Faecal Coliform

Faecal coliform counts /100 ml ranged from a minimum of 200 at Muni-Pomadze and in April, to a maximum of 91224 in February at Kpeshie (Fig. 20). Mean values for the sites ranged from a minimum of 5233.67 at Muni-Pomadze to a maximum of 70424.33 at Kpeshie. The trend for faecal coliform was generally not different from that of total coliform.

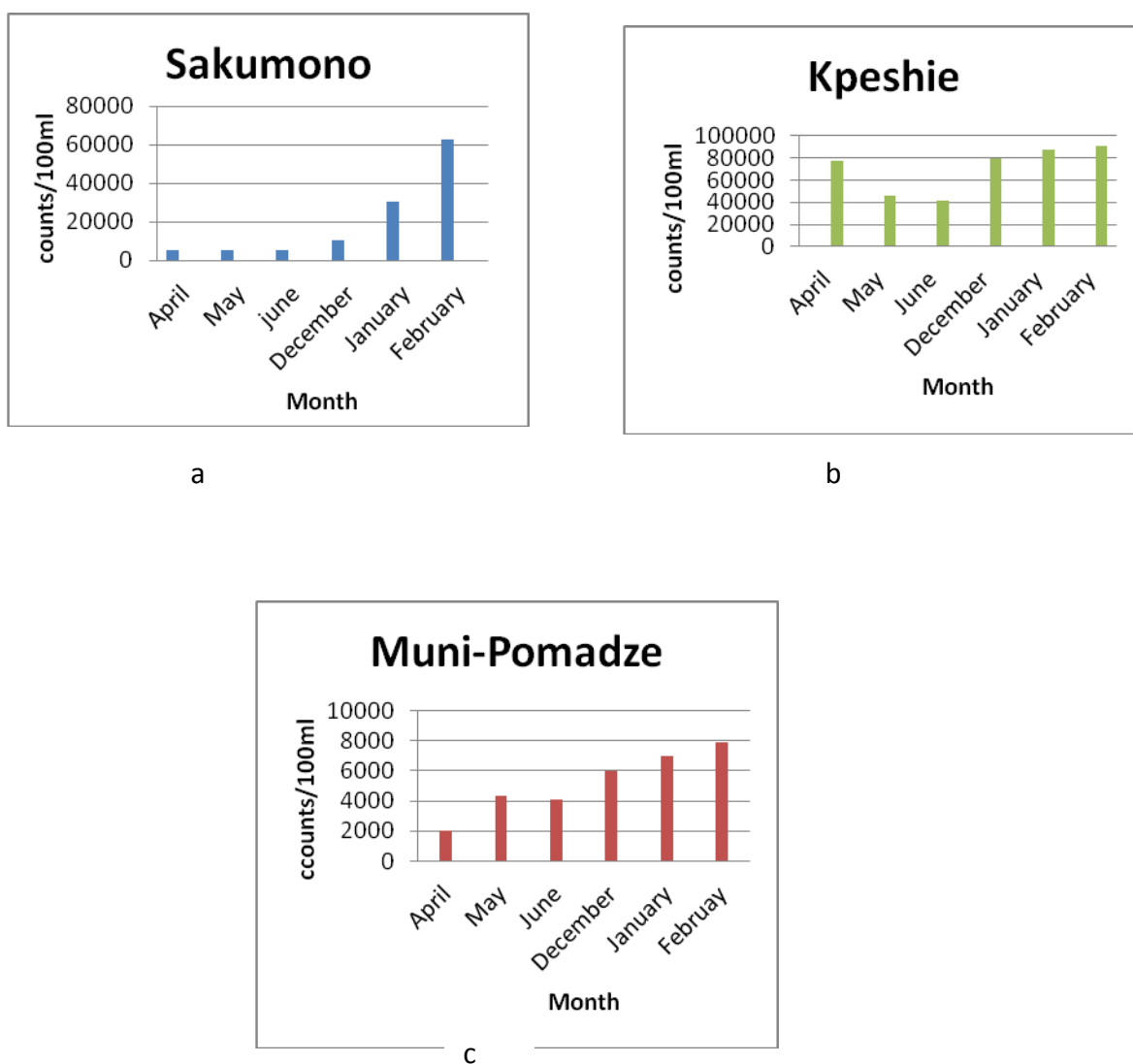


Figure: 20 a-c Monthly Variations in Faecal Coliform

4.7 Trace Metals

Table: 4. Titrimetric Analysis

Season/site	IRON mg/l		LEAD mg/l		CADMIUM mg/l		CALCIUM mg/l		MGNESIUM mg/l		ZINC mg/l	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	wet
Sakumono	2.18	1.83	0.07	NA	0.39	0.24	851.5	616.3	93.9	78.17	0.2	0.1
Kpeshie	0.83	0.2	1.38	0.97	0.62	0.33	612.5	440.5	221	196.7	0.2	0.1
Muni- Pomadze	0.54	0.42	0.7	0.58	0.47	0.95	571.5	325.7	105.6	87.9	0.0	0.0

NA- Not Available

All the trace metals that were tested (e.g Iron, Lead, Cadmium, Calcium, Magnesium and Zinc) recorded higher values during the dry season (Table 4.).

Seasons/sites	Iron		Lead		Cadmium		Calcium		Magnesium		Zinc	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Sakumono	0.61±0.02	0.73±0.09	NA	0.02±0.02	0.08±0.00	0.13±0.003	205.4±3.73	283.7±17.4	26.6±0.5	31.4±2.7	0.1±0.00	0.8±0.08
Kpeshie	0.02±0.01	0.28±0.01	0.3±0.00	0.45±0.05	0.11±0.00	0.21±0.012	146.8±0.25	204.2±18.63	65.6±2.6	73.7±1.5	0.0±0.03	0.1±0.00
Muni-Pomadze	0.14±0.00	0.18±0.12	0.18±0.0	0.23±0.03	0.32±0.41	0.16±0.08	108.6±2.22	190.5±18.10	29.3±0.6	35.2±3.5	0.00±0.0	0.00±0.0

Table: 5 Means and standard deviation values of Trace Metals of the Sakumo, Kpeshie and Muni-Pomdze Lagoons

4.7 Social Survey

4.7.1 Respondent Information

4.7.2 Sex

The questionnaires were distributed in Sakumono, La Trade Fair Area and Mankoadze in Winneba. The distribution of the questionnaires were done in a way to ensure that there were as many men as women. In all, 143 women and 137 men were sampled from the three sites. The population sampled in each of these locations was categorized according to the level of activities carried out by residents in this catchmentsareas. There were 100 respondents each from Sakumo and Mankoadze constituting 71.4% of the total respondents for each of the two sites. This means that there were 80 respondents from the Trade Fair Area, constituting 28.6% of the 280 people sampled for the study.

4.7.3 Educational Level

Sixty-seven individuals (23.9%) sampled had Middle or Junior High School education, 22.14% had Secondary School Education and 16.1% had Vocational, Commercial and Technical Education (Table 6).

Table: 6 Educational Level Breakdown

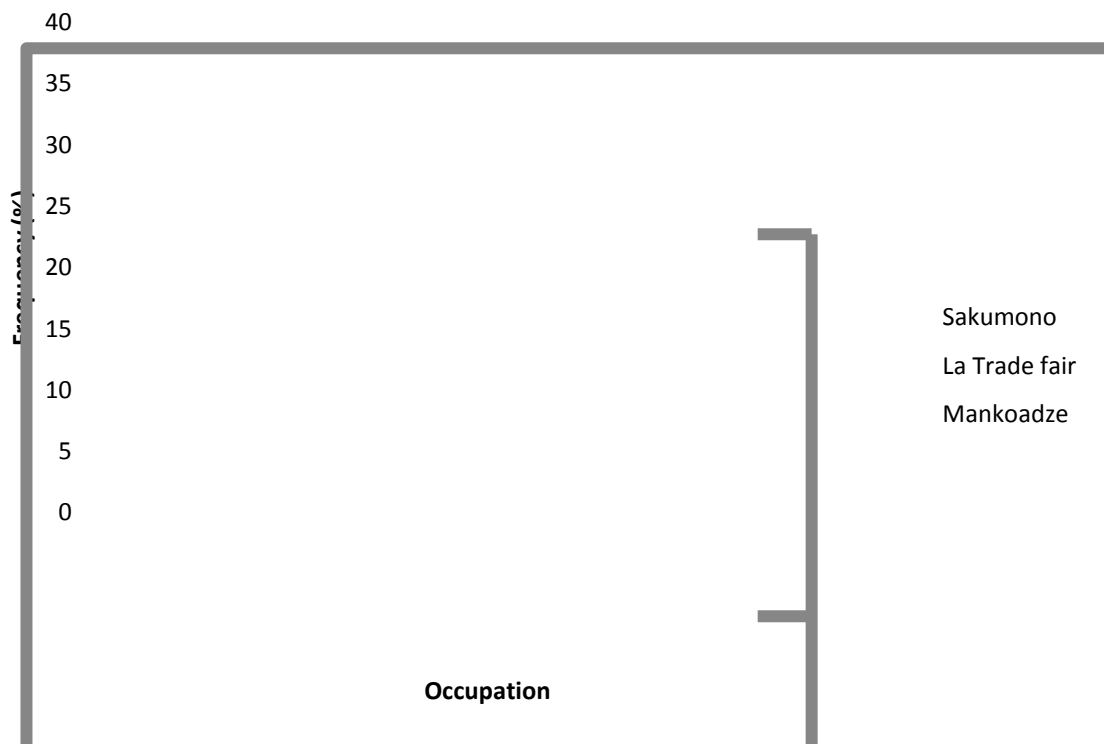
Educational Level	Sakumono	La Trade Fair Area	Mankoadze	Percentage (%)	Total
Primary	15	8	23	16.4	46
Middle/JHS	24	18	25	23.9	67
Secondary/SSS	22	20	20	22.14	62
Voc/Com/Tech	16	15	14	16.1	45
Tertiary	14	17	9	14.3	40
No formal education	9	2	9	7.14	20
Total	100	80	100	100	280

4.7.4 Income Level

Majority of the respondents at Mankoadze (40.14%) earned an income below GH¢ 200 but only 16.4% and 28% of respondents at Sakumono and the Trade Fair area respectively earned below this. About 38.6% and 31.2% of the number of people sampled in these two areas respectively earned from GH¢ 200 to GH¢ 400. None of the respondents at Mankoadze earned an income of GH¢ 800 and above, 8% of the sampled population at Sakumono and 6% of those sampled at Trade Fair in La earned more than GH¢ 800 (Table 7)

Table: 7 Income Level/Month Breakdowns by Category

Category	Sakumono	La Trade Fair	Mankoadze
<200	16.4	28	40.14
200-400	38.6	31.2	20.29
400-600	18.8	12	11
600-800	12	10	8.57
>800	8	6	0
Not sure	6.2	12.8	20
Total %	100	100	100

**Figure: 21 Occupational Statuses of the Respondents**

At Mankoadze the number of unemployed people was 33% of the number sampled in the area. Sakumono also recorded 28.7% for the unemployed while in the case of Trade Fair a high number amounting to 34% of the population sampled at the area responded positively to self-employment. The population of fishermen in Sakumo and Mankoadze were 16.5% and 26% respectively while that of Trade Fair area was just 0.6% (Fig 21).

Figure: 22 shows that 71% of the total number of people sampled for the study do not have access to their own private toilet facilities. Only 29% had their own places of convenience.

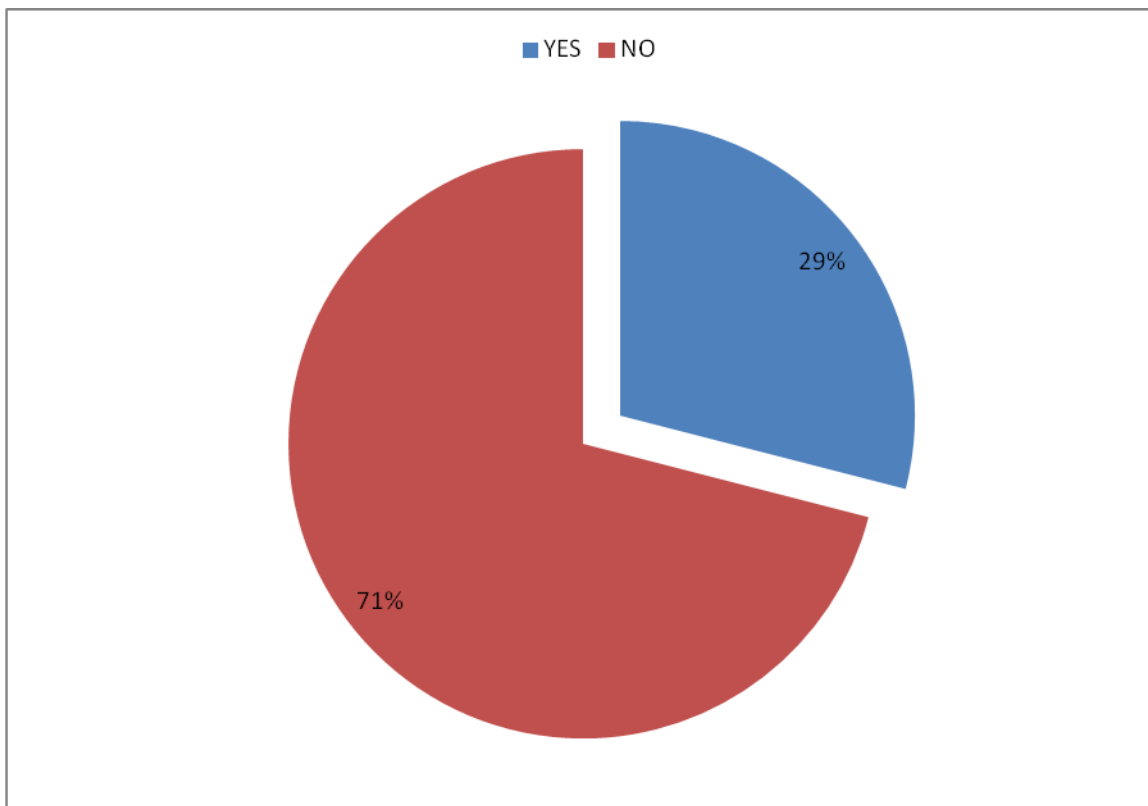


Figure: 22 Proportion of Respondents with or without Private Toilets

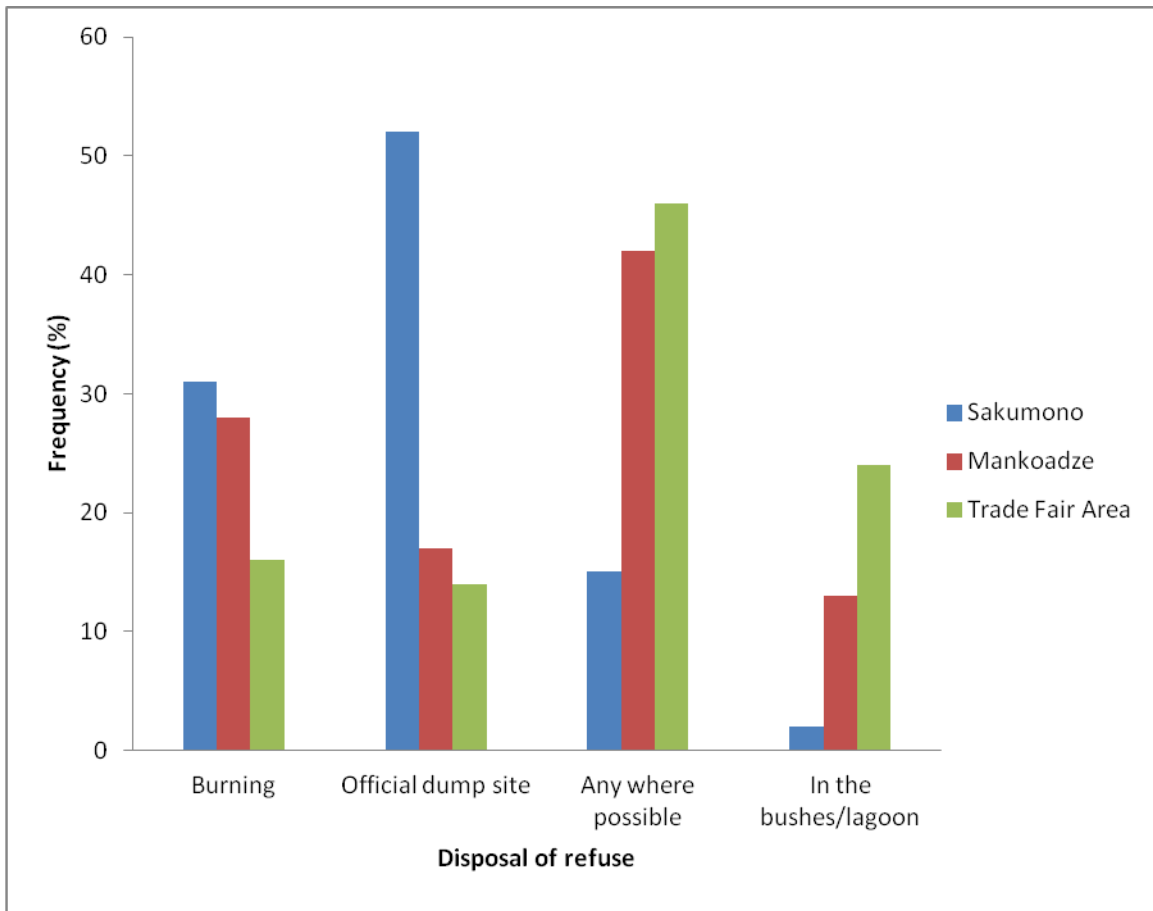


Figure: 23 Mode of Disposal of Refuse

Forty-six percent and 42% of respondents from Trade Fair and Mankoadze respectively disposed off their refuse indiscriminately.

CHAPTER FIVE

DISCUSSION

5.1 Insect Abundance

Of the 5541 individual insect sampled, a total of 22 orders belonging to 112 families were collected and identified from different sites along the Sakumo, Kpeshie and Muni – Pomadze lagoons. The abundant order in Kpeshie was Diptera followed by Hymenoptera, Hemiptera, Coleoptera and Lepidoptera.

For Sakumo the most abundant order was Hymenoptera followed by Diptera and then Hemiptera while Muni – Pomadze had Hymenoptera as the most abundant, followed by Coleoptera and Diptera. Insects comprise more than half of the world's known animal species (Wilson, 1992) of which the second largest and most diverse order is Lepidoptera (Benton, 1995). The most abundant and far more diverse order recorded at all the three sites was the Hymenoptera with Kpeshie being the most diverse followed by Sakumo and Muni- Pomadze.

The abundance and diversity of insects at a particular habitat depends on a wide range of factors including the availability of food, climate condition, abundance of larval food, egg laying and suitable flowers for feeding of adults (Allan et al., 1973; Pollard and Yates 1993). Diptera was abundant and diverse at Kpeshie because the site clearly differs in vegetation structure and botanical composition (Struhsaker, 1998; Nummelin, 1992) and thus it is very likely that the same factors cause differences in species composition within the area. The abundance of insects collected from Kpeshie compared to Muni-Pomadze was very high and

it can be attributed to the thick mangrove and other vegetation in the catchment area of the lagoon. Besides, due to the heavy pollution, of the lagoon, it is completely dead except for some few spots where volumes of water are trapped under the thicket of the mangroves which have some live fishes in them. As a result, the lagoon has lost its economic value since it is no longer possible to fish in it. The conducive environment created by the absence of any form of interference or disturbances has resulted in the high insect abundance. Again, the vegetation and especially the flowers serve as food sources hence the abundance of herbivorous insects.

Insects exploit plants for food by chewing, leaf-mining and boring, gall-formation, sucking and seed-eating. Chewing is the most common among the orders Orthoptera, Coleoptera and Hymenoptera. The mining insects include Lepidoptera, Diptera and Coleoptera.

The feeding habits of the range of specialist to generalist predators, scavengers and omnivores, to seedeaters and fungus feeders are all met due to the high abundance and diversity of both the prey and the predator. In the case of Sakumo and Muni –Pomadze, the Hymenoptera constituted the highest number of insects trapped but were not as abundant as Kpeshie. The difference in abundance at these two other sites can be attributed to the difference in vegetation cover at the sites. While Kpeshie is covered with a canopy of mangrove and other vegetation, Sakumo and Muni-Pomadze are grassy with few mangroves. Secondly, economic activity (e.g. fishing) is very high at these sites, subjecting the lagoons to intensive fishing activities throughout the year. These human activities disturb the breeding and other naturally instinctive behaviours of the insects. Due to the large grassland areas around the lagoons, cattle graze freely at these places and this also affects the ecosystem. Finally, these

are designated wetlands or Ramsar sites for migratory birds from all over the world (especially Sakumo). Some of these birds feed on insects and their larvae and this obviously has a direct effect on the abundance of the insects at these sites.

When the families are ranked according to number of species recorded from all the sites, the Formicidae (order Hymenoptera) was the most dominant, followed by Simulidae and Culicidae (order Diptera). The site with the most abundant insects was Kpeshie (2,128) individuals. Muni – Pomadze followed with 1,883 individuals with Sakumono having the least insect inventory of 1,530 individuals. Very few butterflies were recorded at Sakumo due to the fact that it is grassy with a few mangroves. Kpeshie lagoon is highly polluted (Plate 8) and the surrounding area is creating ideal condition for breeding mosquitoes and thus the high numbers of Culicidae. Insect especially Dipterans feed on rotten vegetation. Kpeshie had the highest abundance of insect because Simulidae was abundant at Kpeshie which was not found in the other two sites, Sakumono and Muni –Pomadze.

5.2. Observed Species Richness

Kpeshie had higher species diversity than the other two sites although it had the smallest area. This is not consistent with the theoretical expectations of species area relationship, where smaller areas tend to support fewer species (Scoener, 1976, May and Stumpf, 2000). Species richness (number of species) is currently the most widely used diversity measure. Relative species abundance in a community is another factor that affects diversity (Whittaker 1865, Hurlbert 1971). It is measured with a standardized index that is typically on a scale ranging from near 0, which indicates low evenness or high species dominance of all species or maximum evenness (Routledge, 1980; Alantato, 1981). Kpeshie recorded the highest indices

for Simpson (1/D) and Shannon Weiner (H) Margalef (D) and Pielou (J) diversity for both the dry and wet seasons. Kpeshie lagoon has suffered the highest human encroachment as individuals and business (La Beach Hotel) who bought land close to the lagoon have filled the lagoon with sand to reclaim the land for development. This has drastically reduced the natural size of the lagoon, to a fraction of what it is used to be. Kpeshie lagoon compared to Muni – Pomadze and Sakumo is highly polluted (Fig 15, 19, 20) Due to the close proximity of both residential and commercial buildings to the lagoon solid waste easily finds its way into the lagoon while for liquid waste, all the major drains from La township, Burma Camp, and part of East Cantonment find their way into the lagoon. Waste water from part of Teshie has been directed into the lagoon as a carriage way into the sea. Despite the effects of all the negative tendencies on the ecological setting, the Kpeshie lagoon area produced the highest trapped insect's in terms of abundance with the commonest species being *Odontomachus haematoda* (formicidae), *Aedes vexans* (culicidae) and *simulium Venustum* (simulidae)

Relatively fewer species were collected at Sakumo, though the lagoon is in the middle of a vast wetland vegetation is very sparse and the area is mostly covered by grass. The variations of temperature recorded in both dry and wet seasons were high as compared to Kpeshie which has more mangroves. Sakumo also has a high salinity and trace metal content, and this can be attributed to the closeness of the lagoon to the harbour and its open estuary to allow sea water to flow into the lagoon during high tides.

5.3. Estimated Species Richness among Sites

For many data sets, all existing methods for estimating undetected species seem to substantially underestimate the number of species present but the best method nonetheless reduces that inherent under sampling bias in observed species counts. Non-parametric estimators (e.g. Chao 1, Chao 2) perform best in empirical comparisons and benchmark surveys, and have a more rigorous framework of sampling theory than parametric estimators. Non-parametric estimators can help to reach inventories in less time and with lower costs (Petersen and McIver, 2003), since they can give a measure of how much sampling effort can be enough to reach a representative inventory. The same accumulation curves illustrate the rate at which new species are encountered and (Fig. 8) depict a gradual decrease in newly observed species during sampling although more effort would have uncovered yet more species. This can be pooled from the species richness estimators provided in Table. 2.

The other estimators of species richness include the Abundance-based Coverage Estimator (ACE), Incidence based Coverage Estimator (ICE), Chao1 and Chao 2 and they all give a fair idea of the actual number of species (Chao, 1987; Chao and Lee, 1992) which is necessary if conservation measures need to be put in place. The species richness recorded in the study however falls within the range of species richness estimators hence a fair sampling of the study areas. In the study, among the incidence estimators, one of better overall performance was ACE followed by Chao 1 then ICE. In the study, Jak 1 had similar performance but not as well as ACE and ICE.

5.4. Water Quality Analysis.

5.4.1. Temperature

According to Davies and Day, (1998) the rate at which chemical reactions occur increases with increasing temperature. The rate of biochemical reactions usually double for every 10 °C rise in temperature. Physically, less oxygen can dissolve in warm water than in cold water because increased temperature decreases the solubility of gases in water. Increased temperature increases respiration leading to increased oxygen consumption and increased decomposition of organic matter (Chapman, 1992). Temperature may be influenced by depth of water and air circulation as well as time of day (Peirce *et al.*, 1998). According to Samways (1991), Mc Geoch (1991) and Corbet (1980), temperature is important in thermoregulations, which affect insects. Temperature is known to affect insect physiology including life – history traits such as development, phenology and seasonal regulations as well as immune function and the production of pigment for thermoregulation. However very low temperatures may also increase stress during development (Chang *et al.*, 2007).

The monthly water surface temperature at Sakumo fluctuated between a range of 35 °C high (Fig. 9) and 30°C low with a mean temperature for both the dry and wet season of 32.4°C. At Muni- Pomadze, the temperature ranges from a high of 37 °C in June to a low of 31°C in December with a mean aggregate of 33.2°C. Kpeshie, due to its high mangrove thicket engulfing the lagoon, recorded the lowest temperature ranging from a high of 33 °C to a low of 27 °C with a mean of 39 °C. Relatively, Muni – Pomadze had the highest temperature range with a mean of 33.2 °C and this has a negative correlation with insect diversity and abundance. Sakumo had the second highest collection of insects despite the temperature level.

It must be stated however that Kpeshie had a positive correlation between insect abundance and diversity and surface water temperature.

5.4.2 pH

At a given temperature, the intensity of the acidic or basic character of a solution is indicated by pH or hydrogen ion activity (APHA, 1995). pH of water is a measure of the concentration of hydrogen ions (Davies and Day, 1998). pH is important in water quality assessment as it influences many biological and chemical processes within a water body (Chapman, 1992). Running waters are normally influence by the nature of deposits over which they flow (Hynes, 1930) while shallow lentic environments which favour the growth of phytoplankton are more influenced by photosynthetic activities which increase pH values (Symoens et al., 1981) The mean pH recorded at the various sites indicates that Kpeshie had the highest mean of 8.3 (Fig. 10) followed by Sakumono and Mini – Pomade which had 8 each. The high figure recorded in Kpeshie could be attributed to algal growth, washing activities and throwing of garbage into the lagoon. A one way ANOVA between groups conducted to assess the pH impact between the various communities, showed statistically significant differences ($p > 0.05$, $n = 6$) in the pH between kpeshie and the other sites, namely Sukumo and Muni- Pomadze.

5.4.3 Salinity

Salinity refers to the saltiness of water and for most purposes it can be considered to be equivalent to TDS. Salinisation also refers to an increased concentration in water of naturally occurring mineral ions, particularly those of sodium, chloride and sulphate (Davies and Day, 1998). The mean salinity value for Muni-Pamadze was significantly higher than Sakumo and

Kpeshie which recorded 2.9‰, 1.9‰ and 2.4‰ respectively (Fig. 11). A one-way between group ANOVA conducted to assess the salinities showed that the result is highly significant ($P < 0.01$).

5.4.4 Conductivity

Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of total concentration, mobility, valence and temperature of measurement of ions (APHA, 1995). Immoderate mean conductivity value should be within the natural background levels of 10-1000 $\mu\text{S}/\text{cm}$ (Chapman, 1992) for most fresh waters in the tropics. The mean conductivity in the wet season range from a maximum of 1513 $\mu\text{S}/\text{cm}$ at Kpeshie to a minimum of 306 $\mu\text{S}/\text{cm}$ for the dry season. The mean conductivity level was once again higher at Kpeshie followed by Sakumo and Muni -Pomadze (Table 3).

5.4.5 Turbidity

Turbidity refers to the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through water, is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms (APHA, 1995; Davies and Day, 1998).

The generally accepted value of turbidity ranges between 3.00-75.00 NTU (Amankwaah and Paintsil, 1996). The study recorded turbidity values that were within the generally accepted turbidity value ranges. Kpeshie recorded the highest with a mean value of 68 NTU followed by Sakumono with 53.7 NTU (Fig. 14) while Muni-Pomandze recorded the lowest value of 24.8 NTU. One way ANOVA indicated that there is highly significant difference in the

turbidity level between the sites ($P > 0.01$, $n = 6$, $P = 0.00$), probably due to algal bloom, which was very high during the dry season and low during the wet season.

5.4.6 Suspended solids

Suspended solids consist of material originating from the surface of the catchment area, eroded from river banks or lake shores and resuspended from the bed of the water body (Chapman, 1992). Suspended solids include tiny particles of silts and clays, living organisms (zooplankton, phytoplankton and bacterioplankton) and dead particulate organic matter (Davies and Day, 1998). Suspended solids normally increase with rainfall as particles are washed from surface soil into river and lagoons (Davies and Day 1998). This falls perfectly in line with the finding of this study from Muni-Pomadze where higher values were recorded in the rainy season than the wet season.

For Sakumo there was not much difference between the wet and dry season, but for Kpeshie showed the opposite (Figure 15) where higher values were recorded for the dry season. This is because during the wet season, the Kpeshie lagoon collects huge water volumes from the surroundings and this puts pressure on the sand bank that separates the lagoon from the sea and this causes it to give way for the lagoon to flow into the sea, thereby releasing most of its solid content to the sea. During the dry season on the other hand all the suspended solids are trapped in the lagoon hence the high figures. According to EPA (2002), background SS concentrations for aquatic ecosystem protection are < 100 mg/l and any changes should be limited to < 10 % of background levels for a specific site and time. Muni-Pomadze was the only site that fell within this range. The value for Kpeshie is about four or three times the background level. A comparison of the sites using one way ANOVA shows a highly

significant ($P < 0.01$) relationship between them which also has a positive correlation between especially Kpeshie and insect abundance and diversity.

5.4.7 Colour

Colour in water may result from the presence of natural metallic ions (iron and manganese), humus and peat materials, plankton, weeds and industrial wastes (APHA, 1995). The EPA (2002) standard or the background level they recommend for colour is less than 15.0 PtCo. High colour value of water could be attributed to suspended solids from rain off and decaying plants algae and other organic compounds in the water. The mean colour of the lagoons range from a high mean of 695PtCo for Kpeshie to a minimum of 191.7PtCo for Sakumo (Fig.16). One way – ANOVA showed a highly significant relationship between the sites ($P < 0.01$, $n=6$). The high figures from the Kpeshie lagoon could be due to large amounts of garbage and other waste materials deposited into it. There is however positive a correlation between insect abundance and diversity and colour at Kpeshie.

5.4.8 Dissolved Oxygen

The amount of oxygen that can be dissolved in water depends on the rate of aeration from the atmosphere, temperature, air pressure and salinity. The actual amount of oxygen in water depends on the relative rates of respiration by all organisms and of photosynthesis by plants. Oxygen levels are naturally low where organic matter accumulates, because aerobic decomposer micro-organisms require and so consume oxygen (Davies and Day, 1998).

The WHO concentration range for the level of Dissolved Oxygen in surface portable water is 5.0 – 7.0mg/l. Kpeshie had the lowest mean of 1.1mg followed by Sakumo (3.0mg/l) and Muni-Pomadze (4.9mg/l). (Fig. 17)

5.4.9 BOD

The biochemical oxygen demand (BOD) is an approximate measure of the amount of biochemically degradable organic matter present in water. BOD is not a specific pollutant but rather a measure of the amount of oxygen required by bacteria and other microorganisms in decomposing organic matter to a stable inorganic form (Chapman, 1992; Peirce et al., 1998). Muni – Pomadze had the highest mean value of 5.4mg/l followed by Sakumono with 3mg/l then Kpeshie with the lowest mean of 1.7mg (fig. 18).

5.4.10 Total Coliform

Total coliform gives a clear indication of the general sanitary quality of water since this group includes bacteria of faecal origin. However, many of the bacteria in this group may originate from growth in the aquatic environment. Total coliform is used to evaluate the general sanitary quality of drinking water and related water (EPA, 2002). The highest level of contamination occurred at Kpeshie with a mean coliform level of 37241cfu/100 Sakumo had a mean of 13047cfu/100 while that of Muni – Pomadze was 1967.7 cfu/100. There was a significant difference ($P > 0.05$, $n=6$. $P = 0.083$) (Fig. 19). The total coliform in Kpeshie was high due to inflow of waste water to the lagoon. Sakumo is also high due to contamination.

5.4.11 Faecal Coliform

Bacteriological examinations of water samples are to determine sanitary quality, and the degree of contamination with wastes (APHA, 1995). Faecal coliform are bacteria that live in the digestive tract of warm-blooded animals and are excreted in the solid wastes of human and other mammals. Where faecal coliforms are present, however, disease-causing bacteria are usually also present. Untreated faecal material that contains faecal coliforms adds excess

organic material to the water. The decay of this material depletes the water of oxygen, which may kill fish and other aquatic life (Spellman and Drinan, 2000).

Faecal coliform contamination is relatively high at Kpeshie due to the high numbers of houses in La and other sites around the lagoon which do not have places of convenience. A lot of faecal waste therefore is dumped into drains and bushes around the lagoon which are washed into the lagoon when it rains. The mean values for faecal coliform for the various sites recorded 70424 cfu/100 for Kpeshie, Sakumo had 19,819 and that of Muni- Pomadze was 4905.7 cfu/100 (Fig. 20). There was a significant difference ($P > 0.05$). It must however be stated that the high faecal coliform level at Kpeshie has a positive correlation with insect abundance and diversity.

5.4.12 Trace Metals

All trace metals tested recorded high values, due to dilution by heavy rains during the wet season. The high dry season concentration (Table 4) could be due to evaporation, which reduces the amount of water in the lagoons and thus increases the amount of the trace metals per liter of water.

The levels of heavy metals in excess of natural loads have become a problem of increasing concern. This may be due to rapid population growth, increased urbanization, agricultural practices as well as lack of enforcement of environmental regulation. Table 4.5 shows the various levels of trace metals in Kpeshie, Skumo and Muni- Pomadze lagoons.

5.4.13 Concentration of Iron/Fe and Lead (Pb)

The highest value for Fe was recorded at Sakum (0 2.177mg/l) during the dry season while the least Fe concentration was recorded at Kpeshie during the wet season. The high level of concentration in the Sakumo lagoon can be attributed to the closeness of the lagoon to the Tema Harbour. A one-way ANOVA showed variance ($P < 0.01$ $n=6$) in the wet season while that of dry season showed a high significance level of $P < 0.01$ $P = 0.00$. The highest concentration of lead was recorded at Kpeshie during the dry season 1.378mg/l with the lowest being absent at Sakumo in the wet season (Table 4). One-way ANOVA revealed a highly significant relationship where $P < 0.01$ in the dry season and $P = 0.00$ for the wet season.

5.4.14 Concentration of Cadmium and Calcium

A maximum of 0.952 mg/l cadmium level was recorded at Muni- Pomadze during the wet season with a minimum of 0.23mg/l recorded at Sakumo during the wet season. One-way ANOVA comparing wet and the dry seasons gave a significant difference of $P < 0.05$, $n=9$, $P = 0.362$ for the dry season and for the wet season, $P = 0.224$. The highest calcium level of 851.5mg/l was recorded at Sakumo during the dry season while the lowest was recorded at Muni- Pomadze during the wet season 325.7mg/l. One-way ANOVA showed a highly significant relationship between the sites during the dry season ($P < 0.01$), while the wet season variance was $P = 0.001$

5.4.15 Magnesium Mg/ Zinc Zn

The highest magnesium level was recorded at Kpeshie during the dry season (221.04mg/l) with the least being recorded at Sakumo during the wet season 78.17mg/l (Table 4). One-way ANOVA for relationship between the sites during the wet season was $P < 0.01$ and $P = 0.00$.

The highest Zinc value was recorded at Sakumo during the dry season 0.239mg/l with the least being 0.005 at Muni- Pomadze during the wet season (Table 4).

5.5. Social Survey

5.5.1 Sex of respondents

A total of 280 people were sampled for the study for the three sites. Out of this number 143 were women and the remaining 137 were men. This means that 51% were women.

5.5.2. Educational level

About 24% of the respondents had Middle School or JHS level of education, while 22.14% of the respondents ended their education at the Ssecondary or SHS level. Fourteen percent had Tertiary education while 7.14% had no formal education. Due to the new infrastructural development around the Kpeshie and Sakumo lagoons urban dwellers are moving to these sites hence, the number of respondents sampled for tertiary education were 14 for Sakumono and 17% for La trade fair area (kpeshe) respectively with Mankwadze having the least with only 9%. Mankwadze recorded the highest number of Middle and JHS leavers with 25% respondents followed by 24% of people for Sakumono and 18% of people for La Trade Fair. Sakumono and La Trade fair had the highest number of respondents of Vocational, Commercial and Technical Educatio status.

5.5.3 Income Level

The number of respondents who were in a category that earn less than GH¢200.00 monthly had the highest figure of 40.14% in the Mankoadze. Whiles Sakomono and La Trade Fair area

had 16%, and 28% respectively. These can be attributed to the fact that Mankoadze has more low income dwellers relative to Sakomo and Kpeshie which have seen the settlement of illegal dwellers due to infrastructural development around these areas. As a result for the category of those who earn GH¢800 and above income, Mankoadze recorded 0.9% compared to Sakumono and Trade fair. It must be pointed out that the development of homes around Trade Fair area has resulted in their liquid waste being channeled into the Sakumo and Kpeshie lagoons. Hence the high level of trace metal and other pollutant, being high in these two sites. This also explains why species such as Culisidae are abundant around these sites.

5.5.4. Occupational Status

Majority of the people were unemployed or engaged in casual jobs. Majority of the respondents in Mankoadze were unemployed with the highest percentage of 33. Forty percent of the people were engaged in fishing (Fig. 21). At Kpeshie, 3.4% of the people were self employed this is due to the building construction going on around this areas.

5.5.5 Waste Disposal and Sanitation

Waste disposal and sanitation are major challenge in Ghana and this was manifested at all the study sites. In the case of Kpeshie for instance, there are a number of hotels in the Municipal area. The La Pleasure Beach Hotel transports its waste water to an activated sludge system which is located around the junction of the lagoon. Kpeshie Lagoon is the receiving water body to the various drains in the Kpeshie catchment (Fig.23). Water that enters the lagoon has its sources from the communities of Burma Camp, La, Tebibiano, Teshie Camp, Africa Lake and from the mangrove swamp surrounding the lagoon. The Africa Lake which receives storm water from its environs opens into the lagoon. The waste water from Burma Camp is

channeled through sewers into a waste stabilization pond. La, Tebibiano and Teshie Camp townships mostly use pit latrines (Kpanja, 2006).

The social survey revealed that a substantial number of inhabitants within the study area had no access to basic sanitation facilities such as toilets and appropriate waste disposal mechanisms. As indicated in Fig. 22 71% of the respondents admitted that they had no access to private toilet facilities. About 45% of the respondents without access to private toilets mentioned bushes, river banks and refuse dump sites as alternatives to public toilets. Again, more than 50% of those who used the public toilets expressed dissatisfaction about the unhygienic nature of the place. Human faeces were seen around most of the sampling sites especially Kpeshie and parts of Mankoadze. Few of the communities visited had official refuse dump sites and some of these official sites were improperly located and not well maintained, which is very typical of a developing country (Noi- Nortey, 1990). For example, at Mankoadze and Trade Fair areas, one of such official dump site had been located extremely close to the lagoons. This observation is in line with Noi – Nortey (1990) and Akuffo (1998), who asserted that in developing countries, sanitation is the least developed and much of the pollution loads come from domestic rather than industrial sources. Thus the neglect of sanitation makes it extremely difficult in controlling water pollution in developing countries.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The main aim of this study was to determine how human activities influence insect diversity and abundance in and around the wetland environment and also to examine the major sources of pollution of the Kpeshie, Muni- Pomadze and Sakumono lagoons. The study also involved the assessment of the physico-chemical quality of the water of the three wetlands. The first aspect of the study involved a reconnaissance visit to the study areas to identify some of the major activities of the area, identify the major sources of pollution that impacted negatively on the three sites and this helped to select the sampling points at Kpeshie, Muni-Pomadze and Sakumo wetland sites.

The following traps were used to capture the insects at selected points around the sites: (i) Malaise traps collected flying insects; (ii) charaxes traps were used to sample butterflies; (iii) pitfall traps collected ground dwelling and crawling insects, (iv) yellow pan traps collected insects that are attracted to the yellow colour; (v) flight interception traps were mainly used to collect flying insects which are not likely to be attracted to bait or light; (vi) sweep nets was used to collect insects around vegetation, and (vii) aerial nets were also used to catch flying insects. Two hundred and eight questionnaires were distributed to respondents in all the three sites. The questionnaires were used to obtain information on the ages, gender, level of education, occupation, level of income of respondents as well as their mode of disposal of both solid and liquid wastes. There was enough evidence that lagoons holds considerable

potential for biodiversity conservation, biodiversity includes genetic diversity species richness and ecosystem diversity and assumes that these are inter dependent (Groom bridge and Jenkins, 2002) and quantified through taxonomy inventories with specified areas (Fox and Rowntree, 2000) There are indications, that with the rapid socioeconomic changes and urbanization, many lagoons have been completely destroyed for example Kpeshie lagoon which is highly polluted and completely destroyed. Others like Sakumo lagoon are under imminent threat from developers who are building so close to the catchment area of the lagoon. People living close to the kpeshie lagoon do not visit it to fish any more but to defecate and dump rubbish into the lagoon. Sakumomo is also having its fair share from residence.

6.2 Recommendation

As a result of the observations and findings made form this study the following recommendations have been suggested to control and manage lagoons and other wetlands.

1. There should be vigorous of education that will stress on the importance of wetlands on the ecosystem by the Environmental Protection Agency.
2. District Assemblies should enact byelaws to curb pollution sources like waste dumping, washing of vehicles and defecating in the lagoons.
3. District Assemblies should re-design the drains and channels at La township, Teshie and Madina to divert water flows into the lagoons.
4. The Environmental Health Department of the various District, Municipal and Metropolitan Assemblies and the Environmental Protection Agency (EPA) should intensify environmental health and sanitation education of the inhabitants within the three sites especially the Kpeshie lagoon catchment areas. The health education should

stress more on the health implications as a result of the high numbers of disease-transmitting insects like the Culicidae and Simulidae which carry the vectors that cause malaria and river blindness respectively.

5. A buffer zone of about 200m wide should be created along the boundaries of the lagoons to prevent encroachment by estate developers who may build too close to the lagoon as pertains at Kpeshie
6. Further research needs to be carried out on insect diversity around lagoons in the different regions of Ghana in order to establish their significance for conservation. Such an approach will be useful in creating global awareness of the insect diversity value of lagoons and wetlands in Ghana.
7. Further research should be carried out to investigate the presence of high numbers of Simulidae around the Kpeshie lagoon.

REFERENCES

- Aide, T. M. (1993).** *Dry season leaf production: an escape from herbivory.* *Biotropica* 24:532-537
- Allan, R. K. (1973).** *Willstatter-stoll theory of leaf reflectance evaluated ray tracing,* *Applied Optics.* Optical Society of America.
- Alloway, B. J. (1990).** *Heavy Metals in Soils.* John Wiley and Sons, Inc. New York.
- Akuffo, S. B. (1998).** *Pollution Control in a Developing Economy. A Study of the Situation in Ghana. (2nd Edition).* Ghana Universities Press, Accra. 128 pages.
- Amankwaah, C., C. & Paintsil A (1996).** *Country Environmental Profile. Europa. E4 development-center.* Ghana.
- Amatekpor, J. K. (1994).** *Soils, Landuse and Land Degradation. Ghana Coastal Wetlands Management Project. Environmental Baseline Studies (Sakumo Ramsar Site).* Prepared for the Department of Game and Wildlife, Government of Ghana. September 1994. 66 pages
- Alcocer, E., Garcera, M. D., & Martinez, R. (2001).** A Novel Class of Luminescent Polymers Obtained by the Sol-gel Approach. *Journal of Alloys and Compounds.*
<http://linkinghub.elsevier.com/retrieve>
- American Public Health Association (APHA), (1995).** *Standard Methods for the Examination of Water and Wastewater. 19th Edition.* Prepared and published jointly by American Public Health Association, American.
- Annang, E. A. (2000).** *Assessment of Water Quality of Two Wetlands- Chemu and Laloi Lagoons- in the Tema Export Processing Zone.* KNUST, Kumasi. MSc. Thesis, pp 17-60
- Anon, (2001).** *Report of the Ad Hoc Technical Expert Group on Forest Biological Diversity (UNEP/CBD/SBSTTA/7/6).*
- Alloway, J. B and Ayres, C. D. (1993).** *Chemical Principles of Environmental Pollution.* Blackie Academic and Professional. New York. 291 pages.
- Barbier, E. B., M. Acreman, and Knowler, D. (1997).** "Economic Valuation of Wetlands: A Guide for Policymakers and Planners," Cambridge, England: Ramsar Convention Bureau, Department of Environmental Economics and Management, University of York.
- Barbour M. G., Burk J. H., Pitts, W. D., Gilliam, F. S., Schwartz M. W. (1998).** *Terrestrial Plant Ecology. 3rd Edition.* Addison Wesley Longman, California.

- Basset, Y. (1991).** The taxonomic *composition of the arthropod fauna associated with an Australian rainforest tree*. Australian Journal of Zoology 39, 171-190.
- Basset, Y. (1991).** The *seasonality of arboreal arthropods foraging within an Australian rainforest tree*. Australia Ecological Entomology 16, 265-278.
- Basset, Y. (1991).** *Influence of leaf traits on the spatial distribution of insect herbivores associated with an over storey rainforest tree*. Australia. Oecologia 87, 388-393
- Basset, Y. (1996).** *Arthropods of Tropical Forests: Spatio-Temporal Dynamics and Resource use*. University Press. Cambridge.
- Benton, T. G. (1995).** *Biodiversity and biogeography of Henderson Island insects*. Biol. J. Linn. Soc., 56(1-2): 245 – 259.
- Biney, C. (1995a).** *The Threat of Pollution to the Coastal Zone of the Greater Accra Metropolitan Area, Ghana*. J. Sci. 31-36, 47-5
- Boorman, J. (1981).** *West Africa Insects*. Longman Group Limited.
- Brook, B. W. and Bradshaw, J. A. (2006).** *Strength of evidence for density dependence in abundance time series of 1198 species*. Ecology, 87, 1445–1451.
- Carter, D. Edmonds, A., Dewhurst, H. Hewson, Bradley, J. D., Webber, C. and Optler, A. (1992).** *Butterflies and Moths*. Stoddart Publishing Co. Limited.
- Chapman, D. and Kimstach, V. (1992).** *The Selection of Water Quality Variables. Water Quality Assessment – A Guide to the use of Biota, Sediment and Water in Environmental Monitoring*. Published on behalf of UNESCO.
- WHO and UNEP, 60- 116**
- Chapman, D. (1992).** *Water Quality Assessments. A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*. Published on behalf of UNESCO. WHO and UNEP London
- Chang, L., Kun L., You, C. & Jongyu, S. (2007).** *Foraging Behaviour of three insect Pollinators of Satropha curcas*. www.scielo.br/scelo.php?pid.
- Chao, A. (1987).** *Estimating the population size for capture-recapture data with unequal catchability*. Biometrics, 43:783-791.
- Chao, A. and Lee, S. M. (1992).** *Estimating the number of classes via sample coverage*. Journal of the American Statistical Association, 87:210-217.

- Collar, N. J., Crosby M. J. and Stattersfield A. J. (1994).** Birds to Watch 2 (The World List of Threatened Birds). *Official Source for Birds on the IUCN Red List*. Birdlife International, Cambridge, UK.
- Coley, P.D. (1980).** *Effects of a leaf age plant life patterns on herbivory*. Utah
- Coley, P.D. and Barone, J. A. (1996).** *Herbivory and plant defences in tropical forests*. *Ann Rev Ecol Syst* 27:305-335.
- Collison, R. C., Harlan, J., & Streeter, L. R. (1995).** *Pattern Recognition in Biology*. NOVA Publishers. Inc. UK.
- Constanza, R. D'arge, R. and De Groot, R. (1997).** *The Value of the World's Ecosystem Services and Natural Capital*. Nature Publishing Group. USA. Books. Pennsylvania State University, USA.
- Corbet, P. (1980).** *Biology of Odonata. Annual Review of Entomology*, Ithaca, New York: Cornell University Press.
- Curry-Lindahl (1972).** *National Parks of the World. The Golden Press*. New York.
- Davies, B. and J. Day, J. (1998).** *Vanishing Waters*. UCT Press. USA.
- Derlinger, D. L. (1980).** *Everything you Need to Know*. www.scribd.com.
- Denlinger, D. L. (1986).** *Low Temperature Biology of Insects*, Cambridge University Press. 390 pp
- Deszoley, A. S. & Resh, V. H. (2000).** *Factors Influencing Macroinvertebrate Colonization of Seasonal Wetland: response to emergent plant cover*. Wiley New York.
- Dial, R. and Roughgarden, J. (1995).** *Experimental removal of insectivores from rain forest canopy: direct and indirect effects*. *Ecology*, 76: 1821-1834 .
- Didham, K. and Springate, D. (2003)** *Determinants of Temporal Variation in Community Structure*, Basset Y., Novotný V., Miller S.E. & Kitching R.L. (Eds): *Arthropods of Tropical Forests: Spatio-Temporal Dynamics and Resource Use in the Canopy*. Cambridge University Press, Cambridge, pp. 28–39.
- Emerton, L., Iyango, L., Luwum, P. and Malinga, A. (1999),** *The Economic Value of Nakivubo Urban Wetland*, Uganda.
- Environmental Protection Agency, Ghana. (2002).** *Water Quality Standards. National Workshop on Water Quality Standards*. Accra, 30th September, 2002.

Food and Agricultural Agency. (1991a). *Strategies for the establishment of a network of in situ conservation areas. secretariat note cpgr/91/6. fourth session of the FAO commission on plant genetic resources, Rome, 15-19 april 1991.* [published in FAO, 1992. FAO activities on in situ conservation of plants genetic resources. forest genetic resources information no. 19. Rome.]

Food and Agricultural Agency. (1991b). *Report of the Committee on Forest Development in the Tropics, Tenth Session.* FO:FDT/91/REP. Rome.

Food and Agricultural Agency. (1991c). *Sustainable management of tropical forests. Secretariat Note. FAO Committee on Forest Development in the Tropics, Tenth Session.* FO:FDT/91/5. Rome.

Floren, A. and Linsenmair, K. E. (2003). *How do Beetle Assemblages Respond to Anthropogenic Disturbance?* Basset Y, Novotny V, Miller SE, Kitching RL (eds) *Arthropods of Tropical Forests: Spatiotemporal dynamics and Resource Use in the Canopy.* Cambridge University Press, Cambridge, pp 190-197.

Fox, R. and Rowntree, K. (2000). *The Geography of South Africa in a Changing World.* Oxford University. Press, Oxford, UK.

Gee, S. J., Schutz, S., Wengatz, I., Goodrow, M. H., Hummel, H. E. (1997). *A Comparison of Aquatic Insect Community Among Agricultural and Forested Lands.* Pro Quest LLC. Ann Arbor. USA.

Ghana News Agency (2010). *RTI a tool for Environmental Protection Report.* www.ghanaweb.com.news

GESAMP (1988) *The Contribution of Science to Integrated Coastal Management Rep. Stud.* GESAMP. Food and Agricultural Organization.

Gordon, I and Cobblah, M. A. (2000). *Insects of the Muni-Pomadze Ramsar Site. Biodiversity and Conservation. Kluwer Academic Publications Vol. 9, No. 4, 479-486.*

Gordon, I. and Cobblah, M. (2009). *Insects of the Muni-Pomadze Ramsar site. Biodiversity and Conservation. Special Issues: Biodiversity and Ecology of Coastal Wetlands in Ghana. Kluwer Academic Publishers. Netherland.*

Gradwohl. J. and Greenberg, R. (1982). *The Effect of a Single Species of Avian Predator on the Arthropods of Aerial Leaf Litter.* Island Press. Appleton, USA.

- Groombridge, B. and Jenkins, M. D. (2002).** *World Atlas of Biodiversity: Earth's living resources in the 21st century.* University of California Press, Berkeley.
- Groves, C. R. (2002).** *Drafting a conservation blueprint: A practitioner's guide to planning for biodiversity.* Island Press, Washington.
- Gullan, P. J. and Cranston, P. S. (2005).** *The Insect— An Outline of Entomology.* Blackwell, London.
- Gyasi, E. A., Agyepong, G. T., Ardayfio-Schandorf, E., Enu-Kwesi, L., Nabila, J. S. and Owusu-Bennoah E. (1995).** Production pressure and environmental change in the forest-savanna zone of southern Ghana. *Global Environmental Change* 5 (4): 355–366..
- Hamer, L., Adachi, K., Montenegro-Chamorro, M. V., Tanzer, M. M., Mahanty, S. K., Lo, C., Tarpey, R.W., Skalchunes, A. R., Heiniger, R. W., Frank, S. A., Darveaux, B. A., Lampe, D. J., Slater, T. M., Ramamurthy, L., DeZwaan, T. M., Nelson, G. H., Shuster, J. R., Woessner, J. and Hamer, J. E. (2001).** *Gene discovery and gene function assignment in filamentous fungi.* Proc. Natl. Acad. Sci. USA 98, 5110–5115.
- Hamer, P. H., Kelly, D. A., Gabriel, L. Focks, T. L. (2005)** *Land Use Habitat Integrity, and Aquatic Insect Assemblages in Central Amazonian Streams.* Springer Science Business Media. Plenum Press. New York.
- Hanski, I., Lindström, J. Niemelä. J. Pietiäinen, H. and Ranta, E. (1998).** *Ekologia.* WSOY. Juva.
- Hannawi, S. & Hush, D. R., (1987).** *Diversity, Abundance and Behaviour of diurnal (insects on flowers.* [http://onlinelibrary.Wiley. Com/login-options](http://onlinelibrary.Wiley.Com/login-options).
- Hopkins, G. W. and Memmott, J. (2003).** *Seasonality of a tropical leaf-mining moth: leaf availability versus enemy-free space.* Ecol Entomol 28:687-693.
- Hurlbert, S. H.(1971).** *Insect Developmental Inhibitor. 3. Effects on Nontarget Aquatic Organisms.* Entomological Society, America.
- Hynes, H. B. N. (1930).** *Taxonomy of Aquatic Insects Nymphs and Larvae:* Cambridge University Press. UK.
- Hynes, H., B., N. (1971).** *Productivity of World Ecosystem. Special Committee for the International Biological Program Seattle, Washington.*

IGBP/HDP. (1993). *International Geosphere and Biosphere Programme/ Human Dimensions Programme (IGBP/HDP). Relating Land Use and Global land-cover Change.* IGBP Report Number 24, HDP Report Number 5 MCG.

Intachat, J, Holloway J. D. and Staines, H. (2001). *Effects of weather and phenology on the abundance and diversity of geometroid moths in a natural Malaysian tropical rainforest.* J Trop Ecol 17:411-429. Malaysia.

Janzen, D. H. (1993). *Herbivores and the number of tree species in tropical forests.* American Naturalist, 104, 501–528

Kalka, M. B., Smith A. R. and Kalko, E. K. V. (2008). *Bats limit arthropods and herbivory in a tropical forest.* University of Wisconsin – Arizona state.

Kamugisha, J. R. (1993). *Degraded Forest in Eastern Africa: Management and Restoration.* Earthscorn Ltd, Dunstan House, 14a st cross street, London.

Karban, R. (1986). *Interspecific competition between folivorous insect *Erigeron glaucus*.* Ecology. University of Wisconsin – Arizona state.

Keith Arthur John. (2013). *Apterygota, Caddisfly and Neuroptera.* **Encyclopaedia Britannica Incorporated.**

Kirkwood, R. C. J. Longley, A. J. (1995). *Clean Technology and the Environment.* Blakie Academic and Professional Glasgow. United States of America

Kpanja, D. (2006). *La Sub Metro Annual Report. Accra, Ghana. pp 8-30.*

Kwei, E. A. (1974). *Periphyton: Ecology, Exploitation and Management.* CABI Publishing, Oxfordshire, UK.

Lawton J. H and Strong, D. R. (1981). *Community patterns and competition in folivorous insects.* Am Nat 118:317-338.

Lawton, J. H, and Hassell M. P. (1981). *Asymmetrical competition in insects.* Nature 289:793-795. Cromwell Road London.

Loiselle, B. A. and Farji-Brener, A. G. (2002). *An experimental comparison of predation levels between canopy and understory in a tropical wet forest.* Biotropica, Washington DC 34, 327–330.

Maltby, L. (1986). *Aquatic invertebrates of Alberta: An illustrated Guide.* The University of Alberta Press, Canada.

- Mather, A. S. (1986).** *Land use*. Longman, London, UK.
- May, R.M. and Stumpf, M.P.H. (2000).** *Estimation of species extinctions. Rain forest conservation fund*. North Clark street. Chicago.
- Mattson, W.J. (1980).** *Herbivory in relation to plants nitrogen content. North central forest experiment*, USDA. Forest service. St Paul Minnesota.
- Mediterranean Wetlands Initiative (2013).** *Our changing environment*. United Nations Environmental Programme.
- Memmott, J., Godfray, H. C. J. and Gauld, I. D. (1994).** *The Structure of a Tropical Host Parasitoid Community*. Journal of Animal Ecology 63, 521-540
- Metcalf, and Eddy, Inc. (2003).** *Wastewater Engineering Treatment and Reuse, 4th edition*. Mc Graw Hill, New York. pp. 29-88.
- Moore, R. (1995).** *Botany*. Mc Graw Hill, New York. pp. 295-300.
- Margalef, R. (1958).** *Temporal succession and spatial heterogeneity in phytoplankton*. In: Perspectives in Marine biology, Buzzati-Traverso (ed.), Univ. Calif. Press, Berkeley, pp. 323-347.
- Ministry of Lands and Forestry, (1999).** *Managing Ghana's Wetlands: National wetlands Conservation Strategy Report*. Ghana.
- Moore, G., Devos, K. M., Wang, Z. and Gale, M. D. (1995).** *Gramineouses, line up and form a circle*. Curr Biol5:737–739
- Morris, R. M. M. S., Rappe, S. A. C., Onnon. K. L. V., Ergin, W. A., Siebold, C. A. Carlson, and S. J. Giovannoni. (2004).** *SAR11 clade dominates ocean surface bacterio plankton communities*. Nature 420:806–810
- Morse, J.C., Stark, B. P. and McCafferty, W. P. (1993).** *Southern Appalachian streams at risk: implication for mayflies, stoneflies, caddisflies, and other aquatic biota*. *Aquatic Conservation: Marine and Freshwater Ecosystems* Illinois 3:293-30
- .Musali, P. (1994).** *Collaborative Forest Management*. School of Forestry, Agricultural and Environmental Studies Makerere University, Kampala.
- Mitsch, W. J. and Gosselink, J. G. (1993).** *Wetlands: Characteristics and Boundaries*. National Academy Press. Washington DC.
- National Academy of Science, (1995).** *Nonindigenous Aquatic Species* data base .Florida.

- Noye-Nortey, H. (1990).** *Effects of pine silviculture on the ant assemblages (hymenoptera:formicidae) of the Patagonian steppe.* Elsevier. www.elsevier.com
- Novotny, V. and Basset, Y. (1998).** *Rare species in communities of tropical insect herbivores pondering the mystery of singletons.* *Oikos* 89:564-572
- Novotny, V., Basset, Y., Miller, S. E., and Pyle, R. (1999).** *Quantifying biodiversity: experience with Parataxonomist and digital photography in Papua New Guinea and Guyana.* *Bioscience* **50(10)**:899-908.
- Novotny, V., Miller, S. E., Basse, Y., Cizek, L., Drozd, P., Darrow, K. and Leps, J. (2002).** *Predictably simple: assemblages of caterpillars (Lepidoptera) feeding on rainforest trees in Papua New Guinea.* *Proc R Soc Lond B.* Papua New Guinea.
- Novotny, V., Basset, Y., Miller, S. E., and Pyle, R. (2003).** *Insect Biodiversity: Science and Society.* Wiley Publication Oxford OX4 UK.
- Ntiamo-Baidu, Y. (1987).** *West African wildlife: a resource in jeopardy.* *Unasylya* 156: 27–42.
- Ntiamo-Baidu, Y. (2010).** *Ghana owns only one wetland in the country out of five.* Ghana News Agency interview Report.
- Ntiamo-Baidu, Y. and Gordon, C. (1991).** *Coastal wetlands management plans: Ghana Environmental Protection Council and World Bank. Ghana Environmental Resource Management Project (GERMP) Report, Accra.*
- Ntiamo-Baidu, Y. (1987).** *Multiple Use Approach to Coastal Wetland Conservation: Case Studies from Ghana.* **Proceedings of the International Seminar on Coastal Wetlands Conservation and Coastal Zone Planning, Their Contribution to Sustainable Development in West Africa, Senegal**
- Ntiamo-Baidu, Y. (1989).** *Conservation of Coastal Lagoons in Ghana. The Traditional Approach.* . Leiden, The Netherlands.
- Nummelin, M. (1996).** *The community structure of arthropods in virgin and managed sites in the Kibale Forest, Western Uganda.*
- O’Neil P. (1994).** *Environmental Chemistry. 2nd edition.* Chapman and Hall, London, UK. pp 883.
- Oduro, W. and Aduse-Poku, K. (2005).** *Preliminary assessment of fruit-feeding butterfly communities in the Owabi wildlife sanctuary.* *Ghana Journal Forestry* **17 and 18:**

- Oertli, B., Joye, D.A., Castella, E. Juge, R., Cambin D. and Lachavanne, J-B.(2002). *Does size matter? The relationship between pond area and biodiversity. Biological Conservation* 104: 59-70
- Publishers, Boca Raton, London, New York Washington D.C. pp38- 90**
- Parker, R. L. (1995).** *The collection and utilization of pollen by the honeybee.* Cornell University Agricultural Experiment Station Memoir, 98:1-55.
- Peirce, J., R.F. Weiner and P.Aarne Vesilind, (1998).** *Environmental Pollution and Control. Fourth Edition.* Boston.
- Peterson, D. and McIver L. J. (2003).** *Physiological systems in insects.* Academic Press, New York.
- Price, P. (1997).** *Insect ecology (3rd ed.).* John Wiley & Sons, Inc. New York.
- Price, P .W. (1983).** *Hypotheses on organization and evolution in herbivorous insects communities.* Academic press, New York.
- Pielou, E. C. (1966).** *The measurement of diversity in different types of biological collections.* J. Theoret. Biol., 13: 131-144.
- Pollard, E and Yates, T.K. (1993).** *Monitoring butterflies for ecology and conservation: The British butterfly monitoring scheme.* Chapman and Hall, London.
- Ramsar Convention, (1987).** *National Framework and Guidance for Describing the Ecological Character of Australian Ramsar Wetlands.* Water Matters Wetlands Australia.
- Ramsar Convention, (1971).** *International Conference on Conservation of Wetlands and Waterfalls, Ramsar, Iran : Proceedings.* Slimbridge: International Wildfowl Research Bureau.
- Resh, V. H. and Carde, R. G. (1978).** *Encyclopedia of insects.* Academic Press, USA.
- Resh, V. and Carde, R. (2003).** *Encyclopedia of Insects.* San Diego, CA: Academic Press, Elsevier Science.
- Ricard, R. B. and Davies R. L. (1978).** *Hydro Dynamics and Sedimentation in Wave Dominated Coastal Environment.* Elsevier Science. New York.
- Richards, L. A. and Coley, P.D. (2007).** *Seasonal and habitat differences affect the impact of food and prédation on herbivores: a comparison between gaps and understory of a tropical forest.* Oikos, 116, 31–40.

Routledge, (1980). *The Routledge Handbook of Tourism and the Environment.* Routledge 2. Park Square. USA.

Russell, D.L. (2006). *Practical Wastewater Treatment.* John Wiley & Sons, Inc., Hoboken, New Jersey. pp 39-88

Ryan, J. M. and Attuquayefio D. K. (2000). Mammal fauna of the Muni-Pomadze Ramsar site, Ghana. *Biodiv. Conserv.* **9**: 541–560.

Ryan, R. O. (2005). *Archives of Insect Biochemistry and Physiology.* John Wiley & Sons Inc. New York.

Ryan, J. M. and Ntiamo-Baidu, Y. (1998). *Studies on the terrestrial fauna of coastal Ramsar sites, Ghana.* Ghana Coastal Wetlands Project.

Sam, E. K. and Ayibotele, N. B. (1987). *Lowlands Favours the Spread of Insects and Rodents.* Link Springer. Com.

Sather, J. M. and Smith, R. D. (1984). *An overview of major wetland functions and values.* Fish and Wildlife Service, FWS/OBS-84/18, Washington DC. 152 pp

Scheren, P.A.G.M., Zanting, H. A. and Lemmens, A. M. C. (2000). *Estimation of water pollution sources in Lake Victoria.* East Africa.

Seyam, I. M., Hoekstra, A. Y., Ngabirano G. S. and Saverije, H. H. G. (2001). *The value of water. Research Report Series No 7.* Netherlands, 2601 DA Delft.

Shelton, A. M. (2005). *Interpreting Drinking Water Quality Analysis: What Do the Numbers Mean? 6th edition.* Rutgers Cooperative Research & Extension. pp 13-45.

South wood. T. R. E. (1978). *Ecological methods.* Chapman and Hall, London, 524 app.

Standard Method. (2005). *Standard Methods for the Examination of Water and Wastewater, 20th edition.* American Public Health Association, Washington D.C. pp 170-287.

Shannon, C. E. and Wiener, W. (1949). *The mathematical theory of communication.* Urbana, University of Illinois Press, 177 p.

Scholtz, J. C and Holm, R. T. (2005). *Climate Change Impact: Insects.* Dartmouth College. New Hampshire, US.

Spellman, F. R. and Drinan, J. (2000). *The Drinking Water Handbook.* Technomic Publishing Company. Inc. U.S.A. 260p.

Samways, M. J. (1991). *Insect Diversity Conservation.* Cambridge University Press, UK

- Struhsaker, T.T. (1998).** *A biologist's perspective on the role of sustainable harvest in conservation. Conservation Biology* **12(4)**: 930-932.
- Twumasi, P. A. (2001).** *Social Research in Rural Communities. Second Edition. Ghana Universities Press. 163 page*
- Tanaka, L.K. and Tanaka, S.K. (1982).** *Rainfall and selected changes in Arthropod abundance on a tropical oceanic island. Biotropica* **14**:114-23
- Tumbulto, J. W. and R. R. Bannerman, (1995).** *Hydrology. Ghana Coastal Wetlands Management Project. Environmental Baseline Studies (Sakumo Ramsar Site). Prepared for the Department of Game and Wildlife, Government of Ghana. October, 1995. 35 pages*
- Turner, R.K. (1998).** *Wetlands conservation: Economics and drainage schemes. Environ. Plan. A* **15**: 871-888
- Turner, B. L., Clark, W. C., Kates, R. W., Richards J. F., Matthews, J. T. and Meyers W. B. (1990).** *The earth as transformed by human action. Cambridge University Press, Cambridge.*
- Van Asch, M. and Visser, M. E. (2007).** *Phenology of Forest Caterpillars and Their Host Trees: The Importance of Synchrony. Annual Review of Entomology* **52**: 37-55.
- Van Bael, S. and Brawn, J. (2005).** *The direct and indirect effects of insectivory by birds in two contrasting Neotropical forests. Proc. Natl. Acad. Sci. USA.*
- Van Schaik, C. P. Terborgh, J. W. and Wright, J.S. (1993).** *The phenology of tropical forests: adaptive significance and consequences for primary consumers. Ann Rev Ecol Syst* **24**:353-377.
- Van Wyk, N. (2013).** *Wetland Insects. Wild Life and Environment Society. Cape Town South Africa.*
- Walker, M., Hartley, S. E. and Jones, T. H. (2008)** *The relative importance of resources and natural enemies indetermining herbivore abundance: thistles, tephritids and parasitoids. J Anim Ecol* **77**:1063-1071. University of Wisconsin –Arizona state.
- Williams, M. (1993).** *Wetlands: A threatened landscape. Blackball Publishers, Oxford.*
- Wigglesworth V.B. (1972).** *The principles of Insect Physiology. Chapman and Hall (7th Edition), London.*

Wilson, E. O. (1971). *The Insect Societies*. The Belknap Press of Harvard University Press, Cambridge, Massachusetts.

Wilson, E. O. (1992). *Fluctuations in abundance of tropical insects*. Harvard University Press, Cambridge, Massachusetts.

Woiwod, I. P. and Hanski, I. (1992). *Patterns of density dependence in moths and aphids*. *Journal of animal ecology*. Great Britain.

Wolda, S. L. and Glomset, J. A. (1988). *Insect Seasonality: Why?* Smithsonian Tropical Research Institute. Barro Colorado, Panama.

APPENDICES

Appendix 1: Formulae for measures of Diversity

Simpson Index

If a community with high diversity was randomly-sampled twice, there is a good chance that the two samples will contain different species. However, if a low-diversity community were sampled twice, it is likely that both of the samples will contain many of the same species. Simpson (1949) derived a formula based on the expected outcome of two random samples.

$$D_s = \frac{N(N-1)}{\sum n_i(n_i-1)}$$

where N = the total number of individuals of all species

n_i = the number of individuals of species I

Shannon-Weiner Index

The Shannon-Weiner index was developed from information theory and is based on measuring uncertainty. The degree of uncertainty of predicting the species of a random sample is related to the diversity of a community. If a community is dominated by one species (low diversity), the uncertainty of prediction is low; a randomly-sampled species is most likely going to be the dominant species. However, if diversity is high, uncertainty is high (Pielou, 1975). The index of diversity is:

$$H' = - \sum p_i \ln p_i$$

Where p_i = the proportion of individuals of species i.

Margalef's index

Margalef's index was used as a simple measure of species richness (Margalef, 1958).

$$\text{Margalef's index} = (S - 1) / \ln N$$

S = total number of species

N = total number of individuals in the sample

ln = natural logarithm

Pielou's Evenness Index

For calculating the evenness of species, the Pielou's Evenness Index (e) was used (Pielou, 1966).

$$e = H / \ln S$$

H = Shannon – Wiener diversity index

S = total number of species in the sample

Nonparametric estimators

The following nonparametric estimators were computed:

Chao 1: The Abundance-based est1

$$S_1 = S_{obs} + \frac{F_1^2}{2F_2}$$

Chao2: Incidence-Based coverage estimator

$$S_2 = S_{obs} + \frac{Q_1^2}{2Q_2}$$

ACE: The Abundance-based coverage estimate

$$S_{ACE} = S_{abund} + \frac{S_{rare}}{C_{ACE}} + \frac{F_1}{C_{ACE}} \gamma_{ACE}^2$$

and the estimate of coefficient of variation of the Fi's is:

$$\gamma_{ACE}^2 = \max \left[\frac{S_{rare} \sum_{i=1}^{10} i(i-1)F_i}{C_{ACE} (N_{rare}) (N_{rare} - 1)} - 1, 0 \right]$$

ICE: Incidence-based coverage

$$\hat{Q}_{0\text{ ICE}} = \frac{S_{infreq}}{\hat{C}_{ICE}} + \frac{Q_1}{\hat{C}_{ICE}} \hat{\gamma}_{ICE}^2 - S_{infreq}$$

and the of the estimate of coefficient of variance of the Qi's, is

$$\hat{\gamma}_{ICE}^2 = \max \left\{ \frac{S_{infreq}}{\hat{C}_{ICE}} \frac{T_{infreq}}{(T_{infreq} - 1)} \frac{\sum_{k=1}^R k(k-1)Q_k}{\left(\sum_{k=1}^R kQ_k\right)^2} - 1, 0 \right\}$$

Key to variables of the above mentioned nonparametric species richness estimators

S_{obs} Total number of species observed in all samples pooled

S_{rare} Number of rare species (each with 10 or fewer individuals) when all samples are pooled

S_{abund} Number of abundant species (each with more than 10 individuals) when all samples are pooled

S_{infr} Number of infrequent species (each found in 10 or fewer samples)

S_{freq} Number of frequent species (each found in more than 10 samples)

m Total number of sample

m_{infr} Number of samples that have at least one infrequent specie

F_i Number of species that have exactly i individuals when all samples are pooled (F_1 is the frequency of singletons, F_2 the frequency of doubletons)

Q_j Number of species that occur in exactly j samples (Q_1 is the frequency of unique and frequency of duplicates)

N_{rare} Total number of individual in rare species

N_{infr} Total number of incidences (occurrences) of infrequent species

C_{ace} Sample abundance coverage estimator

C_{ice} Sample incidence coverage estimator

Appendix 2: Summary of individual insects captured by order and habitat type from the three wet lands.

Order	Sakumono	Kpeshie	Muni-pomadze	RA%
Coleoptera	93	218	372	12
Diptera	256	524	299	20
Hymenoptera	595	518	400	27
Hemiptera	188	415	214	15
Lipidoptera	105	112	145	7
Orthoptera	89	69	96	4.6
Dictyoptera	33	36	36	2
Collembola	51	54	79	3
Dermaptera	3	3	14	0.4
Odonata	15	14	33	1
Epheneroptera	6	6	17	0.5
Mallopaga	0	0	9	0.1
Embioptera	3	0	14	0.3
Psocoptera	26	17	43	1.5
Neuroptera	18	18	16	0.9
Tricoptera	6	23	26	0.9
Trysanopter	18	58	43	2.2
Mecopptera	0	4	5	0.1
Isoptera	10	21	5	0.7
Anoplura	0	4	0	0.07
Homoptera	14	4	14	0.6
SPlecoptera	1	0	3	0.07
Total				
Individual number (N)	1530	2118	1883	100

Appendix 3: Showing some of the insect species collected during the study



Coleoptera, Carabidae



Coleoptera Cerambycidae



Coleoptera Elateridae



Coleoptera Hesteridae



Coleoptera Scarabaeidae



Diptera Calliphoridae



Hymenoptera Formicidae



Hymenoptera Ichneumonidae



Hymenoptera Selionidae



Orthoptera Gryllidae



A collection of insects from pitfall trap

A collection of insect from yellow pan trap



Appendix 4: Insect order, family and species nameSITE: **KPESHE**TRAP: **SWEEPING**

COLEOPTERA	Number Caught
<i>Alaus excavatus</i> (F) Elateridae	9
<i>Phloeobius cordiger</i> Fahrs. Anthribidae	2
<i>CarabidaeHarpalus csliginosus</i> (Fab.) Carabidae	8
<i>Chrysomelascipta</i> Fab.Chrysomelidae	1
<i>Alleucosma viridula</i> Kirby Scarabaeidae	2
<i>Gonocephalum simplex</i> Fab. Tenebrionidae	5
 DIPTERA	
<i>Aedes vexans</i> (Meigen) Culicidae	1
<i>Bibio albipennis</i> Say Bibionidae	1
<i>Finnia scalafis</i> (Fab) Muscidae	7
<i>Odontomacrus haematoda</i> (Linn) Formicidae	20
<i>Camponotus</i> sp. Formicidae	26
<i>Atopomyrmex crytoceroides</i> Emery Formicidae	50
<i>Pseudodoros clavatus</i> (Fab) Syerphidae	1
<i>Sarcophaga haemorrhoides</i> (Fallen) Sarcophagidae	5
<i>Archytas apicifer</i> (Walker) Tachinidae	6
<i>Tipula abdominalis</i> (Say) Tipulidae	3
<i>Psilocephala</i> sp. Therevidae	1
 HYMENOPTERA	
<i>Euphorius</i> sp. Braconidae	3
<i>Mesocomys pulchriceps</i> Cam Chalcididae	2
<i>Cryptus albitarsis</i> (Cresson) Icheumonpdae	1
 HEMIPTERA	
<i>Oxyrachis lamborni</i> Dist. Membracidae	8
<i>Cenaeus distinguendus</i> Blote. Pyrrhocoridae	4
<i>Aphis gossipii</i> Glover Aphididae	1
<i>Aradius acutus</i> Say Aradidae	2
<i>Lyctocoris campestris</i> (Fab) Anthocoridae	5
<i>Poophilus costalis</i> Walker Cercopidae	1
<i>Empoasca facialis</i> (Jacob) Cicadelidae	5
<i>Acanthocoris Obscuricornis</i> Dall. Coreidae	1
<i>Sehirus cinctus</i> (Palisot de Beauvois) Cydnidae	5
<i>Kamendaka albomaculata</i> Derbidae	4
<i>Gerrisremigis</i> Say Gerridae	2
<i>Lygaeus furcata</i> Fab. Lygaeidae	1
<i>Brycorropsis laticollis</i> Schum Miridae	1

<i>Ambrysus</i> sp. Naucoridae	1
<i>Aspavia armigera</i> (Fab.)Pentatomidae	9
<i>Mesohomotoma tessmani</i> (Allum) Psyllidae	1
<i>Harpactor nitidulus</i> F. Reduviidae	2
<i>Pentacolra ligata</i> (Say) Saldidae	3
<i>Homqemus</i> sp. Scutelleridae	6
<i>Urentius</i> sp. Tingidae	2

LEPIDOPTERA

<i>Andronymus Caesar</i> F. Hesperidae	3
<i>Libythea labdaea</i> Westw. Libytheidae	1
<i>Achaea obvia</i> Hmps Noctuidae	1
<i>Bostra glaucalis</i> Hemps Pyralidae	6
<i>Tinea proletaria</i> Meyr. Tineidae	2

ORTHOPTERA

<i>Acanthacris ruficornis</i> (Fab) Acrididae	7
<i>Gryllus lucens</i> Wlk. Gryllidae	3
<i>Zabalius lineolatus</i> (Stal) Tettigonidae	3
<i>Pentelia horrender</i> Walker Tetrigidae	5

DICTYOPTERA

<i>Blatta oreintalis</i> Linn. Blattidae	5
--	---

ODONATA

<i>Libellula depressa</i> Lin Liberullidae	2
--	---

TRICHOPTERA

<i>Ceraclea</i> sp. Lepticeridae	2
----------------------------------	---

EPHEMEROPTERA

<i>Ephemera simulans</i> Walker Ephemeridae	1
---	---

PSOCOPTERA

<i>Psocus leidy</i> Aron Psocida	1
----------------------------------	---

NEUROPTERA

<i>Chrysopa</i> sp. Chrysopidae	3
<i>Mantispa interrupta</i> Say Mantispidae	1

SITE: KPESHE

TRAP: MALAISE

COLEOPTERA	Number Caught
<i>Alaus excavatus</i> (F) Elateridae	2
<i>Apoderus flavoebenus</i> Attelabidae	3
<i>Phloebius cordiger</i> Fahrs. Anthribidae	4
<i>CarabidaeHarpalus csliginosus</i> (Fab.) Carabidae	4
<i>Chrysomela scripta</i> Fab.Chrysomelidae	1
<i>Alleucosma viridula</i> Kirby Scarabaeidae	2
<i>Gonocephalum simplex</i> Fab. Tenebrionidae	5
DIPTERA	
<i>Melanagromyza similis Lamb</i> Agromyzidae	3
<i>Aedes vexans</i> (Meigen) Culicidae	10
<i>Bibio albipennis</i> Say Bibionidae	2
<i>Mayetiola destuctor</i> Cecidomyiidae	2
<i>Rhamphomyia rava</i> Loew Empididae	7
<i>Ephydra cinerea jones</i> Ephydriidae	3
<i>Finnia scalafis</i> (Fab.) Muscidae	13
<i>Symphoromyia atripes</i> Bigot Rhagionidae	3
<i>Simulium venustum</i> Say Simuliidae	20
<i>Sarcophaga haemorrhoides</i> (Fallen) Sarcophagidae	8
<i>Crysops vittatus</i> WiedemannTabanidae	3
<i>Archytas apicifer (Walker)</i> Tachinidae	6
<i>Psilocephala</i> sp. Therevidae	1
HYMENOPTERA	
<i>Euphorius</i> sp. Braconidae	5
<i>Mesocomys pulchriceps</i> Cam Chalcididae	2
<i>Cryptus albitarsis</i> (Cresson) Icheumonpdae	3
<i>Monomorium Pharaonis</i> (Linn) Formicidae	15
<i>Endelomyia aethiops (Fab)</i> Tenthrenidae	11
<i>Platytelenomus hylas</i> Nixon Selionidae	9
HEMIPTERA	
<i>Oxyrachis lamborni</i> Dist. Membracidae	6
<i>Aphis gossipii</i> Glover Aphididae	12
<i>Aradius acutus</i> Say Aradidae	1
<i>Lycocoris campestris</i> (Fab) Anthocoridae	2
<i>Poophilus costalis</i> Walker Cercopidae	10
<i>Empoasca facialis</i> (Jacob) Cicadelidae	7
<i>Acanthocoris Obscuricornis</i> Dall. Coreidae	1
<i>Sehirus cinctus</i> (Palisot de Beauvois) Cydnidae	3
<i>Kamendaka albomaculata</i> Derbidae	1
<i>Lygaeus furcata</i> Fab. Lygaeidae	1
<i>Brycorropsis laticollis</i> Schum Miridae	4
<i>Ambrysus</i> sp. Naucoridae	1
<i>Aspavia armigera</i> (Fab.)Pentatomidae	2

<i>Pentacolra ligata</i> (Say) Saldidae	1
LEPIDOPTERA	
<i>Diacrisia investigatorium</i> (Karsh) Arctidae	1
<i>Achaea obvia</i> Hmps Noctuidae	1
<i>Appias epaphia</i> Cram Pieridae	1
<i>Achaea boris</i> (Geyer) Noctuidae	1
ORTHOPTERA	
<i>Acanthacris ruficornis</i> (Fab) Acrididae	3
<i>Gryllus lucens</i> Wlk. Gryllidae	1
<i>Zabalius lineolatus</i> (Stal) Tettigonidae	1
DICTYOPTERA	
<i>Blatta oreintalis</i> Linn. Blattidae	1
<i>Blattella germanica</i> (Linn) Blattellidae	2
DERMAPTERA	
<i>Forficula auricularia</i> Linn Forficulidae	3
<i>Libia minor</i> (Linn) Labiidae	11
ODONATA	
<i>Agria seduta</i> (Hagen) Coenagrionidae	2
TRICHOPTERA	
<i>Ceraclea</i> sp. Lepticeridae	2
EPHEMEROPTERA	
<i>Baetis</i> sp. Baetidae	1
<i>Siphonurus alternates</i> Say Siphonuridae	1
PSOCOPTERA	
<i>Psocus leidy</i> Aron Psocidae	3
PLECOPTERA	
<i>Allocapnia pygmaea</i> (Burmeister) Capniidae	2
<i>Pteronarcys dosalis</i> (Say) Pteronaryidae	1
MECOPTERA	
<i>Boreus</i> sp. Packard Boreidae	1
NEUROPTERA	
<i>Chrysopa</i> sp. Chrysopidae	1
COLLEMBOLA	

Isotoma viridis (Bourlet) Isotomidae 20

THYSANOPTERA

Frankliniella schulzei (Trybom) Thripidae 5

SITE: KPESHE

TRAP: FIT (GROUND)

COLEOPTERA

Number Caught

Bembidion quadrimaculatum (L) Carabidae 2

Cardiophorus sp. (Elateridae) 1

Brachypeplus pilosellus Murr. Nutidulidae 1

ORTHOPTERA

Acanthacris ruficornis (Fab) Acrididae 6

Gryllus lucens Wlk. Gryllidae 9

Zabalius lineolatus (Stal) Tettigonidae 5

Pantelia horrenda Wlk. Tetrigidae 2

DIPTERA

Pseudodoros clavatus (Fab) Syrphidae 2

Melangromyza lambi (Hend) Agromyzidae 1

Psilocephala sp. Therevidae 2

Bibio albipennis Say Bibionidae 9

Lucilia illustris (Meigen) Calliphoridae 5

Chironomus plumosus (Lin) Chironomidae 12

Aedes vexans (Meigen) Culicidae 6

Acritochaeta excisa Thoms. Muscidae 3

Rhagio mystaccus (Macquart) Rhgionidae 3

ISOPTERA

Nasutitermes arborius Smeath Nasutermitidae 2

Macrotermes bellicosus Fab. Termitidae 4

HYMENOPTERA

Aspidiotiphagus citrinus Craw. Aphelinidae 2

Scleroderma domestica Andre Bethylidae 3

Brachymeria ovate (say) Chalcididae 2

Odontomachus haematoda (Lin) Formicidae > 150

Dasymutilla sackenii (Cresson) Mutilidae 1

Polynema sp. Myrmiridae 5

Platytenomus hylas Nixon Selionidae 2

HEMIPTERA

<i>Aphis gossypii</i> (Harris); Aphididae	8
<i>Aradus acutus</i> Say; Aradidae	2
<i>Acanthocephala terminalis</i> (Dalas); Coreidae	1
<i>Pangaeus bilineatus</i> (Say); Cydnidae	5
<i>Pyrops tenebrosus</i> Fab; Fulgoridae	2
<i>Groptostethus apicalis</i> Dall; Lygaeidae	1
<i>Rantra fusca</i> Palisot de Beauvos; Nepidae	1

DERMAPTERA

<i>Forficula auricularia</i> Linn; Forficulidae	2
<i>Labidura riparia</i> (Pallas) Labiduridae	1

DICTYOPTERA

<i>Mantis religiosa</i> Lin. Mantidae	1
<i>Blatta orientalis</i> Linn. Blattidae	5
<i>Blattella germanica</i> (Linn) Blattellidae	1

ODONATA

<i>Agria sedula</i> (Hagan); Coenagrionidae	3
<i>Epithea princeps</i> (Hagan); Corduliidae	1
<i>Libellula depressa</i> Lin. Libellulidae	4

EMBIOPTERA

<i>Oligotoma nigra</i> Hagan; Oligotomidae	2
--	---

PSOCOPTERA

<i>Liposcelis</i> sp. Liposcelidae (=Troctidae)	2
<i>Psocus leidy</i> Aron; Psocidae	6

TRICHOPTERA

<i>Ceraclea</i> sp. Lepticeridae	2
----------------------------------	---

NEUROPTERA

<i>Ulolodes macleayana hageni</i> Van der Waele Ascalaphidae	1
<i>Chrysopa oculata</i> Say; Chrysopidae	1
<i>Mantispa interrupta</i> Say; Mantispidae	1

SITE: KPESHE

TRAP: YELLOW PAN

COLEOPTERA	Number Caught	
<i>Bembidion quadrimaculatum</i> (L)	Carabidae	6
<i>Cardiophorus</i> sp.	Elateridae	2
<i>Brachypeplus pilosellus</i> Murr.	Nutidulidae	3
<i>Anomala</i> sp.	Scarabaeidae	2
<i>Mordella marginata</i> Melsheimer;	Mordellidae	2
<i>Philonthus cyanipennis</i> (Fab);	Staphylinidae	4
DIPTERA		
<i>Leptogaster flavipes</i> (Loew);	Asilidae	2
<i>Sarcophagahaemorrhoidalis</i> (Fallen);	Sarcophagidae	1
<i>Pseudodorus clavatus</i> (Fab)	Syrphidae	4
<i>Psilocephala</i> sp.	Therevidae	2
<i>Lucilia illustris</i> (Meigen)	Calliphoridae	5
<i>Chironomus plumosus</i> (Lin)		7
<i>Aedes vexans</i> (Meigen)	Culicidae	17
<i>Acritochaeta excisa</i> Thoms.	Muscidae	1
ISOPTERA		
<i>Nasutitermes arborius</i> Smeath	Nasutermitidae	2
<i>Macrotermes bellicosus</i> Fab.	Termitidae	4
HYMENOPTERA		
<i>Aspidiotiphagus citrinus</i> Craw.	Aphelinidae	10
<i>Brachymeria ovate</i> (say)	Chalcididae	5
<i>Odontomachus haematoda</i> (Lin)	Formicidae >	55
<i>Polynema</i> sp.	Myrmiridae	5
<i>Platytelenomus hylas</i> Nixon	Selionidae	11
<i>Caliroa cerasi</i> (Linn);	Tenthredinidae	1
HEMIPTERA		
<i>Aphis gossypii</i> (Harris);	Aphididae	25
<i>Aphis craccivora</i> Kalt;	Aphididae	7
<i>Aradus acutus</i> Say;	Aradidae	1
<i>Acanthocephala terminalis</i> (Dalas);	Coreidae	2
<i>Pangaeus bilineatus</i> (Say);	Cydnidae	5
<i>Pyrops tenebrosus</i> Fab;	Fulgoridae	1
<i>Groptostethus apicalis</i> Dall;	Lygaeidae	7
<i>Rantra fusca</i> Palisot de Beauvos;	Nepidae	4
<i>Phytolyma impunctata</i> Laing;	Psyllidae	8
<i>Cosmolestes aethiopicus</i> Stall;	Reduviidae	1
<i>Pentacora ligata</i> (Say);	Sadidae	2
<i>Homaemus bijugis</i> Uhler;	Scutelleridae	1

LEPIDOPTERA

<i>Acraea alciope</i> Hew ; Acraeidae	3
<i>Diacreisia aurantiaca</i> Holl; Arctidae	1
<i>Acrocercops bifasciata</i> Wlsm; Hesperidae	3
<i>Libythea labdoea</i> Westw; Libtheiridae	1
<i>Aburina sobrina</i> Moschl; Noctuidae	3
<i>Pyrameis cardui</i> (L); Nymphalidae	1
<i>Coniesta ignefusalis</i> Hemps; Pyralidae	1
<i>Imbrasia</i> sp. Saturniidae	2

ORTHOPTERA

<i>Abisarws viridipennis</i> (Burm.); Acrididae	4
<i>Gryllus lzens</i> Wlk. Gryllidae	1
<i>Zabalius lineolatus</i> (Stall.) Tettigonidae	3
<i>Tetrix arenosa</i> Burmeister; Tetrigidae	2
<i>Scpteriscus</i> sp. Gryllotalpidae	2

DICTYOPTERA

<i>Blatta orientalis</i> Linn; Blattidae	2
--	---

ODONATA

<i>Agria sedula</i> (Hagan); Coenagrionidae	1
<i>Libellula depressa</i> Lin. Libellulidae	1

ANOPLURA

<i>Linognathus</i> sp. Linognathidae	1
--------------------------------------	---

THYSANOPTERA

<i>Heliothrips haemorrhoidalis</i> (Bouche); Thripidae	2
<i>Franklinella occidentalis</i> (Pergande); Thripidae	4

NEUROPTERA

<i>Ulolodes macleayana hageni</i> Van der Wheel; Ascalaphidae	1
<i>Chrysopa oculata</i> Say; Chrysopidae	1

SITE: KPESHE
TRAP: PITFALL

COLEOPTERA	Number Caught
<i>Bembidion quadrimaculatum</i> (L) Carabidae	6
<i>Cardiophorus</i> sp. (Elateridae)	2
<i>Curimosphena senegalensis</i> Haag; Tenebrionidae	1
<i>Alcides ashanticus</i> Faust; Curculionidae	1
DIPTERA	
<i>Leptogaster flavipes</i> (Loew); Asilidae	1
<i>Bibio albipennis</i> Say Bibionidae	2
<i>Lucilia illustris</i> (Meigen) Calliphoridae	5
<i>Chironomus plumosus</i> (Lin)	8
<i>Aedes vexans</i> (Meigen) Culicidae	1
<i>Contarina sorgohicola</i> (Coquillett) Cecidomyiidae	1
<i>Drosophila melanogaster</i> Meigen Drosophilidae	2
<i>Rhagionia mystaccus</i> (Macquart) Rhagionidae	1
HYMENOPTERA	
<i>Odontomachus haematoda</i> (Lin) Formicidae >	170
<i>Sceliphron caementarium</i> (Drury) Sphecidae	1
HEMIPTERA	
<i>Poophilus costalis</i> Wlk. Cercopidae	1
<i>Empoasca fabae</i> (Harris) Cicadellidae	5
<i>Aspavia armigea</i> (Fab.) Pentatomidae	1
<i>Phytolma impunctata</i> Laing; Psyllidae	2
ORTHOPTERA	
<i>Abisarws viridipennis</i> (Burm.); Acrididae	1
<i>Gryllus lencs</i> Wlk. Gryllidae	3
<i>Zabalius lineolatus</i> (Stall.) Tettigoniidae	2
ISOPTERA	
<i>Macrotermes bellicosus</i> Smeath; Termitidae	2
DICTYOPTERA	
<i>Periplaneta americana</i> (De Geer); Blattidae	2
THYSANOPTERA	
<i>Frankliniella occidentalis</i> (Pergande). Thripidae	5
COLLEMBOLLA	
<i>Folsomia elongate</i> (MacGillivray); Isotomidae	1

<i>Smithurinus</i> sp. Smithuridae	1
PSOCOPTERA	
<i>Liposcelis</i> sp. Liposcelidae (=Troctidae)	2
<i>Echmepteryx hageni</i> Packard; Lepidosocidae	3
NEUROPTERA	
<i>Chrysopa oculata</i> Say; Chrysopidae	1
<i>Mantispa interrupta</i> Say; Mantispidae	2
SITE: KPESHE	
TRAP: AIRIAL NETTING	
COLEOPTERA	Number Caught
<i>Bembidion quadrimaculatum</i> (L) Carabidae	1
<i>Alcides ashanticus</i> Faust; Curculionidae	1
<i>Largria vilosa</i> Fab. Lagriidae	2
DIPTERA	
<i>Lucilia illustris</i> (Meigen) Calliphoridae	1
<i>Aedes vexans</i> (Meigen) Culicidae	1
<i>Musca domestica</i> Linn; Muscidae	4
<i>Sarcophaga haemorrhoidalis</i> (Fallen); Sarcophagidae	2
<i>Pseudodorus clavatus</i> (Fab) Syerphidae	1
<i>Psilocephala</i> sp. Therevidae	1
HYMENOPTERA	
<i>Aspidiotiphagus citrinus</i> Craw. Aphelinidae	7
<i>Brachymeria ovate</i> (say) Chalcididae	3
<i>Platytenomus hylas</i> Nixon Selionidae	9
HEMIPTERA	
<i>Aphis gossypii</i> (Harris); Aphididae	6
<i>Acanthocephala terminalis</i> (Dalas); Coreidae	1
LEPIDOPTERA	
<i>Acraea alciope</i> Hew ; Acraeidae	3
<i>Diacreisias aurantiaca</i> Holl; Arctidae	1
<i>Acrocercops bifasciata</i> Wlsm; Hesperidae	1
<i>Libythea labdoea</i> Westw; Libtheiridae	1
<i>Pyrameis cardui</i> (L); Nymphalidae	1
<i>Euxanthe eurinome</i> Cram Nymphalidae	1
<i>Acraea egina</i> Cram, Acraeadae	1

<i>Appias epaphia</i> Cram Pieridae	2
<i>Coniesta ignefusalis</i> Hemps; Pyralidae	3

ORTOPTERA

<i>Zabalius lineolatus</i> (Stall.) Tettigonidae	4
--	---

DICTYOPTERA

<i>Periplaneta americana</i> (De Geer); Blattidae	2
---	---

ODONATA

<i>Agria sedula</i> (Hagan); Coenagrionidae	1
<i>Libellula depressa</i> Lin. Liberullidae	

NEUROPTERA

<i>Ulolodes macleayana hageni</i> Van der Wheel; Ascalaphidae	4
<i>Chrysopa oculata</i> Say; Chrysopidae	

SITE: WINNEBA

TRAP: SWEEPING

COLEOPTERA

	Number Caught
<i>Alaus excavatus</i> (F) Elateridae	9
<i>Phloeobius cordiger</i> Fahrs. Anthribidae	2
<i>Carabidae Harpalus csliginosus</i> (Fab.) Carabidae	2

DIPTERA

<i>Aedes vexans</i> (Meigen) Culicidae	1
<i>Bibio albipennis</i> Say Bibionidae	1
<i>Drosophila melanogaster</i> Magein Drosophilidae	2
<i>Rhamphomyia rava</i> Loew Empididae	7
<i>Ephydra cinerea jones</i> Ephydridae	3
<i>Finnia scalafis</i> (Fab.0) Muscidae	7
<i>Pseudodorus clavatus</i> (Fab} Syerphidae	1
<i>Sarcophaga haemorrhoides</i> (Fallen)Sarcophagidae	5
<i>Archytas apicifer</i> (Walker) Tachinidae	6
<i>Tipula abdominalis</i> (Say) Tipulidae	3
<i>Psilocephala</i> sp. Therevidae	1
<i>Simulium venustum</i> Say Similidae	> 200

HYMENOPTERA

<i>Euphorius</i> sp. Braconidae	3
<i>Mesocomys pulchriceps</i> Cam Chalcididae	2
<i>Cryptus albitarsis</i> (Cresson) Icheumonpdade	1
<i>Monomorium Pharaonis</i> (Linn) Formicidae	1

<i>Pompilus luctuosus</i> Cresson	Pompilidae	2
<i>Endelomyia aethiops</i> (Fab)	Tenthrenidae	1
<i>Platytenomus hylas</i> Nixon	Selionidae	6

HEMIPTERA

<i>Oxyrachis lamborni</i> Dist.	Membracidae	8
<i>Cenaeus distinguendus</i> Blote.	Pyrrhocoridae	4
<i>Aphis gossipii</i> Glover	Aphididae	1
<i>Aradius acutus</i> Say	Aradidae	2
<i>Lycocoris campestris</i> (Fab)	Anthocoridae	5
<i>Poophilus costalis</i> Walker	Cercopidae	1
<i>Empoasca facialis</i> (Jacob)	Cicadelidae	5
<i>Acanthocoris Obscuricornis</i> Dall.	Coreidae	1
<i>Shirus cinctus</i> (Palisot de Beauvois)	Cydnidae	5
<i>Kamendaka albomaculata</i> Derbida	Derbidae	4
<i>Gerrisremigis</i> Say	Gerridae	2
<i>Lygaeus furcata</i> Fab.	Lygaeidae	1
<i>Brycoropsis laticollis</i> Schum	Miridae	1
<i>Ambrysus</i> sp.	Naucoridae	1
<i>Aspavia armigera</i> (Fab.)	Pentatomidae	9
<i>Mesohomotoma tessmani</i> (Allum)	Psyllidae	1
<i>Harpactor nitidulus</i> F.	Reduviidae	2
<i>Pentacolra ligata</i> (Say)	Saldidae	3
<i>Homqemus</i> sp.	Scutelleridae	6
<i>Urentius</i> sp.	Tingidae	2

LEPIDOPTERA

<i>Andronymus caesar</i> F.	Hesperiidae	3
<i>Libythea labdaea</i> Westw.	Libytheidae	1
<i>Casphalia flvicollis</i> Walker	Limacodidae	4
<i>Mamara</i> spp.	Lithocolletidae	4
<i>Ascotis reciprocaris</i> Walker	Geometridae	4
<i>Salagena transversa</i> Walker	Metarbelidae	1
<i>Achaea obvia</i> Hmps	Noctuidae	1
<i>Bematistes umbra</i> Durry	Nympharidae	1
<i>Appias epaphia</i> Cram	Pieridae	2
<i>Bostra glaucalis</i> Hemps	Pyralidae	6
<i>Tinea proletaria</i> Meyr.	Tineidae	2

ORTHOPTERA

<i>Acanthacris ruficornis</i> (Fab)	Acrididae	7
<i>Gryllus lucens</i> Wlk.	Gryllidae	3
<i>Zabalius lineolatus</i> (Stal)	Tettigonidae	3
<i>Pentelia horrender</i> Walker	Tetrigidae	5

DICTYOPTERA

Blatta oreintalis Linn. Blattidae 5

ISOPTERA

Nasutitermes latifrons Sjost Nasutitermitidae 2

Macrotermes natalensis (Hav) Termitidae 7

ODONATA

Libellula depressa Lin Liberullidae 2

TRICHOPTERA

Ceraclea sp. Lepticeridae 2

EPHEMEROPTERA

Ephemera simulans Walker Ephemeridae 1

PSOCOPTERA

Psocus leidy Aron Psocida 1

PLECOPTERA

Allocapnia pygmaea (Burmeister) Capniidae 6

MECOPTERA

Bittacus apicalis Hagen Bittacidae 1

NEUROPTERA

Chrysopa sp. Chrysopidae 3

Mantispa interrupta Say Mantispidae 1

SITE: WINNEBA

TRAP: MALAISE

COLEOPTERA

	Number Caught
<i>Alaus excavatus</i> (F) Elateridae	3
<i>Apoderus flavoebenus</i> Attelabidae	3
<i>Phloebius cordiger</i> Fahrs. Anthribidae	1
<i>Carabidae Harpalus csliginosus</i> (Fab.) Carabidae	4
<i>Chrysomelascipta</i> Fab. Chrysomelidae	2
<i>Alleucosma viridula</i> Kirby Scarabaeidae	2
<i>Gonocephalum simplex</i> Fab. Tenebrionidae	2

DIPTERA

<i>Melanagromyza similis</i> Lamb	Agromyzidae	3
<i>Aedes vexans</i> (Meigen)	Culicidae	3
<i>Bibio albipennis</i> Say	Bibionidae	2
<i>Mayetiola destructor</i>	Cecidomyiidae	2
<i>Rhamphomyia rava</i> Loew	Empididae	7
<i>Ephydra cinerea jones</i>	Ephydridae	3
<i>Finnia scalafis</i> (Fab.)	Muscidae	8
<i>Symphoromyia atripes</i> Bigot	Rhagionidae	1
<i>Simulium venustum</i> Say	Simuliidae	4
<i>Sarcophaga haemorrhoides</i> (Fallen)	Sarcophagidae	1
<i>Crysops vittatus</i> Wiedemann	Tabanidae	1
<i>Archytas apicifer</i> (Walker)	Tachinidae	2
<i>Psilocephala</i> sp.	Therevidae	1

HYMENOPTERA

<i>Euphorius</i> sp.	Braconidae	0
<i>Mesocomys pulchriceps</i> Cam	Chalcididae	5
<i>Cryptus albitarsis</i> (Cresson)	Icheumonidae	3
<i>Monomorium Pharaonis</i> (Linn)	Formicidae	2
<i>Endelomyia aethiops</i> (Fab)	Tenthrenidae	4
<i>Platytelenomus hylas</i> Nixon	Selionidae	1

HEMIPTERA

<i>Oxyrachis lamborni</i> Dist.	Membracidae	2
<i>Aphis gossipii</i> Glover	Aphididae	4
<i>Aradius acutus</i> Say	Aradidae	1
<i>Lyctocoris campestris</i> (Fab)	Anthocoridae	2
<i>Poophilus costalis</i> Walker	Cercopidae	6
<i>Empoasca facialis</i> (Jacob)	Cicadelidae	5
<i>Acanthocoris Obscuricornis</i> Dall.	Coreidae	1
<i>Sehirus cinctus</i> (Palisot de Beauvois)	Cydnidae	2
<i>Kamendaka albomaculata</i>	Derbidae	3
<i>Lygaeus furcata</i> Fab.	Lygaeidae	1
<i>Brycorropsis laticollis</i> Schum	Miridae	2
<i>Ambrysus</i> sp.	Naucoridae	1
<i>Aspavia armigera</i> (Fab.)	Pentatomidae	1
<i>Pentacolra ligata</i> (Say)	Saldidae	1

LEPIDOPTERA

<i>Appias epaphia</i> Cram	Pieridae	1
----------------------------	----------	---

ORTHOPTERA

<i>Acanthacris ruficornis</i> (Fab) Acrididae	1
<i>Gryllus lucens</i> Wlk. Gryllidae	1

DICTYOPTERA

<i>Blattella germanica</i> (Linn) Blattellidae	1
--	---

DERMAPTERA

<i>Libia minor</i> (Linn) Labiidae	1
------------------------------------	---

ODONATA

<i>Agria seduta</i> (Hagen) Coenagrionidae	2
--	---

NEUROPTERA

<i>Chrysopa</i> sp. Chrysopidae	1
---------------------------------	---

COLLEMBOLA

<i>Isotoma viridis</i> (Bourlet) Isotomidae	22
---	----

THYSANOPTERA

<i>Frankliniella schulzei</i> (Trybom) Thripidae	3
--	---

SITE: WINNEBA

TRAP: FIT (GROUND)

COLEOPTERA

	Number Caught
<i>Bembidion quadrimaculatum</i> (L) Carabidae	2
<i>Cardiophorus</i> sp. (Elateridae)	1
<i>Brachypeplus pilosellus</i> Murr. Nutidulidae	1

ORTHOPTERA

<i>Acanthacris ruficornis</i> (Fab) Acrididae	6
<i>Gryllus lucens</i> Wlk. Gryllidae	9
<i>Zabalius lineolatus</i> (Stal) Tettigonidae	5
<i>Pantelia horrenda</i> Wlk. Tetrigidae	2

DIPTERA

<i>Pseudodorus clavatus</i> (Fab) Syerphidae	2
<i>Melangromyza lambi</i> (Hend) Agromyzidae	1
<i>Psilocephala</i> sp. Therevidae	2
<i>Bibio albipennis</i> Say Bibionidae	4
<i>Lucilia illustris</i> (Meigen) Calliphoridae	5
<i>Chironomus plumosus</i> (Lin)	3
<i>Aedes vexans</i> (Meigen) Culicidae	2
<i>Acritochaeta excisa</i> Thoms. Muscidae	1

<i>Rhagio mystaccus</i> (Macquart) Rhgionidae	1
ISOPTERA	
<i>Macrotermes bellicosus</i> Fab. Termitidae	1
HYMENOPTERA	
<i>Aspidiotiphagus citrinus</i> Craw. Aphelinidae	2
<i>Scleroderma domestica</i> Andre Bethylidae	3
<i>Brachymeria ovate</i> (say) Chalcididae	2
<i>Odontomachus haematoda</i> (Lin) Formicidae >	43
<i>Dasymutilla sackenii</i> (Cresson) Mutilidae	2
<i>Platytelenomus hylas</i> Nixon Selionidae	7
HEMIPTERA	
<i>Aphis gossypii</i> (Harris); Aphididae	9
<i>Aradus acutus</i> Say; Aradidae	3
<i>Acanthocephala terminalis</i> (Dalas); Coreidae	2
<i>Pangaeus bilineatus</i> (Say); Cydnidae	3
<i>Pyrops tenebrosus</i> Fab; Fulgoridae	2
<i>Groptostethus apicalis</i> Dall; Lygaeidae	1
DERMAPTERA	
<i>Forficula auricularia</i> Linn; Forficulidae	1
DICTYOPTERA	
<i>Mantis religiosa</i> Lin. Mantidae	1
<i>Blatta orientalis</i> Linn. Blattidae	5
<i>Blattella germanica</i> (Linn) Blattellidae	1
ODONATA	
<i>Agria sedula</i> (Hagen); Coenagrionidae	3
<i>Epitheca princeps</i> (Hagen); Corduliidae	1
<i>Libellula depressa</i> Lin. Libellulidae	4
EMBIOPTERA	
<i>Oligotoma nigra</i> Hagen; Oligotomidae	2
PSOCOPTERA	
<i>Liposcelis</i> sp. Liposcelidae (=Troctidae)	2
<i>Psocus leidy</i> Aron; Psocidae	6
TRICHOPTERA	
<i>Ceraclea</i> sp. Lepticeridae	2

NEUROPTERA

<i>Ulolodes macleayana hageni</i> Van der Wheel; Ascalaphidae	1
<i>Chrysopa oculata</i> Say; Chrysopidae	1
<i>Mantispa interrupta</i> Say; Mantispidae	1

SITE: WINNEBA

TRAP: YELLOW PAN

COLEOPTERA**Number Caught**

<i>Bembidion quadrimaculatum</i> (L) Carabidae	1
<i>Cardiophorus</i> sp. (Elateridae	1
<i>Brachypeplus pilosellus</i> Murr. Nutidulidae	1
<i>Anomala</i> sp. Scarabaeidae	1
<i>Mordella marginata</i> Melsheimer; Mordellidae	1
<i>Philonthus cyanipennis</i> (Fab); Staphylinidae	5

DIPTERA

<i>Leptogaster flavipes</i> (Loew); Asilidae	2
<i>Sarcophagahaemorrhoidalis</i> (Fallen); Sarcophagidae	1
<i>Pseudodorus clavatus</i> (Fab) Syerphidae	2
<i>Psilocephala</i> sp. Therevidae	1
<i>Lucilia illustris</i> (Meigen) Calliphoridae	9
<i>Chironomus plumosus</i> (Lin)	7
<i>Aedes vexans</i> (Meigen) Culicidae	21
<i>Acritochaeta excisa</i> Thoms. Muscidae	1

ISOPTERA

<i>Nasutitermes arborius</i> Smeath Nasutermitidae	2
<i>Macrotermes bellicosus</i> Fab. Termitidae	4

HYMENOPTERA

<i>Aspidiotiphagus citrinus</i> Craw. Aphelinidae	3
<i>Brachymeria ovate</i> (say) Chalcididae	2
<i>Odontomachus haematoda</i> (Lin) Formicidae >	85
<i>Polynema</i> sp. Myrmiridae	5
<i>Platytenomus hylas</i> Nixon Selionidae	9
<i>Caliroa cerasi</i> (Linn); Tenthredinidae	3

HEMIPTERA

<i>Aphis gossypii</i> (Harris); Aphididae	5
<i>Aphis craccivora</i> Kalt; Aphididae	1
<i>Aradus acutus</i> Say; Aradidae	1
<i>Acanthocephala terminalis</i> (Dalas); Coreidae	2
<i>Pangaeus bilineatus</i> (Say); Cydnidae	5
<i>Pyrops tenebrosus</i> Fab; Fulgoridae	1

<i>Groptostethus apicalis</i> Dall; Lygaeidae	2
<i>Rantra fusca</i> Palisot de Beauvos; Nepidae	4
<i>Phytolyma impunctata</i> Laing; Psyllidae	34
<i>Cosmolestes aethiopicus</i> Stall; Reduviidae	1
<i>Pentacora ligata</i> (Say); Sadidae	1
<i>Homaemus bijugis</i> Uhler; Scutelleridae	2
LEPIDOPTERA	
<i>Acraea alciope</i> Hew ; Acraeidae	1
<i>Diacreisia aurantiaca</i> Holl; Arctidae	1
<i>Acrocercops bifasciata</i> Wlsm; Hesperidae	1
<i>Libythea labdoea</i> Westw; Libtheiridae	3
<i>Aburina sobrina</i> Moschl; Noctuidae	1
<i>Pyrameis cardui</i> (L); Nymphalidae	1
<i>Coniesta ignefusalis</i> Hemps; Pyralidae	2
<i>Imbrasia</i> sp. Saturniidae	1
ORTHOPTERA	
<i>Abisarws viridipennis</i> (Burm.); Acrididae	1
<i>Gryllus lzens</i> Wlk. Gryllidae	2
<i>Zabalius lineolatus</i> (Stall.) Tettigonidae	2
<i>Tetrix arenosa</i> Burmeister; Tetrigidae	3
<i>Scpteriscus</i> sp. Gryllotalpidae	1
DICTYOPTERA	
<i>Blatta orientalis</i> Linn; Blattidae	1
ODONATA	
<i>Agria sedula</i> (Hagan); Coenagrionidae	1
<i>Libellula depressa</i> Lin. Liberullidae	1
THYSANOPTERA	
<i>Heliothrips haemorrhoidalis</i> (Bouche); Thripidae	1
<i>Franklinella occidentalis</i> (Pergande); Thripidae	3
NEUROPTERA	
<i>Ulolodes macleayana hageni</i> Van der Wheel; Ascalaphidae	1
<i>Chrysopa oculata</i> Say; Chrysopidae	1

SITE: WINNEBA

TRAP: PITFALL

COLEOPTERA	Number Caught
<i>Bembidion quadrimaculatum</i> (L) Carabidae	1
<i>Cardiophorus</i> sp. (Elateridae	2
<i>Curimosphena senegalensis</i> Haag; Tenebrionidae	2
<i>Alcides ashanticus</i> Faust; Curculionidae	3
DIPTERA	
<i>Leptogaster flavipes</i> (Loew); Asilidae	2
<i>Bibio albipennis</i> Say Bibionidae	4
<i>Lucilia illustris</i> (Meigen) Calliphoridae	2
<i>Chironomus plumosus</i> (Lin)	6
<i>Aedes vexans</i> (Meigen) Culicidae	1
<i>Contarina sorgohicola</i> (Coquillett) Cecidomyiidae	1
<i>Drosophila melanogaster</i> Meigen Drosophilidae	2
<i>Rhagio mystaccus</i> (Macquart) Rhgionidae	1
HYMENOPTERA	
<i>Odontomachus haematoda</i> (Lin) Formicidae >	130
<i>Sceliphron caementarium</i> (Drury) Shecidae	1
HEMIPTERA	
<i>Poophilus costalis</i> Wlk. Cercopidae	4
<i>Empoasca fabae</i> (Harris) Cicadelidae	7
<i>Aspavia armigea</i> (Fab.) Pentatomidae	2
<i>Phytolma impunctata</i> Laing; Psyllidae	13
ORTHOPTERA	
<i>Abisarws viridipennis</i> (Burm.); Acrididae	1
<i>Gryllus lzens</i> Wlk. Gryllidae	1
<i>Zabalius lineolatus</i> (Stall.) Tettigonidae	4
ISOPTERA	
<i>Macrotermes bellicosus</i> Smeath; Termitidae	1
DICTYOPTERA	
<i>Periplaneta americana</i> (De Geer); Blattidae	6
THYSANOPTERA	
<i>Frankliniella occidentalis</i> (Pergande). Thripidae	10
OLLEMBOLLA	
<i>Folsomia elongate</i> (MacGillivray); Isotomidae	6

<i>Smithurinus</i> sp. Smithuridae	1
PSOCOPTERA	
<i>Liposcelis</i> sp. Liposcelidae (=Troctidae)	2
<i>Echmepteryx hageni</i> Packard; Lepidosocidae	2
NEUROPTERA	
<i>Chrysopa oculata</i> Say; Chrysopidae	3
<i>Mantispa interrupta</i> Say; Mantispidae	3
SITE: WINNEBA	
TRAP: AIRIAL NETTING	
COLEOPTERA	Number Caught
<i>Bembidion quadrimaculatum</i> (L) Carabidae	1
<i>Alcides ashanticus</i> Faust; Curculionidae	1
<i>Largria vilosa</i> Fab. Lagriidae	2
<i>Anomala</i> sp. Scarabaeidae	1
<i>Philonthus cyanipennis</i> (Fab); Staphylinidae	4
DIPTERA	
<i>Lucilia illustris</i> (Meigen) Calliphoridae	1
<i>Chironomus plumosus</i> (Lin)Chironomidae	4
<i>Aedes vexans</i> (Meigen) Culicidae	5
<i>Musca domestica</i> Linn; Muscidae	4
<i>Sarcophagahaemorrhoidalis</i> (Fallen); Sarcophagidae	1
<i>Pseudodoros clavatus</i> (Fab) Syerphidae	2
<i>Psilocephala</i> sp. Therevidae	1
HYMENOPTERA	
<i>Odontomachus haematoda</i> (Lin) Formicidae >	400
<i>Aspidiotiphagus citrinus</i> Craw. Aphelinidae	4
<i>Brachymeria ovate</i> (say) Chalcididae	1
<i>Polynema</i> sp. Myrmiridae	2
<i>Platytenomus hylas</i> Nixon Selionidae	9
<i>Caliroa cerasi</i> (Linn); Tenthredinidae	3
HEMIPTERA	
<i>Aphis gossypii</i> (Harris); Aphididae	2
<i>Aradus acutus</i> Say; Aradidae	3
<i>Acanthocephala terminalis</i> (Dalas); Coreidae	2

LEPIDOPTERA

<i>Libythea labdoea</i> Westw; Libtheiridae	1
<i>Aburina sobrina</i> Moschl; Noctuidae	1
<i>Pyrameis cardui</i> (L); Nymphalidae	1
<i>Coniesta ignefusalis</i> Hemps; Pyralidae	1

ORTHOPTERA

<i>Abisarws viridipennis</i> (Burm.); Acrididae	3
<i>Gryllus lzens</i> Wlk. Gryllidae	1
<i>Zabalius lineolatus</i> (Stall.) Tettigonidae	1
<i>Tetrix arenosa</i> Burmeister; Tetrigidae	1
<i>Scpteriscus</i> sp. Gryllotalpidae	1

DICTYOPTERA

<i>Periplaneta americana</i> (De Geer); Blattidae	2
---	---

ODONATA

<i>Agria sedula</i> (Hagan); Coenagrionidae	1
<i>Libellula depressa</i> Lin. Libellulidae	2

ANOPLURA

<i>Linognathus</i> sp. Linognathidae	1
--------------------------------------	---

THYSANOPTERA

<i>Heliothrips haemorrhoidalis</i> (Bouche); Thripidae	4
--	---

NEUROPTERA

<i>Chrysopa oculata</i> Say; Chrysopidae	
--	--

SITE: SAKUMONO
TRAP: AIRIAL NETTING

COLEOPTERA	Number Caught
<i>Alaus excavatus</i> (F) Elateridae	1
<i>Hololepta quadridentata</i> (Fab) Hesteridae	2
<i>Haptoncus luteola</i> Er. Nutidulidae	5
<i>Stenodontes</i> sp Prionidae	1
<i>Alleucosma viridula</i> Kirby Scarabaeidae	2
<i>Malthodes leonensis</i> Pic. Telephoridae	2
DIPTERA	
<i>Melangromyza lambi</i> (Hend) Agromyzidae	1
<i>Bibio albipennis</i> Say Bibionidae	1
<i>Aedes vexans</i> (Meigen) Culicidae	3
<i>Pseudodorus clavatus</i> (Fab) Syerphidae	1
<i>Tipula abdominalis</i> (Say) Tipulidae	1
<i>Psilocephala</i> sp. Therevidae	1
HYMENOPTERA	
<i>Cryptus albitarsis</i> (Cresson) Icheumonpdae	1
<i>Polynema</i> sp. Mymaridae	5
<i>Platytelenomus hylas</i> Nixon Selionidae	7
HEMIPTERA	
<i>Oxyrachis lamborni</i> Dist. Membracidae	1
<i>Cenaeus distinguendus</i> Blote. Pyrrhocoridae	1
LEPIDOPTERA	
<i>Andronymus caesar</i> F. Hesperidae	1
<i>Libythea labdaea</i> Westw. Libytheidae	1
<i>Bematistes umbra</i> Durry Nympharidae	1
<i>Cymothoe egesta</i> Cram. Nympharidae	2
<i>Appias epaphia</i> Cram Pieridae	2
<i>Catopsilia florella</i> F. Pieridae	1
<i>Bostra glaucalis</i> Hempt Pyralidae	6
ORTHOPTERA	
<i>Acanthacris ruficornis</i> (Fab) Acrididae	1
<i>Gryllus lucens</i> Wlk. Gryllidae	1
<i>Zabalius lineolatus</i> (Stal) Tettigonidae	2

DICTYOPTERA

Mantis religiosa Lin. Mantidae 1

ODONATA

Libellula depressa Lin Liberullidae 2

TRICHOPTERA

Ceraclea sp. Lepticeridae 2

SITE: SAKUMONO

TRAP: FIT (GROUND)

COLEOPTERA**Number Caught**

Bembidion quadrimaculatum (L) Carabidae 2

Cardiophorus sp. (Elateridae 1

Brachypeplus pilosellus Murr. Nutidulidae 1

ORTHOPTERA

Acanthacris ruficornis (Fab) Acrididae 6

Gryllus lucens Wlk. Gryllidae 9

Zabalius lineolatus (Stal) Tettigonidae 5

Pantelia horrenda Wlk. Tetrigidae 2

DIPTERA

Pseudodorus clavatus (Fab) Syerphidae 2

Melangromyza lambi (Hend) Agromyzidae 1

Psilocephala sp. Therevidae 2

Bibio albipennis Say Bibionidae 9

Lucilia illustris (Meigen) Calliphoridae 5

Chironomus plumosus (Lin) 12

Aedes vexans (Meigen) Culicidae 6

Acritochaeta excisa Thoms. Muscidae 3

Rhagio mystaccus (Macquart) Rhgionidae 3

SOPTERA

Nasutitermes arborius Smeath Nasutemitidae 2

Macrotermes bellicosus Fab. Termitidae 4

HYMENOPTERA

Aspidiotiphagus citrinus Craw. Aphelinidae 2

Scleroderma domestica Andre Bethylidae 3

Brachymeria ovate (say) Chalcididae 2

Odontomachus haematoda (Lin) Formicidae > 150

Dasymutilla sackenii (Cresson) Mutilidae 1

<i>Polynema</i> sp. Myrmiridae	5
<i>Platytenomus hylas</i> Nixon Selionidae	7
HEMIPTERA	
<i>Aphis gossypii</i> (Harris); Aphididae	16
<i>Aradus acutus</i> Say; Aradidae	2
<i>Acanthocephala terminalis</i> (Dalas); Coreidae	1
<i>Pangaeus bilineatus</i> (Say); Cydnidae	5
<i>Pyrops tenebrosus</i> Fab; Fulgoridae	2
<i>Groptostethus apicalis</i> Dall; Lygaeidae	1
<i>Rantra fusca</i> Palisot de Beauvos; Nepidae	1
DERMAPTERA	
<i>Forficula auricularia</i> Linn; Forficulidae	2
<i>Labidura riparia</i> (Pallas) Labiduridae	1
DICTYOPTERA	
<i>Mantis religiosa</i> Lin. Mantidae	1
<i>Blatta orientalis</i> Linn. Blattidae	5
<i>Blattella germanica</i> (Linn) Blattellidae	1
ODONATA	
<i>Agria sedula</i> (Hagan); Coenagrionidae	3
<i>Epithea princeps</i> (Hagan); Corduliidae	1
<i>Libellula depressa</i> Lin. Libellulidae	4
EMBIOPTERA	
<i>Oligotoma nigra</i> Hagan; Oligotomidae	2
PSOCOPTERA	
<i>Liposcelis</i> sp. Liposcelidae (=Troctidae)	2
<i>Psocus leidy</i> Aron; Psocidae	6
TRICHOPTERA	
<i>Ceraclea</i> sp. Lepticeridae	2
NEUROPTERA	
<i>Ulolodes macleayana hageni</i> Van der Wheel; Ascalaphidae	1
<i>Chrysopa oculata</i> Say; Chrysopidae	1
<i>Mantispa interrupta</i> Say; Mantispidae	1

SITE: SAKUMONO
TRAP: YELLOW PAN

COLEOPTERA	Number Caught
<i>Bembidion quadrimaculatum</i> (L) Carabidae	6
<i>Cardiophorus</i> sp. (Elateridae	2
<i>Brachypeplus pilosellus</i> Murr. Nutidulidae	3
<i>Anomala</i> sp. Scarabaeidae	2
<i>Mordella marginata</i> Melsheimer; Mordellidae	2
<i>Philonthus cyanipennis</i> (Fab); Staphylinidae	4
 DIPTERA	
<i>Leptogaster flavipes</i> (Loew); Asilidae	2
<i>Sarcophagahaemorrhoidalis</i> (<i>Fallen</i>); Sarcophagidae	1
<i>Pseudodoros clavatus</i> (Fab) Syerphidae	4
<i>Psilocephala</i> sp. Therevidae	2
<i>Lucilia illustris</i> (Meigen) Calliphoridae	5
<i>Chironomus plumosus</i> (Lin)	7
<i>Aedes vexans</i> (Meigen) Culicidae	17
<i>Acritochaeta excisa</i> Thoms. Muscidae	1
 ISOPTERA	
<i>Nasutitermes arborius</i> Smeath Nasutermitidae	2
<i>Macrotermes bellicosus</i> Fab. Termitidae	4
 HYMENOPTERA	
<i>Aspidiotiphagus citrinus</i> Craw. Aphelinidae	7
<i>Brachymeria ovate</i> (say) Chalcididae	3
<i>Odontomachus haematoda</i> (Lin) Formicidae >	24
<i>Polynema</i> sp. Myrmiridae	5
<i>Platytelenomus hylas</i> Nixon Selionidae	9
<i>Caliroa cerasi</i> (Linn); Tenthredinidae	3
 HEMIPTERA	
<i>Aphis gossypii</i> (Harris); Aphididae	10
<i>Aphis craccivora</i> Kalt; Aphididae	3
<i>Aradus acutus</i> Say; Aradidae	1
<i>Acanthocephala terminalis</i> (Dalas); Coreidae	2
<i>Pangaeus bilineatus</i> (Say); Cydnidae	5
<i>Pyrops tenebrosus</i> Fab; Fulgoridae	1
<i>Groptostethus apicalis</i> Dall; Lygaeidae	7
<i>Rantra fusca</i> Palisot de Beauvos; Nepidae	4
<i>Phytolyma impunctata</i> Laing; Psyllidae	16
<i>Cosmolestes aethiopicus</i> Stall; Reduviidae	1
<i>Pentacora ligata</i> (Say); Sadidae	2

<i>Homaemus bijugis</i> Uhler; Scutelleridae	2
LEPIDOPTERA	
<i>Acraea alciope</i> Hew ; Acraeidae	3
<i>Diacreisia aurantiaca</i> Holl; Arctidae	1
<i>Acrocercops bifasciata</i> Wlsm; Hesperidae	1
<i>Libythea labdoea</i> Westw; Libtheiridae	1
<i>Aburina sobrina</i> Moschl; Noctuidae	1
<i>Pyrameis cardui</i> (L); Nymphalidae	1
<i>Coniesta ignefusalis</i> Hemps; Pyralidae	3
<i>Imbrasia</i> sp. Saturniidae	2
ORTHOPTERA	
<i>Abisarws viridipennis</i> (Burm.); Acrididae	5
<i>Gryllus lzens</i> Wlk. Gryllidae	2
<i>Zabalius lineolatus</i> (Stall.) Tettigonidae	4
<i>Tetrix arenosa</i> Burmeister; Tetrigidae	3
<i>Scpteriscus</i> sp. Gryllotalpidae	1
DICTYOPTERA	
<i>Blatta orientalis</i> Linn; Blattidae	1
ODONATA	
<i>Agria sedula</i> (Hagan); Coenagrionidae	1
<i>Libellula depressa</i> Lin. Liberullidae	2
ANOPLURA	
<i>Linognathus</i> sp. Linognathidae	1
THYSANOPTERA	
<i>Heliothrips haemorrhoidalis</i> (Bouche); Thripidae	1
<i>Franklinella occidentalis</i> (Pergande); Thripidae	3
NEUROPTERA	
<i>Ulolodes macleayana hageni</i> Van der Wheel; Ascalaphidae	1
<i>Chrysopa oculata</i> Say; Chrysopidae	1

SITE: SAKUMONO

TRAP: PITFALL

COLEOPTERA	Number Caught
<i>Bembidion quadrimaculatum</i> (L) Carabidae	6
<i>Cardiophorus</i> sp. (Elateridae)	2
<i>Curimosphena senegalensis</i> Haag; Tenebrionidae	1
<i>Alcides ashanticus</i> Faust; Curculionidae	1
DIPTERA	
<i>Leptogaster flavipes</i> (Loew); Asilidae	1
<i>Bibio albipennis</i> Say Bibionidae	2
<i>Lucilia illustris</i> (Meigen) Calliphoridae	5
<i>Chironomus plumosus</i> (Lin)	11
<i>Aedes vexans</i> (Meigen) Culicidae	1
<i>Contarina sorgohicola</i> (Coquillett) Cecidomyiidae	1
<i>Drosophila melanogaster</i> Meigen Drosophilidae	2
<i>Rhagionia mystaccus</i> (Macquart) Rhagionidae	1
HYMENOPTERA	
<i>Odontomachus haematoda</i> (Lin) Formicidae >	210
<i>Sceliphron caementarium</i> (Drury) Sphecidae	1
HEMIPTERA	
<i>Poophilus costalis</i> Wlk. Cercopidae	3
<i>Empoasca fabae</i> (Harris) Cicadellidae	3
<i>Aspavia armigea</i> (Fab.) Pentatomidae	1
<i>Phytolma impunctata</i> Laing; Psyllidae	1
ORTHOPTERA	
<i>Abisarws viridipennis</i> (Burm.); Acrididae	3
<i>Gryllus lencs</i> Wlk. Gryllidae	5
<i>Zabalius lineolatus</i> (Stall.) Tettigoniidae	2
ISOPTERA	
<i>Macrotermes bellicosus</i> Smeath; Termitidae	1
DICTYOPTERA	
<i>Periplaneta americana</i> (De Geer); Blattidae	6
THYSANOPTERA	
<i>Frankliniella occidentalis</i> (Pergande). Thripidae	1
COLLEMBOLLA	
<i>Folsomia elongate</i> (MacGillivray); Isotomidae	1
<i>Smithurinus</i> sp. Smithuridae	2

PSOCOPTERA

<i>Liposcelis</i> sp. Liposcelidae (=Troctidae)	2
<i>Echmepteryx hageni</i> Packard; Lepidosocidae	1

NEUROPTERA

<i>Chrysopa oculata</i> Say; Chrysopidae	1
<i>Mantispa interrupta</i> Say; Mantispidae	1

SITE: SAKUMONO

TRAP: SWEEPING

COLEOPTERA**Number Caught**

<i>Bembidion quadrimaculatum</i> (L) Carabidae	5
<i>Alcides ashanticus</i> Faust; Curculionidae	3
<i>Largria vilosa</i> Fab. Lagriidae	2
<i>Anomala</i> sp. Scarabaeidae	2
<i>Philonthus cyanipennis</i> (Fab); Staphylinidae	4

DIPTERA

<i>Lucilia illustris</i> (Meigen) Calliphoridae	1
<i>Chironomus plumosus</i> (Lin)Chironomidae	8
<i>Aedes vexans</i> (Meigen) Culicidae	17
<i>Musca domestica</i> Linn; Muscidae	4
<i>Sarcophaga haemorrhoidalis</i> (Fallen); Sarcophagidae	1
<i>Pseudodorus clavatus</i> (Fab) Syerphidae	3
<i>Psilocephala</i> sp. Therevidae	1

HYMENOPTERA

<i>Odontomachus haematoda</i> (Lin) Formicidae >	138
<i>Aspidiotiphagus citrinus</i> Craw. Aphelinidae	7
<i>Brachymeria ovate</i> (say) Chalcididae	3
<i>Polynema</i> sp. Myrmiridae	5
<i>Platytenomus hylas</i> Nixon Selionidae	9
<i>Caliroa cerasi</i> (Linn); Tenthredinidae	3

HEMIPTERA

<i>Aphis gossypii</i> (Harris); Aphididae	6
<i>Aradus acutus</i> Say; Aradidae	5
<i>Acanthocephala terminalis</i> (Dalas); Coreidae	2
<i>Pangaeus bilineatus</i> (Say); Cydnidae	1
<i>Apache degeerii</i> (Kirby) Derbidae	3
<i>Phytolyma impunctata</i> Laing; Psyllidae	20
<i>Cosmolestes aethiopicus</i> Stall; Reduviidae	1

<i>Homaemus bijugis</i> Uhler; Scutelleridae	2
LEPIDOPTERA	
<i>Acraea alciope</i> Hew ; Acraeidae	3
<i>Diacreisia aurantiaca</i> Holl; Arctidae	1
<i>Acrocercops bifasciata</i> Wlsm; Hesperidae	1
<i>Libythea labdoea</i> Westw; Libtheiridae	1
<i>Aburina sobrina</i> Moschl; Noctuidae	1
<i>Pyrameis cardui</i> (L); Nymphalidae	1
<i>Coniesta ignefusalis</i> Hemps; Pyralidae	3
<i>Imbrasia</i> sp. Saturniidae	2
ORTHOPTERA	
<i>Abisarws viridipennis</i> (Burm.); Acrididae	5
<i>Gryllus lzens</i> Wlk. Gryllidae	2
<i>Zabalius lineolatus</i> (Stall.) Tettigonidae	4
<i>Tetrix arenosa</i> Burmeister; Tetrigidae	3
<i>Scpteriscus</i> sp. Gryllotalpidae	1
DICTYOPTERA	
<i>Periplaneta americana</i> (De Geer); Blattidae	2
ODONATA	
<i>Agria sedula</i> (Hagan); Coenagrionidae	1
<i>Libellula depressa</i> Lin. Libेरullidae	2
ANOPLURA	
<i>Linognathus</i> sp. Linognathidae	1
THYSANOPTERA	
<i>Heliothrips haemorrhoidalis</i> (Bouche); Thripidae	4
NEUROPTERA	
<i>Ulolodes macleayana hageni</i> Van der Wheel; Ascalaphidae	4
<i>Chrysopa oculata</i> Say; Chrysopidae	1

**APENDIX 5:
QUESTIONNAIRE**

**TOPIC: INFLUENCE OF HUMAN ACTIVITIES ON INSECT
DIVERSITY AND ABUNDANCE IN THE WETLAND ENVIRONMENT.**

This questionnaire is meant to invite your contribution to a social survey aimed at obtaining information on the above mentioned project. This questionnaire is solely for an academic purpose and respondent's confidentiality is assured. Thank you.

SECTION A: BACKGROUND INFORMATION OF RESPONDENT

1. Community/settlement.....
2. Gender
Male Female
3. Age
10-19 20-29 30-39 40-49 50+
4. Level of education.
Primary J.S.S/Middle Secondary/Vocation
Tertiary Other
5. Occupation
Salaried worker Self-employed Farmer
Fishing

SECTION B: AGRICULTURAL ACTIVITIES (For Farmer)

1. Do you farm along the bank of the lagoon?
Yes No
- 1a. If yes, why?.....
- 1b. If no, why?
2. What type of cultivation do you practice?
Shifting cultivation Mixed cultivation
3. Type of land preparation
Slash and burn Slash Other
4. Type of crop(s) cultivated
5. Do you use fertilizer? Yes No
- 5a. If yes, indicate type of fertilizer used
6. What types of implements do you use?
Hoe and cutlass Mechanized Others

SECTION C: RESPONDENT'S KNOWLEDGE ON WATER POLLUTION

1. How do you understand the term "water pollution".....
2. When you consider water pollution, what are some of the characteristics you look out for?

3. What in your view are some of the activities in your locality that pollute the lagoon?.....

4. Do you have any belief of superstition/deities attached to the lagoon

Yes No

SECTION D: WASTE DISPOSAL AND SANITATION

1. Do you have access to private toilet facility in your home?

Yes No

1a. If yes, indicate the type

KVIP Pit latrine n latrine ater closet

Other (specify)

1b. If no, state where you attend "nature's call"?

Public toilet Other (specify)

2. Do you pay to use the public toilet?

Yes No

2a. If yes how much do you pay to the facility (public toilet)

3. Are you satisfied with the public toilet facility in your community?

Yes No

3a. If no could you please give reasons.....

4. How do you dispose your refuse?

Burning Official dumping her (specify)

5. Have you ever thrown anything considered as waste/rubbish into the lagoon before?

Yes No

Appendix 6: Values of some physical and chemical parameters.**A: Values of Temperature ($^{\circ}\text{C}$) sites and seasons**

Months/Seasons	Sakumono	Kpeshie	Muni-Pomadze
April	32	28	34
May	30	27	31.5
June	30.5	28.7	33.7
December	31.5	29	31
January	35	33	32.8
February	34.7	32.5	33
Mean	32.3	29.7	32.6

B: Values of pH of water for sites and seasons

Month/Seasons	Sakumono	Kpeshie	Muni-Pomadze
April	7.5	7	7.5
May	9	7.9	8
June	8.7	8.2	7.6
December	8	8.5	8.5
January	7.5	8.9	8.9
February	7.5	9.2	8.2
Mean	8.0	8.3	8.1

C: Value of Salinity ($^0/_{00}$) of water for sites and seasons

Month/Seasons	Sakumono	Kpeshie	Muni-Pomadze
April	1.5	2.1	2.7
May	1.4	2	2.5
June	1.3	2.2	2.2
December	2.1	2.2	2.5
January	2.5	2.8	3.2
February	2.6	3	3.5
Mean	1.9	2.3	2.8

D: Value of Turbidity (NTU) of water for sites and seasons

Month/Season	Sakumono	Kpeshie	Muni-Pomadze
April	30	48	15
May	42	50	20
June	50	76	33
December	63	78	102
January	125	123	82
February	121	146	65
Mean	71.8	86.3	52.8

E: Value of Suspended Solids (mg/l) of water for sites and seasons

Months/Seasons	Sakumono	Kpeshie	Muni-Pomadze
April	384	270	177
May	250	250	259
June	224	311	199
December	287	350	100
January	303	468	98
February	311	440	99.8
Mean	276.5	348.2	155.5

F: Value of Colour (ptco) of water for sites and seasons

Month/Season	Sakumono	Kpeshie	Muni-Pomadze
April	120	400	20
May	90	577	24
June	130	537	22
December	200	637	29
January	250	956	42
February	360	1066	50
Mean	191.7	695	31.2

G: Value of Dissolved Oxygen (mg/l) of water for sites and seasons

Month/Season	Sakumono	Kpeshie	Muni-Pomadze
April	13	5	17
May	16	8	22
June	20	10	15
December	13	5	12
January	11	3	10
February	7	3	88
Mean	13.3	5.7	25.2

H: Value of Biochemical Oxygen Demand (mg/l) of water for sites and seasons

Month/Season	Sakumono	Kpeshie	Muni-Pomadze
April	8	72	6
May	12	66	8
June	11	48	7
December	15	46	12
January	20	49	11
February	20	36	15
Mean	14.7	52.8	9.8

I: Value of Total Coliform (count/100ml) of water for sites and seasons

Month/Season	Sakumono	Kpeshie	Muni-Pomadze
April	200	5000	100
May	250	1100	245
June	200	10025	120
December	400	10290	3000
January	30000	100777	3974
February	40000	110754	4367
Mean	12008.3	39657.7	1967.7

J: Value of Faecal Coliform (count/100ml) of water for sites and seasons

Month/Season	Sakumono	Kpeshie	Muni-Pomadze
April	5060	76788	2000
May	5100	54671	4340
June	5246	41678	4120
December	10788	79742	6024
January	302478	87424	7001
February	62478	91224	7929
Mean	19819.8	70424.3	5235.6