ASSESSING THE RELATIONSHIP BETWEEN REGULATING AND PROVISIONING SERVICES OF LUTEMBE BAY WETLAND, UGANDA

Master of Science Thesis
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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been submitted or presented for examination in any institution

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RECOMMENDATION

This proposal has been submitted with our approval as supervisors for examination according to Egerton University regulations

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ABSTRACT

Wetlands are among the most valuable natural resources providing a number of ecosystem services (ES) such as food, raw materials, water supply and space for recreation. Since wetlands provide a variety of ecosystem services including providing food and water, many stakeholders rely on this ecosystem for their livelihoods. This reliance and continued use may lead to a decline in ecosystem services provided by these wetlands. Lutembe Bay wetland in Uganda situated on the shores of Lake Victoria is prone to human pressures and unsustainable use of ecosystem services. This study aimed to assess the relationship between regulatory and provisioning services for better management of Lutembe Bay wetland ecosystem. The study was carried out for a period of three (3) months between December 2015 and February 2016. Questionnaire survey and focus group discussion (FGDs) were used to assess the major provisioning services in 1999 (16 years ago) and at present (2015/2016) using indicators of measurements for ES such as number of wetland users engaged in particular activities and respondent's perceptions on importance levels of provisioning ES. The results showed that the most important provisioning ES at present (2015/2016) were clay mining, sand mining and fishing while in 1999 before the expansion of developments the major provisioning ES were fishing, cultivation of crops and clay mining. The water purification as an ecosystem service was assessed by analysis of water quality changes through measurements of physico-chemical parameters, nutrients and total suspended solids content in water from Nakaga stream as the inlet and Lutembe Bay as the outlet. Water samples were collected four times a month in the inlet and bay of Lutembe Bay wetland for total suspended solids and nutrients analysis using standard methods. The results showed that the wetland had a 50% retention of total suspended solids. However nutrients concentration were higher in the outlet of the wetland indicating no retention. It was shown that there was no significant difference ($p > 0.05$) in the mean concentrations of ammonium, nitrite and total nitrogen in the inlet and the outlet. However, there was a significant difference ($p < 0.05$) in the mean concentrations of nitrate, soluble reactive phosphorus, total phosphorus and total suspended solids in the inlet and outlet. The changes in water quality in relation to changes in the major provisioning ES were used to assess relationships between ecosystem services and it was shown that a positive correlation though not significant ($r = 0.103$; $p > 0.01$) was observed between the major provisioning ES and Lutembe Bay Wetland purification function. The results of this study are envisaged to avail new knowledge on the relationships between provisioning and regulatory services.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

DO	Dissolved Oxygen
ES	Ecosystem Services
FA	Field Assistant
FGD	Focus Group Discussion
GF/C	Glass Fibre Filter
GIS	Geographical Information System
H_2SO_4	Sulphuric Acid
LWUA	Lutembe Wetland Users Association
MEA	Millennium Ecosystem Assessment
N	Nitrogen
NH_4-N	Ammonium-nitrogen
NO_2-N	Nitrite-nitrogen
NO_3-N	Nitrate-nitrogen
P	Phosphorus
QA	Questionnaire Assistant
QF	Questionnaire Facilitator
RA	Research Assistant
SRP	Soluble Reactive Phosphorus
TEEB	The Economics of Ecosystems and Biodiversity
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solid

CHAPTER ONE

INTRODUCTION

1.1 Background information

Lutembe Bay wetland lies on the northern shores of Lake Victoria at the mouth of Murchison Bay between Entebbe and Kampala in Uganda. It is an important ecosystem supporting local community livelihoods by providing raw materials for various uses; building, crafts making, water for domestic consumption by livestock and humans and fish for food and income (Boere *et al*., 2006). The adjacent communities also benefit from services such as water quality regulation, flood control, climate regulation, disease control and also nonmaterial benefits such as aesthetic and spiritual benefits. Wetlands around Lake Victoria serve a major function of improving and maintaining lacustrine water quality (Kansiime *et al.*, 2007). According to Byaruhanga *et al*. (2001), Lutembe Bay wetland has been ranked as one of the 30 most important bird sanctuaries in Uganda owing to its biodiversity that is recognised locally, nationally, regionally and internationally making it a high potential eco-tourism spot. Although the wetland faces ecological degradation through the conversion of the wetland by cultivation of crops to generate income and household food, mining of clay and sand for income and cutting of papyrus for sale in the local markets for crafts and fencing, some parts of the wetland remain intact with *Cyperus papyrus* L*, Typha domingensis,* and *Phragmites mauritianus* being the dominant vegetation. Lutembe Bay wetland also supports globally threatened species of Cichlid fish and is a breeding ground for *Clarias* species and lung fish (Byaruhanga and Kigoolo, 2005)

According to Daily (1997), ecosystem services are the processes and conditions through which natural ecosystems and the flora and fauna that make them up, foster human life. The ecosystem service (ES) concept put forward by MEA (2005) describes ES as services that improve social and cultural well-being of humans and categorised them as regulating (climate regulation, water storage and ground water recharge, water purification and waste treatment, erosion regulation, pollination), provisioning (food, freshwater, fibre and fuel, medicines, genetic material), supporting (soil formation, nutrient cycling) and cultural (spiritual and inspirational, recreational, aesthetic, educational) (McInnes 2007). Wetlands contribute approximately half of these services. This concept was derived from past studies on the functioning of wetland ecosystems resulting to human benefit by Maltby, 1986; Barbier *et al*., 1997 among others.

Emphasis on ecosystem service concept has been used to justify ecosystem conservation and improve on land management. This approach is based on the assumption that humans will derive more benefit when natural ecosystems are conserved. However this assumption might be limited by competition with other land uses which may result in wetland degradation or loss. According to this concept ecosystems are regarded as providers of essential goods and services for human well-being. As a result, linking human livelihood quality to ecosystem functions is therefore believed to underscore the importance of conservation and management of environmentally sensitive landscape and natural resources. (Ghazoul, 2007).

The ES approach provides a framework by which the society can evaluate the importance of natural environments including wetlands and make informed decisions on their conservation or sustainable management of their services (Balvanera *et al*. 2001). According to MEA (2005), an investigation of how various ecosystem services are interlinked with each other has also not been well studied. Some ecosystem services are directly proportional to each other whilst others are inversely proportional to one another (TEEB, 2010) which implies that intensive use of a selected type of ecosystem services may lead to a decline of other ecosystem services.

Although existing links between ecosystem services are known to occur, the methods used to assess their relationships for better management of ecosystems are still un-clear. Most scientific assessment methods are based on the assumption that ecosystem services are not significantly related to one another (Tallis *et al*., 2008). In most cases, ecosystem services are assessed individually and links between more than two services are rarely mentioned (MEA, 2005). According to Carpenter *et al.* (2009), the knowledge about the links between provision of services and other ecosystem processes, is limited. Therefore their overall interaction remains unclear hence the need for this current study.

Provisioning services (food, fresh water, genetic material, fibre, fuel, natural medicines and pharmaceuticals) of Lutembe Bay wetland are well known and understood and are usually given priority over regulating services (namely; water regulation, erosion regulation, water purification, climate regulation, waste regulation and natural hazard regulation) in decision making, especially in Uganda. This is because regulatory services are more difficult to value and appreciate owing to inadequate or lack of understanding of their fundamental processes. Activities such as mining of clay and sand for building, agriculture and abstraction of water that communities engage in for their day to day wellbeing tend to enhance the provisioning services of the wetlands but diminish the regulating services thereby creating an imbalance among ecosystem services necessary for long term wetland use. This study has highlighted some impacts of major provisioning services on Lutembe wetland function such as clay mining encroaching on the wetland leading to deterioration of water quality. This will availing new knowledge on the relationships between provisioning and regulatory services and possible trade-offs in Lutembe Bay wetland and aid the wider scientific discourse to sustainably improve the ability to manage wetland systems to provide multiple ecosystem services.

1.2 Statement of the problem

Wetland resources represent one of Uganda's vital economic natural resources. The Global Water Partnership in East Africa have documented that approximately 15% of Uganda's Gross Domestic Product (GDP) is lost due to degradation of its natural resources, wetlands included. Wetlands degradation alone cost Uganda nearly 2 billion Uganda shillings annually while contamination of water resources including eutrophication costs Uganda nearly 38 billion Uganda shillings per year. Lutembe Bay Wetland, which is the study site faces ecological degradation through uncontrolled conversion of the wetland through cultivation of crops to generate income and household food, mining of clay and sand for income and harvesting of papyrus for sale in the local markets for crafts making and fencing. In addition this ecosystem is threatened with pollution from agrochemicals such as nitrogen and phosphorus from agricultural activities. Excessive input of these nutrients into the system have resulted to enrichment of adjacent water bodies causing eutrophication. This therefore has had a direct impact on livelihoods of local communities that benefit from provisioning services of these ecosystems e.g. documented losses of fish breeding grounds in the wetland. Provisioning ES of Lutembe Bay Wetland such as clay and sand mining have been given a priority over regulating ES such as water purification. Therefore monitoring is deemed necessary in order to assess the potential impacts of agro-chemicals used by flower farms near the wetland and other human activities such as land reclamation, stone quarrying and sand mining. The consequence is that the ES provided by the wetland to its local communities will be compromised or lost if management measures to stem the aforementioned causes of degradation are not enacted. The uncontrolled exploitation of ES at Lutembe Bay Wetland is mainly due to lack of scientific information to aid improve existing knowledge and management for sustainable utilization of multiple ES.

1.3 Objectives

1.3.1 General Objective

To assess the relationship between regulating and provisioning services of Lutembe Bay wetland and its impact on the ES provided by the wetland to its local communities.

1.3.2 Specific Objectives

1. To assess the most important provisioning services at present (2015/2016) and before developments in 1999 at Lutembe Bay wetland.
2. To determine nutrients and total suspended solids concentration retention capacity of Lutembe Bay wetland
3. To evaluate the relationship between the nutrient concentration and most important provisioning ecosystem services between 1999 and 2015/2016 of Lutembe Bay wetland.

1.4 Hypotheses

1. H_o: There is no significant difference in the provisioning services at present (2015/2016) and before developments in 1999 at Lutembe Bay wetland.
2. H_o: There is no significant difference in nutrients and total suspended solids concentration retention capacity of Lutembe Bay wetland.
3. H_o: There is no significant relationship between nutrient concentration and most important provisioning services between 1999 and 2015/2016 of Lutembe Bay wetland.

1.5 Justification

Wetland resources represent one of Uganda's vital economic natural resources. Not only do they have direct use values such as fishing, crop cultivation and extraction of useful materials but are also important for life support processes such as protection of river banks, stabilization of hydrological cycle and microclimate regulation, nutrient and toxin retention and sewerage treatment among other uses. Due to private sector development and population increase, wetlands surrounding Lake Victoria, Lutembe bay wetland inclusive are under pressure from anthropogenic activities such as land reclamation and industrial development and associated pollution. Consequently resulting to eutrophication due to runoff water from urban and agricultural areas typically containing large concentrations of nitrates (NO_3-N) and phosphorus, hence stimulating algal growth. The death and subsequent decay of algae lowers oxygen concentrations and in extreme cases causes fish kills and disrupts the aquatic food chain. Lutembe Bay wetland which provides a number of ecosystem services important to meet community livelihoods is not an exception to these kinds of degradation. Lutembe Bay wetland has been ranked as one of the 30 most important bird sanctuaries in Uganda owing to its biodiversity that is recognised locally, nationally, regionally and internationally making it a high potential eco-tourism spot

Lutembe Bay wetland has been strongly affected by industrial and commercial development and conversion of land for agriculture. Some parts on the northwest of the landward side of Lutembe Bay wetland have been recently cleared for horticultural farming hence reduction in wetland cover. Lutembe Bay wetland supports globally threatened species of Cichlid fish and is a breeding ground for *Clarias* species and lung fish. The fishing industry in Uganda is thriving with tonnes of fish harvested from wetlands, contributing to 2.9 % share of the GDP in 2008/09 fiscal year with many people being indirectly dependent on this industry. Fisheries is one of the most important wetland resource for local communities and the magnitude of this economic activity depends on the ecological condition of the wetland and the socio-economic status of the local community. Agricultural, industrial and commercial activities lead to nutrient input into the bay which could lead to eutrophication. The implication is that eutrophication will have a direct impact on livelihoods of local communities that benefit from provisioning services of Lutembe Bay Wetlands such as loss of fish breeding grounds. This study therefore investigated the importance of Lutembe Bay Wetland on water quality through nutrient and total suspended solids retention and the relationship to provisioning services for better management, decision making and conservation of the system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Global wetland coverage

Wetlands cover about 6 % to 7 % of the Earth's surface (Lehner and Doll, 2004). In sub-saharan Africa wetlands occupy 6 % of the land surface which is considered to be a relatively large area (Stevenson and Frazier, 1999). Wetlands are considered to have a higher production potential and more resilient than upland ecosystems to human activities such as drainage interventions and agriculture (MEA, 2005).

Wetland loss and degradation resulting mainly from anthropogenic modification of wetland systems is a major global problem. It has been estimated that up to half of the world's wetlands have been lost due to human activities (Mitsch and Gosselink, 2000). Land cover changes may lead to direct ecosystem loss as well as fragmentation leading to increases in wetland stress and decreases in wetland quality. This directly results in loss of fauna and flora, and other ecosystem services such as nutrient retention, ground-water recharge, flood control and heavy metal retention.

Due to urbanisation and the ever increasing population in East Africa, dependence on wetlands for food security is particularly high and therefore there is a notable shift towards production of high-value food crops in wetlands. Schuyt (2005) noted that wetlands in East Africa provide 10-40% of the annual food needs for the local population. This may rise up to 100% during periods of food scarcity (MEA, 2005; Rebelo *et al*., 2010). The emerging economy and growing population in wetlands that surround Lake Victoria, Lutembe Bay wetland inclusive, tend to exert pressure on these important ecosystems which provide various ES to the community.

The wetland catchment areas around Lake Victoria have reduced by more than half its size in 14 years from 7,167.6 km^2 in 1994 to 3,310 km^2 in 2008. In Uganda there has been a tremendous reduction in the area covered by wetlands. In 1964 the total area covered by wetlands was estimated at 32,000 km^2 but by the year 1999 this had decreased to 30,000 km^2, translating to approximately 6% of Uganda's total surface area. (Wetlands Management Department, MWE (2009). According to data from the National Biomass Study Unit of the National Forestry Authority (NFA) (2008), Uganda's wetland coverage has now been reduced to 26,308 km^2 translating to 11% of the total land area.

2.2 Ecosystem service concept

The concept of ecosystem services dates back to the 1970s but only picked up pace in the 1990s (De Groot 1992, Costanza and Folke 1997, Daily 1997). The concept was put forward by the Millennium Ecosystem Assessment which distinguished regulatory, cultural, provisioning and supporting services and since then efforts to put the concept into practice have notably increased (Daily and Matson 2008, Tallis *et al*., 2008). Ecosystem services may be defined as the processes, conditions and components of the natural environment that provide both tangible and intangible benefits for sustaining and satisfying human life and well-being (Daily *et al*., 1997). The Millennium Ecosystem Assessment (MEA) used a new conceptual framework for analysing and understanding the impacts of environmental change on ecosystems and human wellbeing, using the ecosystem services concept as the core principle (MEA, 2005). Although the MA exhausted evaluating the effects of policies on ecosystem services and human well-being, some basic information is still lacking about the dynamics of social–ecological systems and the interrelationship between ecosystem services and human well-being (Carpenter *et al*., 2009). It is also still not clear how to best define the difference between ecosystem services and functions in order to measure them in a reliable way (Wallace 2007, Fischer *et al*., 2009). A follow up to the Millennium Ecosystem Assessment is The Economics of Ecosystems and Biodiversity (TEEB) framework which as opposed to MEA can be used in relating ecosystems to human wellbeing. The TEEB study is an important international initiative to attract attention to the global economic benefits of biodiversity, to point out the growing costs of biodiversity loss and ecosystem degradation and to bring together expertise from the fields of science, economics and policy to enable practical actions moving forward. TEEB framework shows that economics can be a useful tool in biodiversity policy, both by supporting decision processes and by forging dialogues between science, economics and governing structures (Ring *et al*., 2010)

Ecosystem functions play an intermediate role between ecosystem services and processes and can be defined as the capability of ecosystems to provide goods and services that satisfy human needs directly and indirectly (De Groot, 1992). Actual use of goods and services provides benefits to humans through health, nutrition and pleasure which can then be valued in monetary and economic terms. Although this linkage is generally accepted the difference between benefit, service and function is still in dispute ((Balmford *et al*. 2008). Other aspects which are still under debate include how to distinguish ecosystems from landscape functions and services, and how to value services provided by natural versus artificial systems such as fish from lakes compared to fish from aquaculture, coupled with notion of land use function which is a combination of benefits, functions and services (Pérez-Soba *et al*., 2008).

2.3 Ecosystem services provided by wetlands

Wetland ecosystem services have been generally classified as regulating, provisioning, cultural and supporting (MEA, 2005). Humans derive benefit such as food, water, raw materials and clean air as well as the contribution of cultural and social well-being from this natural asset (Fischer *et al.,* 2009; Barbier, 2011). Provisioning services are products such as food, fresh water, genetic material, fibre, fuel, natural medicines and pharmaceuticals, genetic resources that are obtained from ecosystems. Cultural services are non-material benefits people obtain from ecosystems through cognitive development, spiritual enrichment, recreation, reflection and aesthetic experiences, (knowledge systems, cultural diversity, social relations, educational values, sense of place cultural heritage) and ecotourism.

Regulating services are benefits derived from the regulation of ecosystem processes, (erosion regulation, water regulation, water purification, climate regulation, waste regulation) and natural hazard regulation (storms, floods, droughts). On the other hand supporting services are those that are necessary for the production of all other ecosystem services. They are different from regulating, provisioning and cultural services as their impacts on people are often indirect or occur over long periods of time, whereas changes in the other categories have relatively direct and short term impacts on people. Some services, like erosion regulation, can be categorised as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people. Supporting services include primary production, nutrient cycling and water cycling.

A follow up to Millennium Ecosystem Assessment is The Economics of Ecosystems and Biodiversity (TEEB) framework which does not seek to develop new techniques and methods of classification of ES but rather endeavours to synthesis the present state of knowledge in order to provide a basis for assessing the stock of natural capital and the flow of ecosystem services (Ring *et al*., 2010). TEEB calls for a change to the current economic model and at the same time it recognizes the persuasive power of economic reasoning in modern societies (Sukhdev, 2009). TEEB aims at drawing attention to the worldwide economic benefits of biodiversity while emphasizing the growing costs of biodiversity loss and ecosystem degradation. Ecosystem services are often assessed and valued at specific sites for specific services although some uses require combined values over larger spatial and temporal scales.

A technique used in Costanza and Folke (1997) assumes a constant unit value per hectare of ecosystem type and multiplies that value by the area of each type to arrive at collective totals. In that study the value of 168 biomes of inland wetlands was put at 104,924 US dollars/ha/year.

2.4 Quantification of provisioning and regulatory services

With the continued use of ecosystem services by humans, there is need for more studies on the quantification of ecosystem service trade-offs (Carpenter *et al*., 2009). Assessing ecological resources and processes in terms of goods and services they provide, break-down the complexity of the environment into more easily understood functions which can be appreciated by non-scientists and policy makers. This makes it more easy to comprehend the trade-offs for better ecosystems management (Holmlund and Hammer 1999, Borgese 2000, Weslawski *et al*., 2006).

Quantification of ES functions, goods and services has been approached at different levels and scope (Burkhard *et al*., 2009) and in different ways (De Groot *et al*., 2010). Approaches include economic valuation methods (Grêt-Regamey and Kytzia 2007), non-monetary methods (Egoh *et al*., 2008, Sherrouse *et al*., 2011) and integrated methods with indicators of different types (De Groot, 2006).

Provisioning services quantification involves analysis of wetland agricultural production, yield, trade numbers as well as products' market prices which serve as good indicators of measure although changing markets and scarcity of resources need to be considered (Burkhard *et al.*, 2012). According to Hein *et al.*, (2006) before provisioning services can be valued they have to be assessed in bio-physical terms which involves the quantification of the flows of goods harvested in the ecosystem in a physical unit such as crop production in tonnes per hectare per year (ton ha^{-1} $year^{-1}$) and freshwater supply in cubic meters per year (m^3/year). In addition the spatial distribution of crops in terms of area or land cover serves as a measure for the provisioning ES (Maes *et al.*, 2011)

Regulatory services quantification is not as straightforward as the provisioning services and it requires use of indirect methods. The Millennium Ecosystem Assessment described the water purification function of wetland ecosystems among other regulating functions as the least understood but potentially most valuable ES (MEA, 2005). It explains how wetland ecosystems including lakes, rivers, marshes and coastal areas are a source of a number provisioning ES that are sensitive to water quality. Fish as an example is an important source of protein for rural communities but has declined due to land-based pollution from nutrients, sediments and pesticides among other pollutants. Since wetlands have the capacity to reduce the likelihood that land-based nutrients flow will lead to eutrophication of water body's, an economic value can be attached to the fish biomass productivity which depends on the water purification function of wetlands (Simonit &Perrings, 2011).

2.5 Nitrogen and phosphorus removal by natural wetlands

Fresh water eutrophication caused by excess inputs of N and P from agriculture and urban activities is a common and ever increasing problem in rivers, lakes, estuaries and oceans (Smith, 1998). Eutrophication has many negative impacts on aquatic ecosystems the most notable being excessive growth of algae and aquatic weeds which interfere negatively with the use of water for drinking, fisheries, industry, recreation and agriculture. N and P enter wetlands mainly through run off from catchment areas, stream flow and rainfall. Nutrients once in wetlands end up; being adsorbed onto organic surfaces, taken up by wetland vegetation, assimilated into plant material and being part of trophic dynamic metabolism, lost through degassing and may directly flow through the wetland into the recipient water body (Howard-Williams and Gaudet, 1985). The degree of removal of nutrients particularly nitrogen (N) and phosphorus (P) from wetland systems is a function of the removal mechanisms within these systems.

Nitrogen retention in wetlands occurs through various processes: nitrification, denitrification, uptake by aquatic plants and sedimentation. Nitrification is the process whereby ammonium nitrogen (NH_4-N) is converted to nitrate (NO_3-N) under aerobic conditions. Denitrification occurs when facultative anaerobic bacteria produce N_2 or N_2O gas by using nitrate (NO_3^-) or nitrite (NO_2^-) as terminal electron acceptors (Knowles, 1982). Denitrifying bacteria release N_2 into the atmosphere thereby permanently removing it from aquatic systems. Nitrogen is also retained when particulate matter from water flowing into the wetland becomes incorporated into the sediment. Lastly, macrophytes influence nitrogen cycling by taking up and storing nitrogen in their shoots and roots during the growing season (Hill, 1986).

Phosphorus (P) entering a wetland is typically in inorganic and organic forms. The different forms include; dissolved inorganic P, particulate inorganic P, dissolved organic P and particulate organic P. The relative proportion of each form depends on the soil type, land use and geological characteristics of the catchment area (Reddy *et al*., 1999a) and the various forms of P present to a large extent determine the fate and transport of P in soils (Reddy *et al*., 1999b)

Significant quantities of phosphorus (P) in water can be removed by wetlands through the processes of plant uptake, sedimentation, microbial immobilization, adsorption and precipitation reactions with clay, Al, Fe, and Ca minerals (Gale *et al*., 1994; Walbridge and Lockaby, 1994; Vymazal, 1995; Reddy *et al*., 1999a). P retention capacities of wetlands occurs through biotic and abiotic processes. The biotic processes include uptake by vegetation, periphyton, plankton and microorganisms, whereas the abiotic processes are adsorption by sediments, sedimentation, exchange processes between sediment and the overlying water column and precipitation (Meyer and Likens, 1979).

2.6 The relationship between provisioning and regulatory ecosystem services

Ecosystem services relationships can be categorised using two types of mechanisms causing them; effects of drivers on multiple ecosystem services and interactions among ecosystem services (Bennett *et al*., 2009). Drivers of provisioning services may affect one ES with negligible effects to the other services of interest or may have significant effects on multiple services at once. However some drivers can enhance both ES while others diminish both services (Hey, 2002; Zedler, 2003). For example, restoration of a wetland may improve flood control by temporarily storing and slowly releasing storm water and also improve water quality through their natural filtration capabilities through trapping pollutants. An example of a scenario of which drivers diminish both services can be shown when wetland is converted to agricultural land to enhance the provision of food crops. This may cause over extraction of agricultural crop biomass which reduces soil organic matter of the agricultural land. Ultimately erosion regulation will reduce leading to lower crop yields (Hey, 2002; Zedler, 2003).

Overtime, humans have altered the supply of numerous ES to enhance the production or delivery of a particular good or service. An example of such a scenario is when afforestation, agriculture and building of dams are used to increase the provision of raw materials for building, food crops and water respectively. Provisioning and regulating ES are dependent on each other making their management challenging (Heal *et al*., 2001). Attempts to overuse a given service may often lead to loss or reduction of other services. This is referred to as a trade-off (Holling and Meffe, 1996). Some ecosystem services co-vary positively whereby more of one service translates to more of another for example maintaining soil quality may enhance nutrient cycling and primary production, enhance carbon storage and hence climate regulation. This will in turn help regulate water quality and water flows thereby improving most provisioning services such as food, fibre and natural medicines. Other services co-vary negatively whereby more of one service translates to less of another; increased provision of agricultural crops may reduce water purification since wetlands filter water by slowing down the flow of water thus allowing it to move around the plants which thereby makes suspended sediment to drop out and settle to the wetland bottom, soil quality through over-extraction of crop biomass which reduces soil organic matter resulting in soil erosion and climate regulation; carbon sequestration, maintenance of temperature and precipitation (Elmqvist *et al*., 2013).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

3.1.1 Description of the study area

Lutembe Bay wetland lies on the northern shores of Lake Victoria in Murchison Bay. It is situated in the sub-counties of Ssisa and Katabi in Wakiso district, central Uganda covering an area of 98 ha. The Bay is situated between Entebbe and Kampala, at an altitude of 1 130 m above sea level; with geographical coordinates; 32º32”– 32º36”E and 00 º 09” – 00 º11”N covering an area of 500 ha. It is almost completely cut off from the main body of Lake Victoria by two papyrus islands (Figure 1). The diversity of natural vegetation in the urban wetlands of Murchison-Lutembe Bay is low, dominated by *Cyperus papyrus* in the main open water side of the lake and patches of *Phragmities mauritianus, Cyperus papyrus* and *Vossia cuspidata* towards dry land areas. The bay extends into a *Miscanthidium violaceum* swamp and merges with forest remnants to the north and horticultural farms to the northwest on the landward side, with shallow waters and scattered islets of mud in the open area of the bay. Lutembe Bay wetland was designated as a Ramsar site in 2006 (NatureUganda, 2014).

The protection of the bay from the open water wave action has enhanced establishment and proliferation of the invasive water hyacinth *Eichhornia sp*, although that has since the year 1999 declined (NatureUganda, 2014). The bay and its associated wetlands are important to the surrounding communities as a source of raw materials for local crafts, building materials, and water for domestic use and, probably more importantly, fish as food and income. The bay supports globally threatened species of birds like *Chloropeta gracilirostris*, *Laniarius mufumbiri*, *Balaeniceps rex* and *Rhynchops flavirostris,* migratory Palearctic (*Chlidonias hybridus*) and Afrotropical (*Anastomus lamelligerus*) among others. In addition it supports huge congregations of other species of birds with more than 1% of the White-winged Black Terns’ population (NatureUganda, 2014). Rare butterfly species like *Acraea pharsalus*, *Belenois solilucis*, *Cacyreus virilise* inhabit the wetland. The bay acts as a breeding ground for clarias and lungfish with a high abundance of endangered Cichlid fish.

Lutembe Bay Wetland System is underlained by the Pre-Cambrian rocks. The rocks comprise of the Cenozoic – Pleistocene to recent series with partly granite formations; and the pre-Cambrian Buganda – Toro system. Argillites predominate, but basal or near basal arenites are important features. Large tracts of the system are granite; and low – grade phyllites also occur.

The above rocks give rise to ferrallitic soils, mainly sandy loams with a dominant yellow colour and sandy clay loams with a dominant red colour. These soils dominate the system. The dominant yellow colour soils are derived from the basement complex of gneisses and granite and these have a medium productivity rating. The dominant red color clay loams are derived from Buganda-Toro rock system mixed schists and these have a high productivity rating (NatureUganda, 2014).

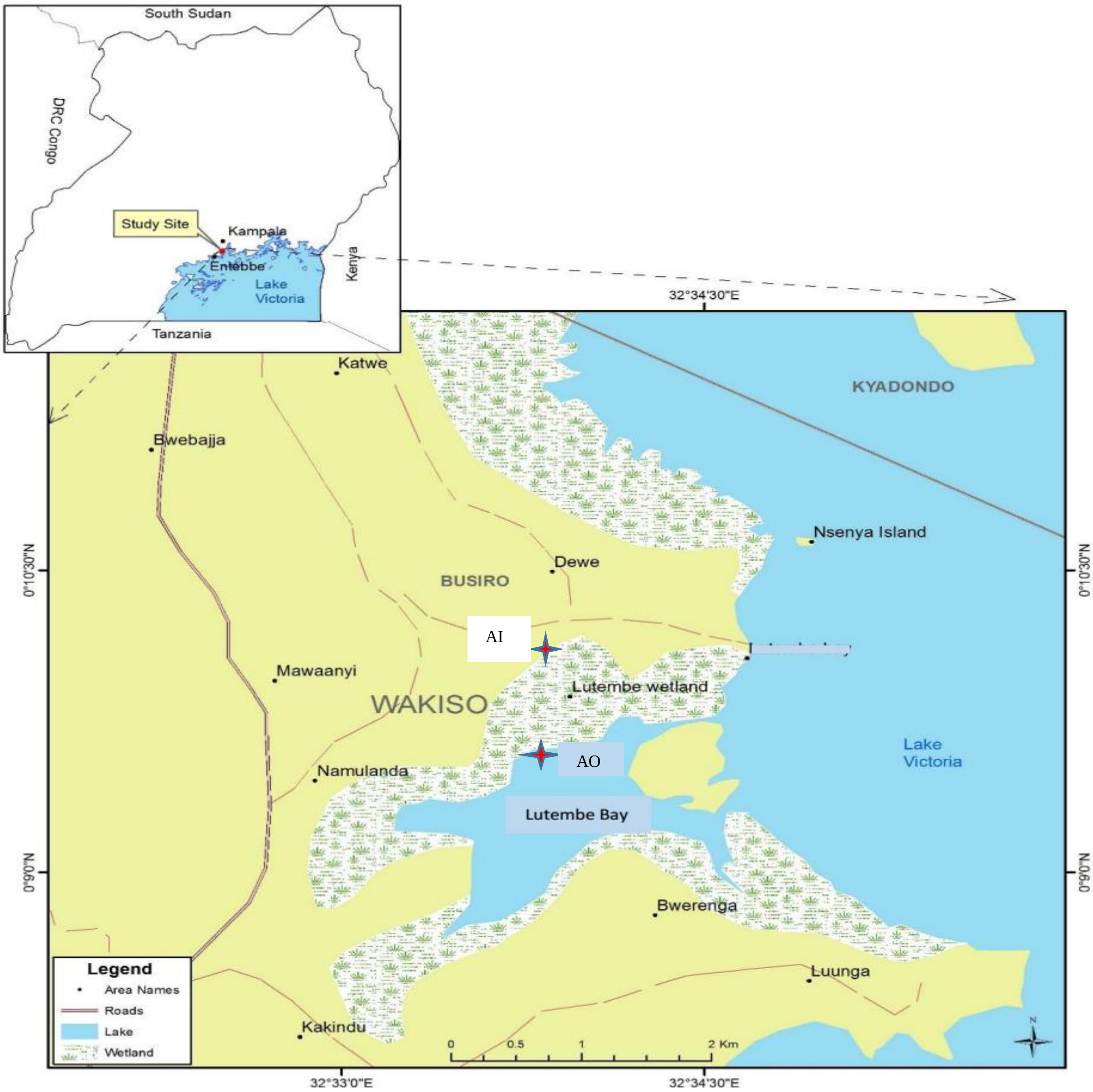


Figure 1: Map of Lutembe Bay Wetland Ramsar Site showing boundaries of the wetland (Source: Ministry of Lands Housing and Urban Development, Survey of Uganda. Scale 1:50,000). AI and AO represent sampling sites.

3.1.2 Climate of the study area

Lutembe Bay Wetland system climate is tropical in nature and locally falls in the Lake Victoria Climate zone (NEMA, 2002). Air currents which comprise of southeast and northeast monsoons passing over Lake Victoria influence the climate of Lutembe Bay Wetland system. The system experiences rainy and dry seasons with a bimodal (in the months of March and October) rainfall pattern receiving high rainfall ranging between 2000-2500 mm. The minimum and maximum mean temperature in this area is 17.4^{o}C and 26.7^{o}C respectively and experiences evapotranspiration ranging from 1450 – 1600 mm (NEMA, 1998).

3.1.3 Land use activities in Lutembe Bay Wetland

The major land use activities in Lutembe Bay Wetland comprise of commercial flower farming mainly horticulture for export, small scale subsistence farming where crops grown include cassava, sugarcane, maize, yams, sweet potato, vegetables, bananas, coffee plus livestock, fisheries; fishing, fish processing and marketing, manufacturing fish nets, boat building and fish culture in ponds, clay mining and sand mining (NatureUganda, 2014).

3.2 Study design

This study constituted the use of quantitative methods whereby water samples were collected in Lutembe Bay wetland at two sampling points outlined in Figure 2 and used to determine the water purification function of the wetland by analysing water quality changes through measurements of physico-chemical parameters, nutrients and TSS content between the inlet and outlet of the wetland. General questionnaire surveys targeting community members who directly benefit from ES at Lutembe Bay wetland were conducted. A total of 203 respondents were used during this study because these are the known registered members. This was followed by Focus Group Discussions (FGDs) consisting of five local community members whose livelihoods depend on the wetland products, two leaders of the Lutembe Bay Wetland Users Association and two community elders. The main purpose of the FGDs was to validate and clarify information provided by the respondents in the questionnaires as well as obtain new information not previously captured. Indicators for measurements of the ES include the number of community members that benefit from the wetland products, fish species abundance for provisioning services and land use and cover as a proxy for nutrient and total suspended solids retention regulating service.

In this study the difference in the concentration of nutrients in the inlet and outlet of the wetland was used as a proxy to quantify the regulatory service of Lutembe Bay wetland. The difference in concentration of nutrients in the bay at present (2015) and before developments in 1999 was used to explain the relationship between provisioning (clay mining, sand mining, fishing) and regulating services in Lutembe Bay wetland.

3.2.1 Questionnaire survey and Focus group discussion (FGDs)

Purposive sampling based on a reconnaissance survey done with the guidance from the Lutembe Wetland Users Association (LWUA) leaders was undertaken to identify the rightful respondents. A general questionnaire survey was administered to 203 community members whose livelihoods depend on ecosystem services provided by Lutembe Bay Wetland. Respondents were also subjected to face to face semi- structured interviews to determine the most important provisioning services in 1999 which was the year developments including expansion of flower farms, building construction started and at present (2015) (see appendix 1) as well as changes in wetland products before and after developments (see appendix 2). Prior to use, the questionnaires were pre-tested on 20 of the community members after which they were adjusted accordingly. Focus group discussions with Lutembe Bay Wetland users were then conducted to assist in validating the information provided by the respondents in the questionnaires, for example, the most important provisioning services obtained from Lutembe Bay wetland and the number of community members per group who benefit from these ES (see appendix 3).

3.2.2 *In-situ* measurements and water sampling

Physico-chemical parameters which include pH, water temperature, dissolved oxygen, and electrical conductivity were measured at Nakaga stream as the inlet (AI) and bay as the outlet (AO) as outlined in Figure 2 for a period of 3 months using calibrated meters; Cyberscan pH 110 for pH, HANNA HI 8733 for electrical conductivity and temperature, Cyberscan DO 110 for dissolved oxygen.

Sampling Layout

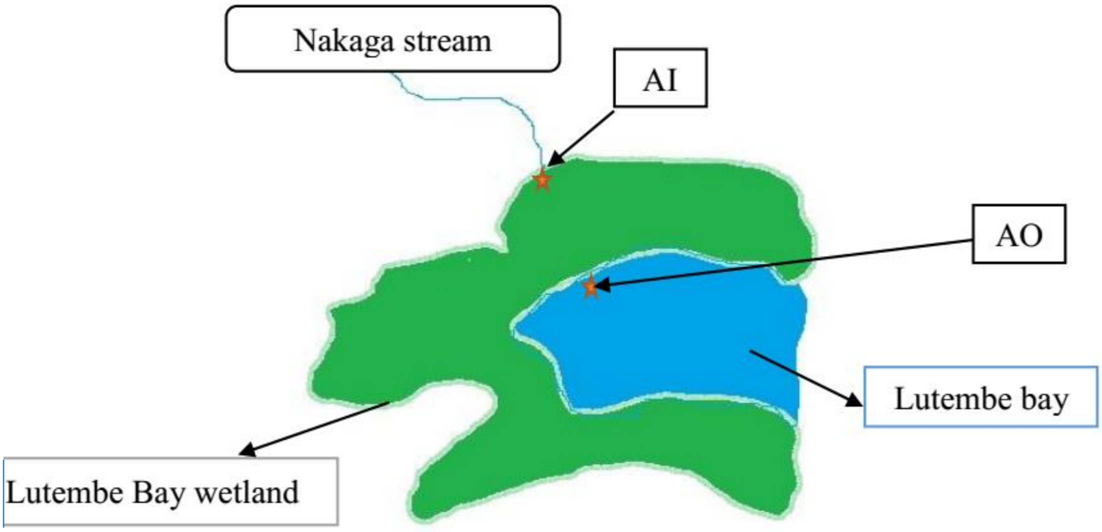


Figure 2: A schematic representation of the sampling lay out for Lutembe Bay wetland. (Source: Self developed)

Water samples for nutrients (SRP, TP, NO_3-N, NO_2-N, NH_4-N and TN) and TSS were within this same time collected in duplicate using 500ml acid washed plastic bottles from the inlet (AI) and outlet (AO) of the wetland, once per week. Two (2) water samples were collected in duplicate per week for the 3 months period, translating into a total of 48 water samples. These samples were used to determine the water purification function of the wetland by analysing the water quality changes within the wetland. For quality control, the water samples collected were stored in a cool box and transported to water quality laboratory at Makerere University for analysis immediately on arrival.

3.2.3 Determination of nitrogen, phosphorus and TSS

Different forms of nitrogen were determined; Ammonium-Nitrogen (NH_4-N), Nitrate-Nitrogen (NO_3-N), Nitrite-Nitrogen (NO_2-N), and Total Nitrogen (TN) using standard methods by APHA (2004). The NH_4-N was determined by the sodium–salicylate method, where 2.5ml of sodium salicylate solution and 2.5ml of hypochloride solution were added to 25ml of filtered water samples from Nakaga stream and Lutembe Bay. The samples were incubated in the dark for 90 minutes after which the absorbance read at wavelength of 665nm using a Palintest 7100 photometer. NO_3-N was determined using sodium-salicylate method, where 1 ml of freshly prepared sodium salicylate solution was added to 20 ml of filtered water sample. The processed samples were then placed in the oven and evaporated to complete dryness at 95°C. The resulting residue was dissolved using 1ml H_2SO_4, followed by addition of 40ml of distilled water and 7ml potassium-sodium hydroxide-tartrate solution respectively and read at a wavelength of 420 nm. NO_2-N was analyzed through the reaction between sulfanilamid and N-Naphthyl-(1) ethylendiamin-dihydrochlorid and absorbance read at a wavelength of 543nm.

Total nitrogen (TN) was determined through persulphate digestion in which 1 ml of warm potassium persulphate was added to 25 ml of unfiltered water sample to convert the nitrogen forms into ammonium. The samples were then autoclaved for 90 minutes at 120ºC and 1.2atm. After digestion, the total reduced forms into ammonium were analysed using sodium-salicylate method. The final concentrations of NH_4-N, NO_3-N, NO_2-N and TN were calculated from their respective equations generated from standard calibration curves (APHA, 2004).
Soluble reactive phosphorus (SRP) was analyzed using the ascorbic acid method (APHA, 2004). The prepared reagents of ammonium molybdate solution (A), sulphuric acid (B), ascorbic acid (C) and potassium antimonyltartrate solution (D) were mixed in a ratio of A:B:C:D= 2:5:2:1 (ml). The resulting mixed solution was added to the filtered water sample at a ratio of 1:10 and the absorbance read at 885nm wavelength using a Palintest 7100 photometer after 15 minutes of reaction and concentration determined from known concentrations of standard solutions (APHA, 2004). Total phosphorus (TP) was determined through persulphate digestion of unfiltered water to reduce the forms of phosphorus present into SRP. After the digestion, evaporated water was replaced and TP analyzed as SRP using ascorbic acid method. The concentration of TP was determined from known concentrations of standard solutions (APHA, 2004).

Total Suspended solids (TSS) was estimated gravimetrically by filtering 150ml of well-mixed water samples through pre-weighed Whatman GF/F filters of pore size 0.7µm. The filter papers were dried to a constant weight at 105ºC for 1 hour cooled in a desiccator and weighed. The TSS weight was then calculated using modified APHA (2004) formula;

$$TSS = \left((Wc - Wf) \times 10^6\right) V^{-1} \qquad (1)$$

Where TSS = Total suspended solids (mg l^{-1}), Wf = Weight of dried filter paper in grams, Wc = Constant weight of filter paper + residue in grams and V=Volume of water filtered (ml).

3.2.4 Hydrological measurements

Water discharge flowing into Lutembe Bay wetland was determined using the Velocity- Area float method. A float and a timer was used to measure the mean water velocity at two premarked upstream and downstream points. The mean cross sectional area was measured using measuring tape and the discharge calculated according to Wetzel (2001) formula;

$$Q = \sum yiAi \quad (2)$$

Where Q = Discharge, y_i = mean current velocity (m/s) and A_i = channels cross sectional area (m^2).

3.2.5 Determination of loading rates

Nutrient and sediment loading in Lutembe Bay Wetland were determined according to Kitaka (2000) as shown below;

$$\text{Nutrient loading/loss} = \text{Discharge} \times \text{nutrient concentration} \times 0.0864 \quad (3)$$

$$\text{Sediment loading/loss} = \text{Discharge} \times \text{nutrient concentration} \times 0.0864 \quad (4)$$

Where nutrient loading/loss (kg/day), discharge (L/S), nutrients/sediment concentration (mg/L) and 0.0864 is concentration time conversion factor from $mgs^{-1}$to kgd^{-1}

3.2.6 Estimation of nutrient and sediment retention

Nutrient and sediment retention were calculated based on methods by Kanyiginya *et al.*, (2010) as shown in the formulae below;

$$\text{Nutrient Retention (\%)} = \frac{\text{Inlet concentration} - \text{Bay concentration}}{\text{Inlet concentration}} \times 100 \quad (5)$$

$$\text{TSS \%} = \frac{\text{Inlet concentration} - \text{Bay concentration}}{\text{Inlet concentration}} \times 100 \quad (6)$$

3.2.7 Sampling and determination of above ground biomass of papyrus plants and nutrient analysis

The above ground biomass of papyrus in Lutembe Bay wetland were determined by harvest method (Kanyiginya *et al.*, 2010). The dominant wetland macrophyte *Cyperus papyrus* where harvested to determine the above ground biomass and nutrient uptake by the plant. Papyrus biomass were harvested in 0.5m×0.5m randomly selected quadrats by cutting above the ground level. The harvesting was done thrice (once every month for three months) during the sampling period to determine the above ground biomass and nutrient uptake. The biomass was determined by measuring the total fresh weight of the papyrus using a field scale (Salter 50 kg × 100 or 200g), sub samples of known weight were then taken for dry weight analysis. This was achieved by oven drying the papyrus material at 70°C to a constant weight to establish the dry weight per m^2. The dry weight of the sub-sample will be used to recalculate the total dry weight biomass per m^2 as follows;

$$DW = \frac{DWs}{WWs} \times TW \qquad (7)$$

Where DW = Dry weight of the standing biomass per m^2, DWs = Dry weight of the sub sample in kg, WWs = wet weight of the sub sample in kg and TW = Total Weight of the sample plot in kg.

Nutrient concentration in papyrus materials collected was determined by analysing TN and TP from known weight of dried and ground papyrus samples. Total nitrogen (TN) was determined through persulphate digestion in which 1 ml of warm potassium persulphate was added to 25 ml of sample to convert the nitrogen forms into ammonium. The samples were then autoclaved for 90 minutes at 120ºC and 1.2atm. After digestion, the total reduced forms into ammonium were analysed using sodium-salicylate method. The final concentrations of NH_4-N, NO_3-N, NO_2-N and TN were calculated from their respective equations generated from standard calibration curves (APHA, 2004).
The TN concentration in the digest and the blank was calculated from standard calibration curve. The nitrogen concentration in plant material was estimated as follows;

$$TN\,\% = \frac{a \times v \times 100}{1000 \times w \times al \times 1000} \qquad (8)$$

Where *a* = concentration of N in the digest, v = volume of digest and plus reagents, w = weight of dried sample (0.1 g) and al = aliqout of the solution analysed.

Total phosphorus (TP) was analyzed using ascorbic acid method (Okalebo *et al.*, 2002). Clear digested supernatant (5ml) was added to 20 ml of distilled water and 10 ml of ascorbic acid respectively and topped up with distilled water to a volume of 50ml. The sample was then mixed and left to settle for 1 hour to full colour development and absorbance read at 880nm. The concentration of TP in the digest was calculated from equation generated from standard calibration curve. The final TP concentration in the plant samples was expressed in % as follows;

$$TP\,\% = \frac{c \times v \times f}{w} \qquad (9)$$

Where c = concentration of P in the digest, v = volume of digest, f = dilution factor and w = weight of the sample (0.1g).

3.3 Data analysis and management

Data collected was stored in Microsoft Office Excel 2013. Statistical analysis were carried out using SigmaPlot® and R software. All tests were carried out at $p<0.05$ significance level and data subjected to a normality and homogeneity of variance test. Normality was checked by Shapiro-Wilk test while homogeneity of variance by Levene's test. The data for in situ and nutrients measurements were not normally distributed. Standardization of the values and log transformation was used on variable prior to conducting parametric tests. For the most important provisioning services, frequency classification was used to identify the percentage of the community members scoring high, medium or low levels of benefit from each wetland product as well as the percentage of the community members taking part in given wetland activities. Variations in mean concentrations of nutrients; NO_3-N, NO_2-N, NH_4-N TN, SRP, TP and TSS in the inlet and outlet of the wetland was compared using Mann-Whitney U test. And nutrients variations between the sampling months was compared using Kruskal Wallis H-test. The difference in means between the sampling months were tested using ANOVA. A Tukey's *post hoc* test was applied to separate means. Pearson's correlation between changes in water quality in relation to changes in major provisioning services was used to assess the relationship between regulatory services and provisioning services.

CHAPTER FOUR

RESULTS

4.1 Most important provisioning ES of Lutembe Bay wetland at present (2015/2016) and in the past (1999)

A total of 173 community members gave their responses on the survey carried out on the most important provisioning services and natural products at present (Figure 3) and the past in Lutembe bay wetland. These provisioning ES services included cultivation of crops for food, water abstraction for domestic use, papyrus harvesting for roofing, basket/mat making, clay mining for making bricks, sand mining, and fishing for food and income. The natural products included food crops, water, papyrus, clay, sand and fish. Most of the respondents reported not being sure and relied on hearsay about the levels of importance of the provisioning ES in 1999 before developments as they had not lived long enough in Lutembe bay wetland area (Figure 4)

4.1.1 Crops production

Cultivation of crops was being carried out at present (2015/2016) at Lutembe Bay wetland where 39.9% (69) reported that it was the most important provisioning ES because it is a cheaper source of food compared to buying from the market. A total of 30 (14.8%) out of the 203 registered wetland users take part in cultivation of crops. This form of agriculture is mostly small scale subsistence agriculture whereby farmers grow crops for domestic consumption and the excess was sold for income. A variety of food crops were being grown which included potatoes, maize cassava, bananas, vegetables, sugarcane, yams, beans, mangoes, papaya. 50.3% (87) reported that it is an important ES, 2.9% (5) least important and 6.9 % (12) had no opinion on the matter. Nonetheless, 34% (59) reported that cultivation of crops was the most important provisioning ES in 1999, 9.8% (17) said it was important, none said it was the least important and 56.1% (97) said they were not sure

4.1.2 Water abstraction

Abstraction of water was not widely carried with 21 (10.3%) out of the 203 registered wetland users taking part in this activity. Most said they only abstracted water from Lutembe wetland for domestic use at times of tap water shortages. Also water was being abstracted at the fish landing site on the fringes of the wetland for the purposes of processing the fish, cleaning fishing boats 1.2% (2) reported water abstraction as the most important provisioning ES at present. 8.7% (15) said it was important, 86.1% (149) said it was the least important provisioning ES because they rely on tap water supplied by the water board because it is clean and convenient while 4% (7) had no opinion on the matter.

Abstraction of water from the wetland was also carried out in 1999 with 7.5% (13) of the respondents reporting that it was the most important provisioning ES, 25.4 % (44) said that it was important, none reported that it was the least important and the majority, 67.1% (116) had no opinion on the matter.

4.1.3 Papyrus harvest

Harvesting of papyrus was also not commonly practised with only 12 (5.9%) out of the 203 registered wetland users participating in this activity. No member reported that it is the most important provisioning ES, only 4.6% (8) said that it is important, 94.2% (163) said that it is the least important provisioning ES while 1.2 % (2) had no opinion on the matter. In 1999 harvesting of papyrus was an activity that was carried out with only 1.7% (3) of the respondents reporting that it was the most important provisioning ES, 5.2% (9) said it was an important activity, 7.5% (13) said it was the least important and majority 85.5% (148) had no opinion on the matter.

4.1.4 Clay mining

Clay mining was perceived by 69.9% (121) as the most important provisioning ES with 76 (37.4%) community members taking part in this activity. Clay was mined from the wetland vegetation zone and this raw material was used mainly for making bricks. 18.5% (32) respondents reported that clay mining was important, 6.9 % (12) said it was the least important ES while 4.6 % (8) had no opinion on the matter. 30.1 % (52) reported that clay mining was the most important provisioning ES in 1999, none reported it as important or least important and 69.9% (121) had no opinion on the matter.

4.1.5 Sand mining

A total of 46 (22.7%) members out of the 203 registered wetland users were engaged in mining of sand at Lutembe bay wetland. From this survey 50.3% (87) of the respondents reported that mining of sand was the most important provisioning ES provided by Lutembe Bay wetland, 34.1% (59 said that sand mining was important, 9.2% (16) perceived it as the least important of the ES while 6.4% (11) had not opinion on this matter. Sand mining was also carried out in 1999 with 22% (38) of the respondents reporting that it was the most important provisioning ES, 2.9% (5) said it was important, only 1.2% (2) reported that it was the least important and 74% (128) where not sure.

4.1.6 Fishing production

Fishing at the open waters of bay was reported by 60.1% (104) as the most important provisioning ES with a total of 40 (19.7%) members out of the total number of registered wetland users engaged in this activity. 35.3% (61) of the respondents said that fishing was important, only 1.7% (3) said that it was the least important provisioning ES and 2.9% (5) had no opinion on the matter. Fishing was carried out in 1999 with 37% (64) of the respondents reporting that it used to be the most important provisioning ES in 1999, no respondent said it was important or least important and 63% (109) had no opinion on the matter.

Figure 3: Some important provisioning ES derived from Lutembe Bay Wetland. (a) Clay mining, (b) Sand mining, (c) Cultivation of crops, (d) Some fish caught from Lutembe Bay

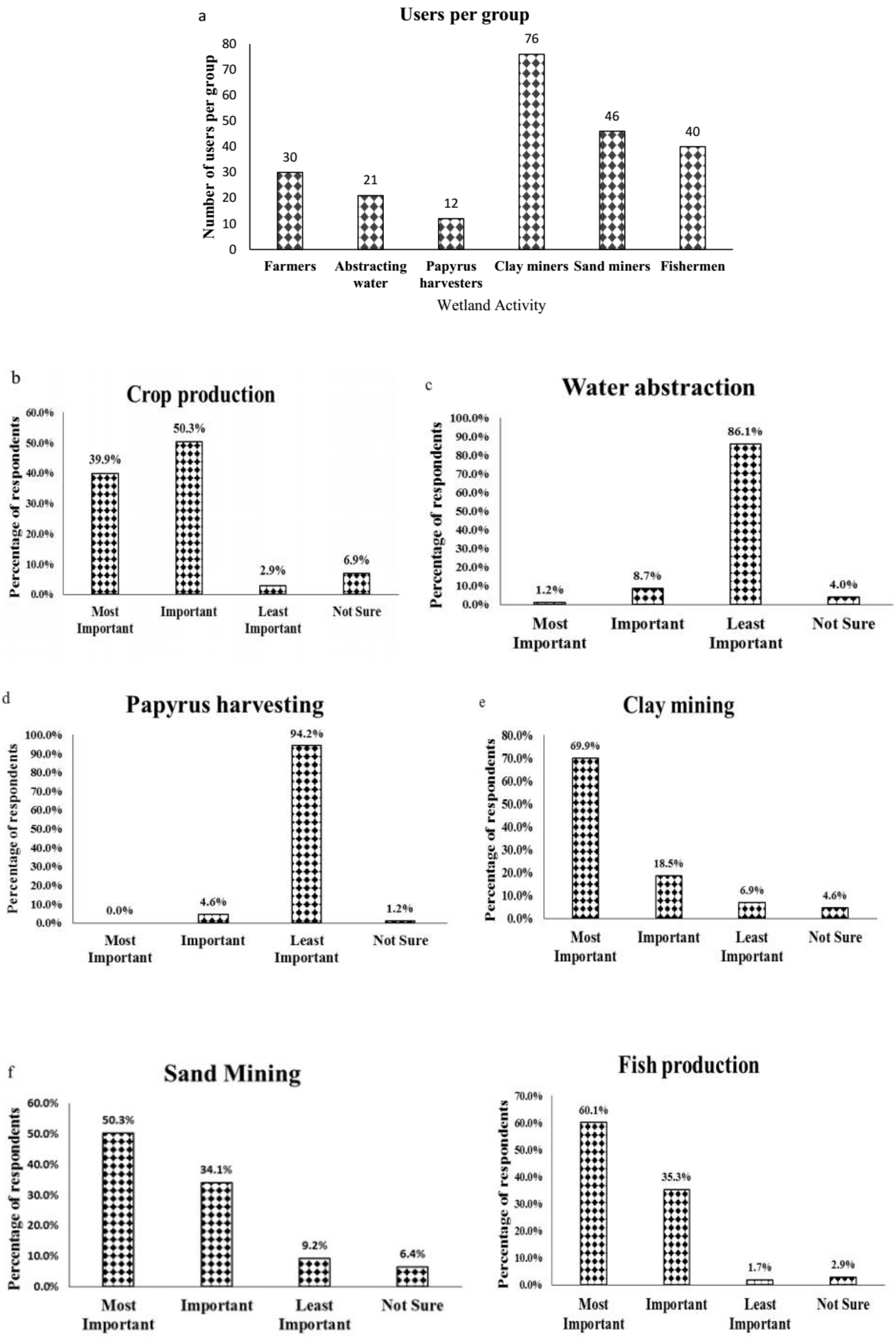


Figure 4: Community's perception of levels of importance of Lutembe wetland provisioning ES in 2015/2016. (a) Wetland users per group, (b) Crop production, (c) Water abstraction, (d) Papyrus harvesting, (e) Clay mining, (f) Sand mining and (g) Fish product

Community perception on importance of different provisioning services of Lutembe bay wetland before intensive development in 1999 are shown in Figure 4. However majority of the members were not sure of the most important provisioning services then as the majority of the current members were not resident of the area then

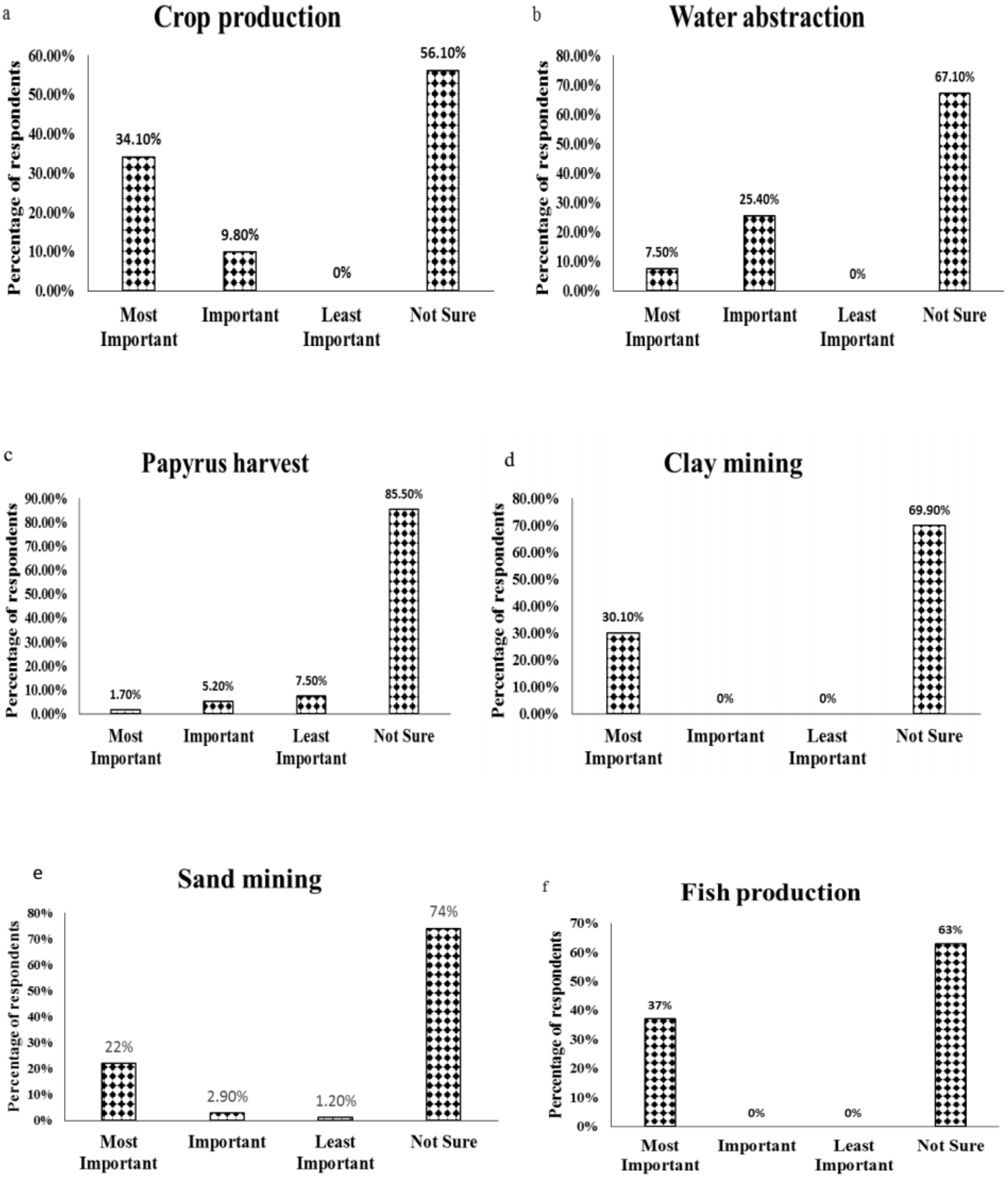
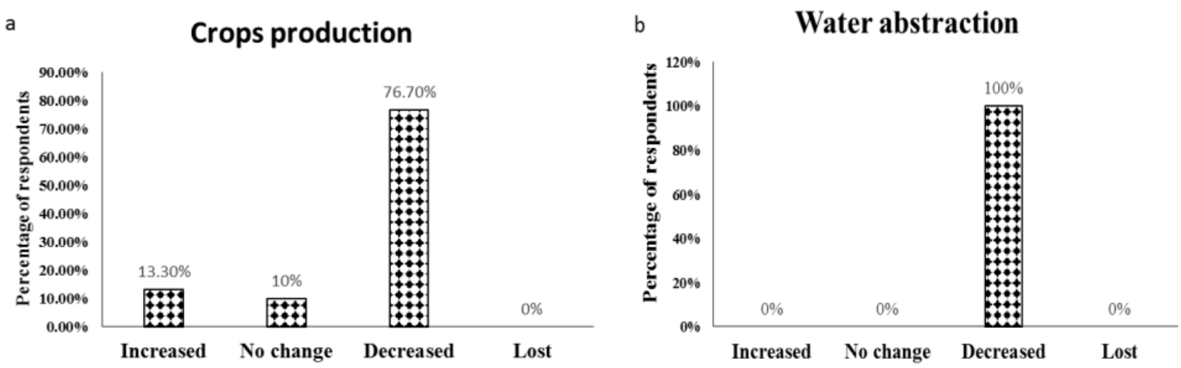


Figure 5: Community perception of levels of importance of Lutembe wetland provisioning ES in 1999. (a) Crop production, (b) Water abstraction, (c) Papyrus harvesting, (d) Clay mining, (e) Sand mining and (f) Fish production

Follow up questions where further posed to the specific groups of wetland users through FGD. The questions were about whether the ES have increased, not changed, decreased or have been lost (Figure 5). 13% (4) of the 30 farmers said cultivation of crops had increased, 10% (3) said there was no change, the majority 76.7% (23) reported that this ES had decreased and none said it had been lost. They attributed the decrease in crop production to chemicals from the flower farms which have repelled the insects which pollinate the plants.100% (21) of the sector who abstract water all reported that abstraction of water had decreased which they attributed to degradation of the wetland by addition of sand to reclaim land for construction of buildings. 100% (12) of the papyrus harvesters reported that this activity had decreased. 50% (38) of the clay mining sector said that this activity had increased, 3.9% (3) said there was no change and 46.1% (35) reported that clay mining had decreased. 89.1% (41) out of the 46 sand miners reported that sand mining had increased and 5 (10.9%) said that it had decreased. 17.5% (7) of the fish folk reported that fishing had increased while the rest 82.5 % (33) said that fishing had decreased.



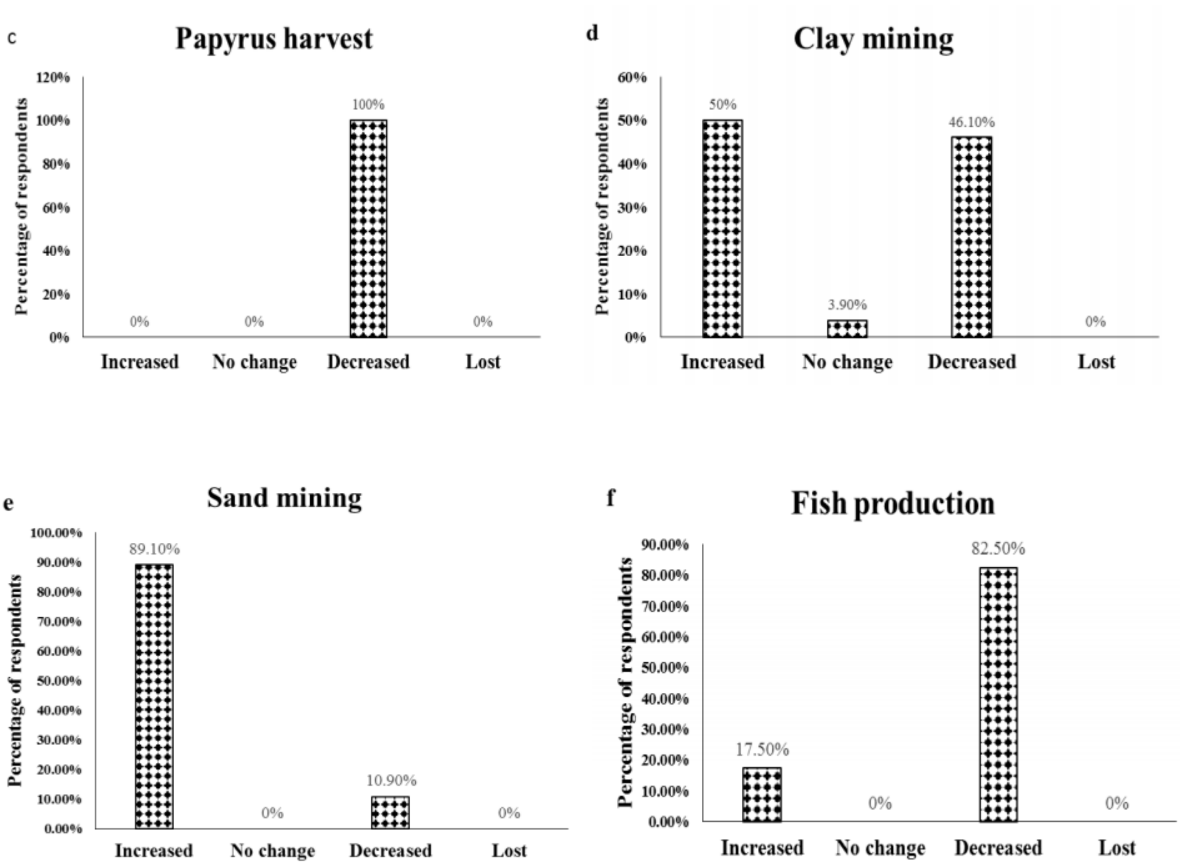


Figure 6: Community perception of changes in most importance provisioning ES. (a) Crop production, (b) Water abstraction, (c) Papyrus harvesting, (d) Clay mining, (e) Sand mining and (f) Fish production

4.2 Water purification ES in Lutembe bay wetland

4.2.1 Spatial variation of physico-chemical parameters in Lutembe bay wetland

(a) Variation of in situ measurements in Nakaga stream inlet and outlet of the wetland

The mean values and ranges for pH, EC, DO and water temperature at the inlet and outlet of Lutembe bay wetland are presented in Table 1. The pH at both the inlet (Nakaga stream) and outlet of the wetland (bay) was relatively alkaline and ranged from 7.42 to 8.95. The EC was significantly higher at the inlet 173.1±12.4 than at the outlet 126.3±4.1µS/cm ($t=91.0$, d.f=1, $p=0.001$). The mean dissolved oxygen concentration did not vary significantly between the sites using two tailed t-test. The mean DO concentration did not vary significantly within the sites ($t=171.0$, d.f=1, $p=0.236$). The mean water temperature increased significantly from the stream to the bay. The mean water temperature at the stream was 23.4±0.3^{o}C and at the bay was 24.3±0.3^{o}C, there was a significant variation between the sites ($t=2.2$, d.f=1, $p=0.038$).

Table 1: Mean values and ranges of physico-chemical variables in Nakaga stream and Lutembe bay. ± represents standard error of the mean and the values in parenthesis are the ranges (n=24)

Physico-chemical Variables	Nakaga stream	Lutembe Bay
pH range	(7.42-8.95)	(7.24-8.74)
EC (µS/cm)	173.1±12.4 (122.6-265.0)	126.3±4.1 (116.0-158.7)
DO (mg/l)	8.32±0.24 (7.31-9.72)	8.93±0.39 (7.79-12.37)
Temp^{o}C	23.4±0.3 (22.0-25.1)	24.3±0.3 (22.9-26.4)

(b) Variation in ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen and total nitrogen concentration in Nakaga stream and Lutembe bay.

Results for spatial variation in NH_4-N, NO_3-N, NO_2-N and TN at the inlet and outlet of the wetland during the study period of December 2015 to February 2016 are presented in Figure 6. Ammonium-nitrogen (NH_4-N) concentration was lowest (0.182±0.017mg/l) in the stream while the highest concentration was observed at the bay (0.381±0.083mg/l). No significant difference was observed between the sites (t=1.6, d.f =1, p = 0.117). Mean nitrate concentration was 0.110±0.014mg/l and 0.111±0.012mg/l in the stream and bay respectively. The mean concentration of nitrate was significantly lower in the bay than at Nakaga stream (t= 300.0, d.f=1, p = 0.001) using two tailed t-test. Mean nitrite concentration was 0.035±0.003 mg/l in the stream and 0.037±0.007 mg/l at the bay. There was no significant difference in the mean nitrite concentration between the sites (t = 618.5, d.f=1, p=0.535). Total nitrogen (TN) concentration was lowest (0.37±0.02 mg/l) in the stream while highest (0.56±0.09 mg/l) at the bay. Though there was no significant difference in the mean TN concentrations between sites (t=518.0, d.f =1, p=0.151)

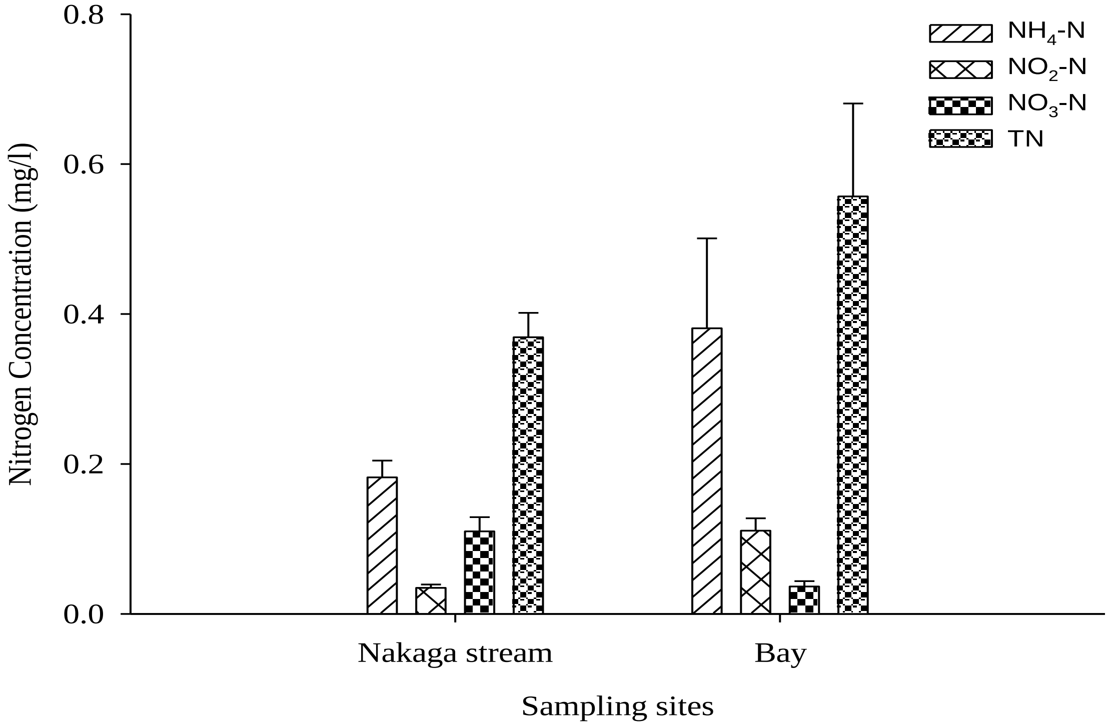


Figure 7: Variation in ammonium, nitrate, nitrite and total nitrogen concentration in Nakaga stream and Lutembe Bay. Bars indicate standard error of the mean (n=2)

(c) Variations in SRP, TP and TSS concentration in Nakaga stream and Lutembe bay

Soluble reactive phosphorus at the bay was significantly higher than that at Nakaga stream (t=839.0, d.f=1, p=0.001). The mean SRP concentration recorded in the stream was 0.47 ± 0.15 mg/l and in the bay was 0.65± 0.15mg/l (Figure 7). TP concentration was lowest at the stream with a mean value of 0.60 ± 0.17 mg/l and highest in the bay (1.00 ±0.19 mg/l). The TP concentration was significantly higher in the bay than in Nakaga stream (t=554.0, d.f=1, p=0.490). Phosphorus in both the stream and the bay was dominated by SRP. In the stream, 78.3% and 21.7% were observed as SRP and PP respectively. At the bay SRP was 65% and PP was 35%. The mean TSS concentration was highest at the stream compared to the bay. The lowest concentration of 0.05±0.00 mg/l was observed in the bay. The mean concentrations were 0.10 ±0.01 mg/l and 0.05±0.00 mg/l at the stream and bay. The TSS concentration was significantly higher at Nakaga stream than at the bay (t=876.0, d.f=1, p = 0.001).

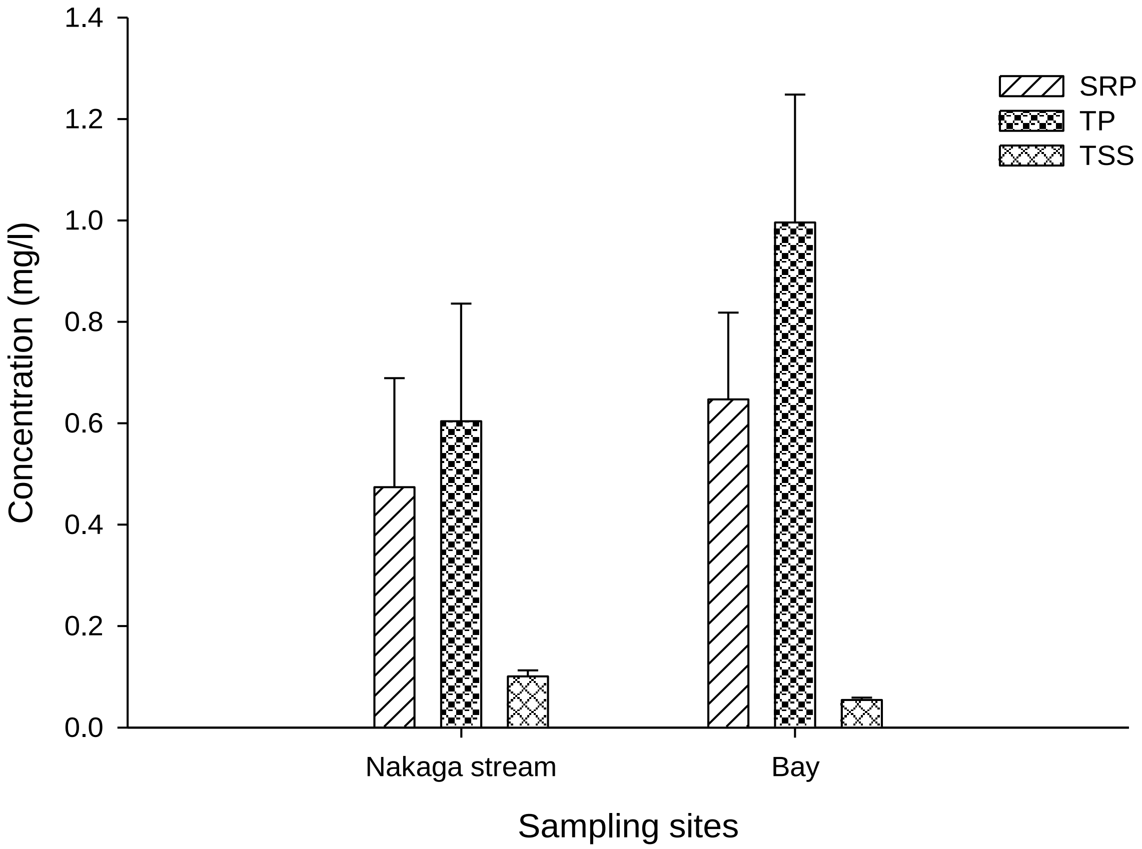


Figure 8: Variation in soluble reactive phosphorous, total phosphorus and total suspended solids concentration in Nakaga stream and Lutembe Bay. Bars indicate standard error of the mean (n=2)

4.2.2 Macrophyte biomass and nutrients accumulation

The above ground mean biomass of papyrus harvested in the wetland was 9.6±0.5 KgDW/m^2. The biomass ranged from 9.12 KgDW/m^2 to 10.05 KgDW/m^2 over the sampling period. The overall total nitrogen accumulation in the plants is 0.024KgN/m^2 and 0.013KgP/m^2 for total phosphorus.

Table 2: Total nitrogen and total phosphorus accumulation for above ground biomass of papyrus plants.

Papyrus	Biomass (KgDWm^2)	N accumulation (KgN/m^2)	P accumulation (KgP/m^2)
Quadrant 1	10.0	0.021	0.011
Quadrant 2	9.1	0.026	0.015
Quadrant 3	9.7	0.024	0.013
Mean	9.6±0.5	0.024	0.013

4.2.3 Nutrients and TSS loadings into Lutembe bay wetland from Nakaga Stream

The amounts of nutrients discharged into Lutembe bay wetland from Nakaga stream ranged from 0.08 to 1.45kg/day (Table 2). Suspended particle loading on the other hand was 0.24 Kg/day with a discharge of 2419m^3/day.

Table 3: Nitrogen, phosphorus and TSS loadings into Lutembe bay wetland from Nakaga inlet Stream. Values based on mean nutrient concentrations and mean discharge.

Variable	**Concentration (mg/l)**	**Load (Kg/day)**
NH_4-N	0.182	0.44
NO_3-N	0.110	0.27
NO_2-N	0.035	0.08
TN	0.37	0.89
SRP	0.47	1.14
TP	0.60	1.45
TSS	0.10	0.24

4.2.4 Nutrients and Sediments retention in Lutembe Bay Wetland

Due to the challenges in determining the amount of water discharged from the wetland to the bay since there was no clear outlet channel, the retention results are presented using concentrations rather than loading rates as expected. Nutrients concentrations were higher at the bay than at Nakaga stream as shown in Table 3 below. On the contrary, sediments concentrations were higher at Nakaga stream than the bay.

Table 4: Nitrogen, phosphorus and TSS concentrations and retention in Lutembe bay wetland

Variable	**Concentration (mg/l)** Nakaga Stream	**Concentration (mg/l)** Bay	**Nutrient Concentration retention (%)**
NH_4-N	0.182	0.381	-109.34**
NO_3-N	0.110	0.111	-0.91**
NO_2-N	0.035	0.037	-5.71**
TN	0.37	0.56	-51.35**
SRP	0.47	0.65	-38.29**
TP	0.60	1.00	-66.67**
TSS	0.10	0.05	50*

*Indicates retention by the wetland **Indicates no retention but instead the wetland acting as a source

4.2.5 Temporal variation in physico-chemical parameters in Lutembe bay wetland.

(a) Temporal variation of *in situ* measurements; DO, EC, water temperature and pH at the inlet and outlet of the wetland.

The mean values for DO, water temperature and EC with their variations among the sampling months are presented in Figure 8. The mean DO concentration at the inlet of the wetland ranged from 7.31-9.72mg/l while at the bay it ranged from 7.79-12.37mg/l. The mean DO concentration at the inlet of Lutembe wetland did not vary significantly over time during the study period (ANOVA, F=0.939, d.f=2, p=0.426). The DO concentration at the outlet of the wetland also did not vary significant over time (ANOVA, F=1.551, d.f=2, p=0.264). The EC at the inlet of the wetland varied significantly among the sampling period (ANOVA, F=9.701, d.f=2, p=0.006). The highest EC of 265.0µS/cm was observed in December while the lowest of 122.6µS/cm was observed in February. Based on Tukey's *post hoc* test the EC in January and February were similar but significantly lower than the EC in December ($p<0.05$). The EC at the bay showed similar trend with significant variation among sampling months (ANOVA, F=7.385, d.f=2, p=0.015). Based on Tukey's *post hoc* test the EC in January and February were similar but significantly lower than the EC in December ($p<0.05$). Water temperature at the inlet of the wetland showed no significant variation among the sampling period (ANOVA, F=3.137, d.f=2, p=0.093). The bay showed similar trend without significant change among the sampling period (ANOVA, F=0.231, d.f=2, p=0.798). During the sampling session the water temperature ranged from 22.0-25.1ºC at the inlet of the wetland and 22.9-26.4ºC at the bay.

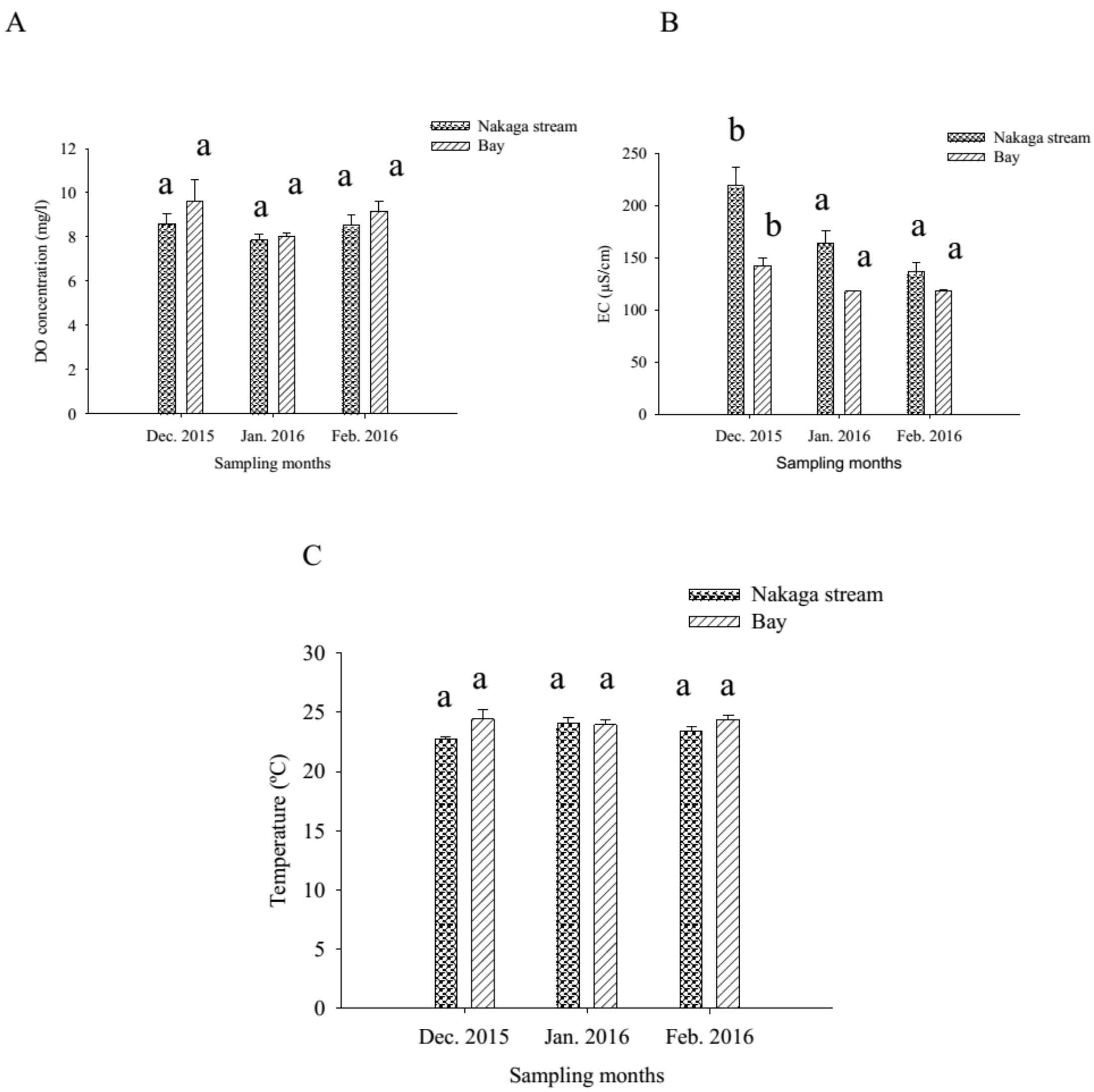


Figure 9: Temporal variation of in situ measurements of DO, EC and temperature at Nakaga stream and the bay (values presented as means ±SE, n=3). (A) Dissolved Oxygen concentration, (B) Electrical conductivity and (C) Temperature. Bars with the same letters are not significantly different (Tukey's post hoc test).

(b) Temporal variation in ammonium-nitrogen, nitrate-nitrogen, nitrite-nitrogen and total nitrogen concentration in Lutembe bay wetland

The temporal variation in NH_4-N, NO_3-N, NO_2-N and TN at Nakaga stream and the bay during the study period of December 2015 to February 2016 are presented in Figure 9. The mean ammonium concentration differed significantly at the stream during the sampling period (ANOVA, $F=17.803$, d.f=2, $p=0.001$). The concentration increased from December to

February. Based on Tukey's *post hoc* test, the NH_4-N concentration was similar in January and February but significantly lower in December ($p<0.05$). At the bay, the ammonium concentration did not differ significantly during the sampling period (ANOVA; F=2.663, d.f=2, p=0.264). The mean nitrate concentration at the stream differed significantly during the sampling period (ANOVA, F=16.880, d.f=2, p=0.001). The concentration also increased from December to February. Based on Tukey's *post hoc* test, nitrate concentration was significantly higher in February than in December ($p<0.05$). The concentration at the inlet of the wetland was highest (0.279±0.014mg/l) in February but lowest in December (0.034±0.014mg/l). The same trend was observed the bay with nitrate concentration being significant higher in February than in December ($p<0.05$). The nitrite concentration at Nakaga stream did not differ significantly during the sampling period (ANOVA; F=0.725, d.f=2, p=0.616). The nitrite concentration at the bay followed the same trend and did not significantly vary during the sampling period (ANOVA; F=5.771, d.f=2, p=0.056). The mean TN concentration followed a similar trend as nitrate. The concentration at Nakaga stream increased from December to February. There was a significant difference in the TN concentration during the sampling period (ANOVA, F=14.300, d.f=2, p=<0.001). Based on Tukey's *post hoc* test, TN concentration was significantly higher in February than in December ($p<0.05$) but were similar amongst the sampling period. At the bay, there was no significant variation in the TN concentration during the sampling period (ANOVA, F=4.913, d.f=2, p=0.086).

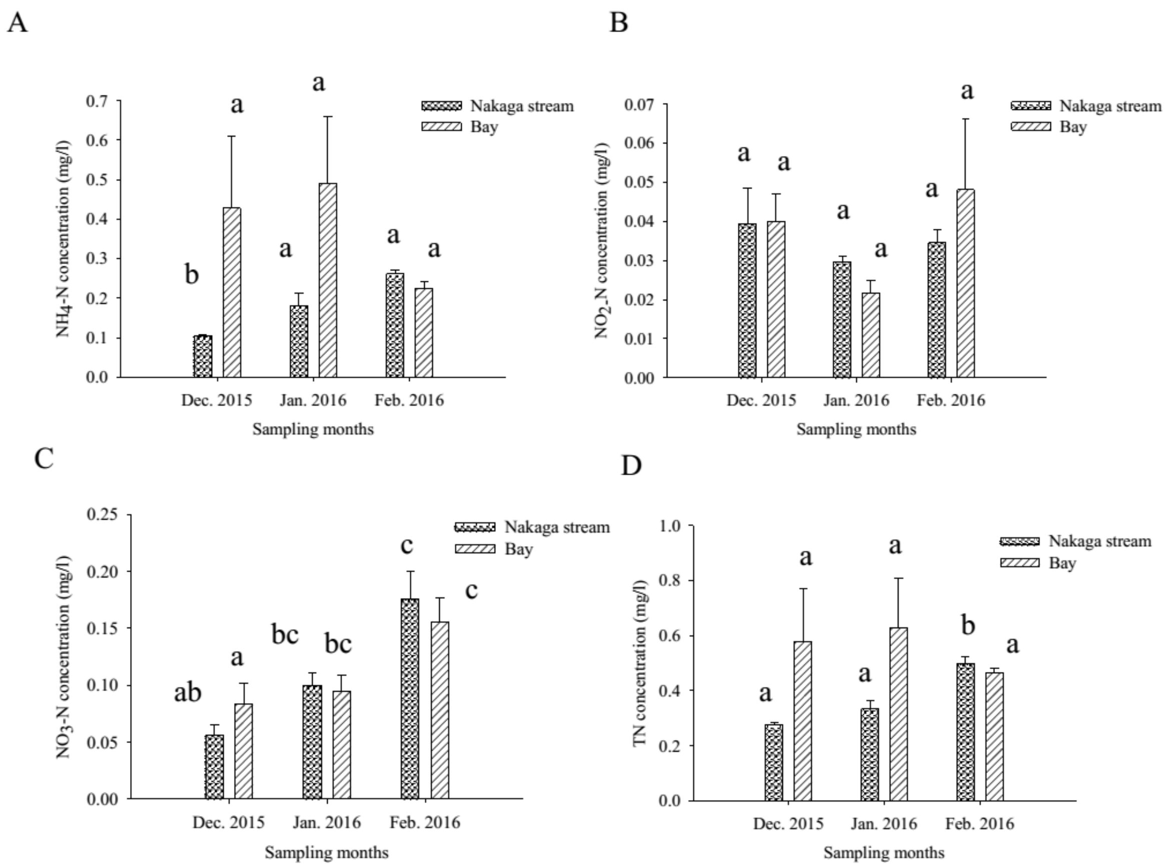


Figure 10: Temporal variation in ammonium, nitrate, nitrite and total nitrogen in Lutembe bay wetland bay. (A) Ammonium nitrogen concentration, (B) Nitrite nitrogen concentration, (C) Nitrate nitrogen concentration and (D) Total nitrogen concentration. (Values presented as means ±SE, n=3). Bars with the same letters are not significantly different (Tukey's post hoc test).

(c) Temporal variations in SRP, TP and TSS concentration in Nakaga stream and Lutembe bay

The highest mean SRP concentration of 3.3±0.15 was observed in December at the inlet to the wetland (Figure 10). The lowest SRP concentration at the inlet to the wetland 0.09±0.15 mg/l was also observed in December. At Nakaga stream, there was no significant variation in the concentration among the sampling period (ANOVA, F=2.370, d.f=2, p=0.306). The mean SRP concentration at the bay varied significantly from December to February (ANOVA, F=10.417, d.f=2, p=0.005). Based on Tukey's *post hoc* test, the SRP concentration was significantly higher in February than in December ($p<0.05$). The TP concentration at Nakaga stream did not vary significantly from December to February (ANOVA, F=11.281, d.f=2, p=0.278). The TP concentration at the bay followed a different pattern from the stream. The concentration increased from December to February and there was a significant difference among sampling period (ANOVA, F=6.025, d.f=2, p=0.004). Based on Tukey's *post hoc* test, the TP concentration in February was significantly higher than in the month of December ($p<0.05$). The mean TSS concentration at Nakaga stream varied significantly during the sampling period (ANOVA, F=14.292, d.f=2, p=0.001). Based on Tukey's *post hoc* test the TSS concentration was significantly higher in December than in both January and February ($p<0.050$). At the bay, the TSS concentration varied significantly among the sampling period (ANOVA, F=2.261, d.f=2, p=0.004). Based on Tukey's *post hoc* test the TSS concentration was higher in February than in both December and January ($p<0.05$).

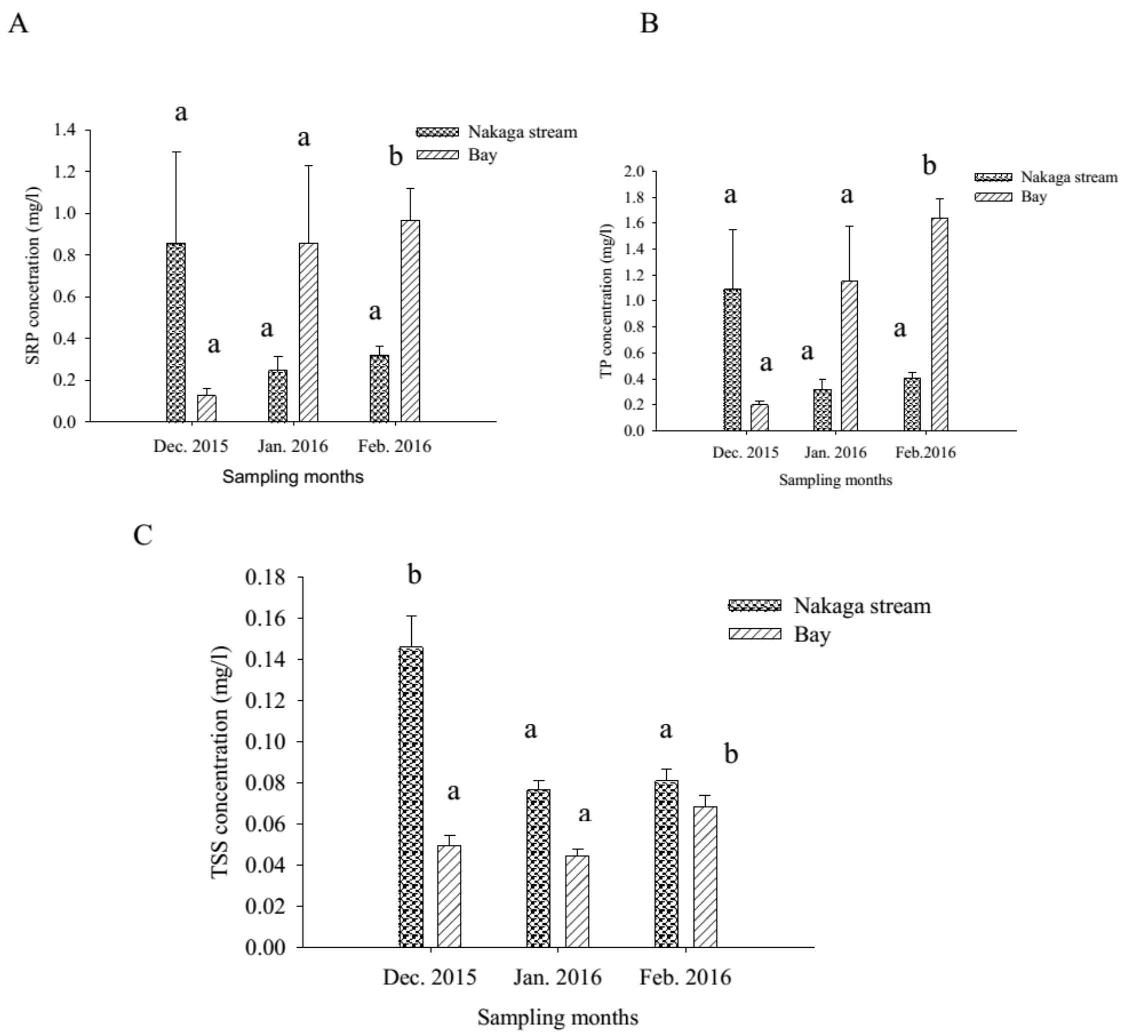


Figure 11: Temporal variation in soluble reactive phosphorus, total phosphorus and total suspended solids concentration in Lutembe bay wetland bay. (A) SRP concentration, (B) TP concentration and (C) TSS concentration. (Values presented as means ±SE, n=3). Bars with the same letters are not significantly different (Tukey’s post hoc test).

4.3 Relating changes in water quality in 1999 and 2015/2016 to the increase of major provisioning ES activities in Lutembe bay wetland

The concentrations of NH_4-N, NO_3-N, NO_2-N, TN and TP at Lutembe bay in 1999 and 2015/2016 are shown in Figure 11 below. The results showed that the mean nutrient concentrations at Lutembe bay were lower in 1999 than in 2015/2016. The highest nutrient concentration increase observed at the bay was for TP where the concentration increased by 0.89mg/l (809%) followed by ammonium which increased by 0.30 mg/l (376%). Changes in the most important provisioning ES at present in relation to the major ES in the past are shown in Figure 12. The community members engaged in specific wetland activities gave their responses about how major provisioning ES at present may be interrelated with other provisioning ES as well as wetland water purification function. 100% (21) of the sector who abstract water all reported that abstraction of water had decreased. 89.1% (41) out of the 46 sand miners reported that sand mining had increased. 82.5 % (33) said that fishing had decreased while 50% (38) of the clay mining sector said that this activity had increased.

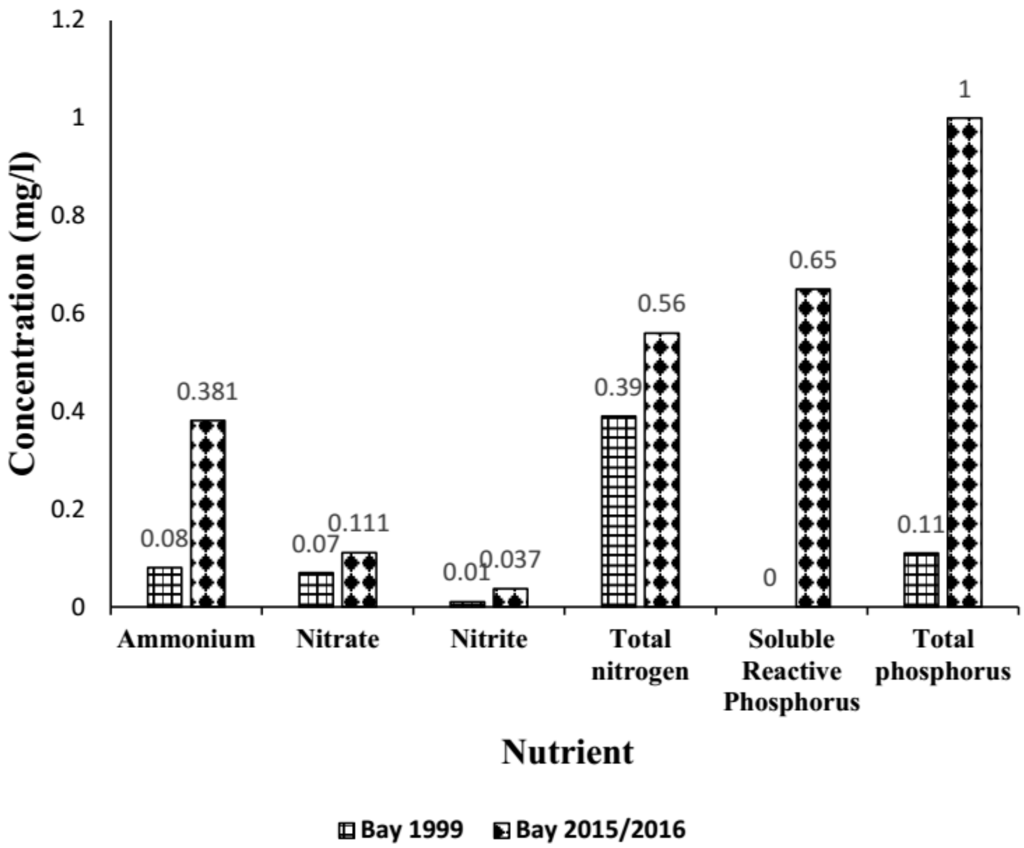


Figure 12. Comparison of nutrients concentrations in 1999 and 2015/2016 in Lutembe bay. SRP was not measured in 1999. (Source of data for 1999: NatureUganda)

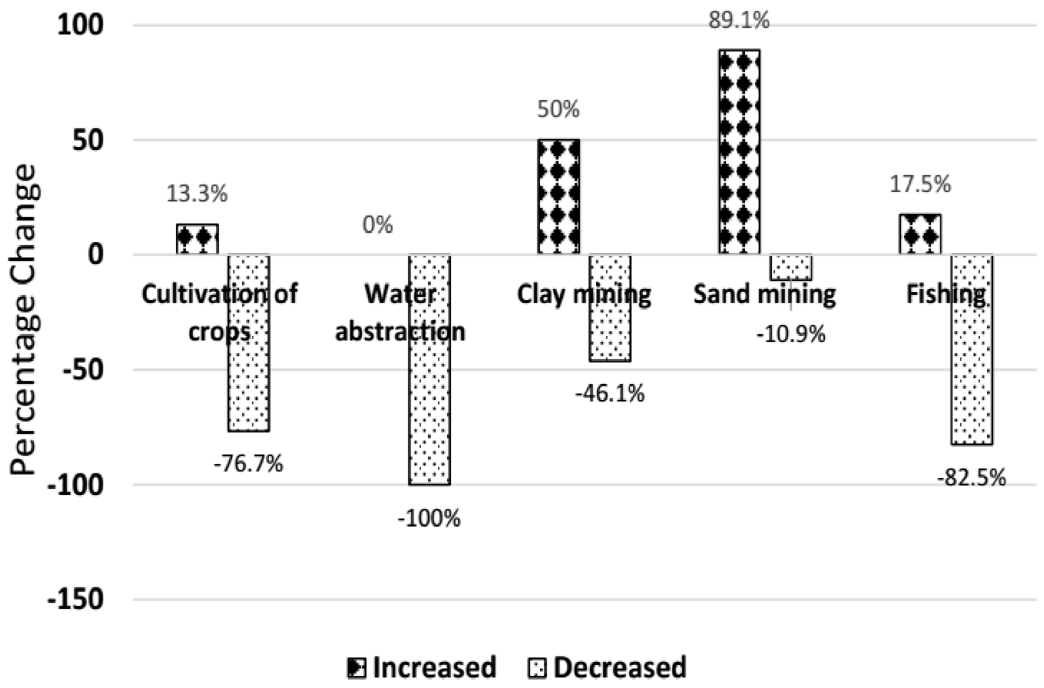


Figure 13. Respondents' perceptions on changes of most important provisioning ES in 2015/2016 in relation to 1999

The concentrations of NH_4-N, NO_3-N, NO_2-N, TN and TP were positively correlated to the most important provisioning ES between 1999 and 2015/2016 of Lutembe Bay Wetland (Table 5). The correlation though was not significant with respect to the most important provisioning activities and nutrients. The correlation was significant between 1999 and 2015/2016.

Table 5: Correlation matrix between major provisioning ES and Lutembe bay water quality in 1999 and 2015/2016.

		Year	NH_4-N	NO_3-N	NO_2-N	TN	SRP	TP
Year	Pearson correlation	1	1.000**	1.000**	1.000**	1.000**	1.000**	1.000**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000	0.000
		Importance	NH_4-N	NO_3-N	NO_2-N	TN	SRP	TP
Importance	Pearson correlation	1	0.103	0.103	0.103	0.103	0.103	0.103
	Sig. (2-tailed)		0.845	0.845	0.845	0.845	0.845	0.845

**. Correlation is significant at the 0.01 level (2-tailed)

CHAPTER FIVE

DISCUSSION

5.1 Historical overview and present status of Lutembe Bay wetland

Lutembe bay wetland like most wetlands in Uganda are protected and supported by the National Wetlands Policy of 1995. However, Lutembe bay wetland still faces degradation from anthropogenic activities such as clay mining and sand mining. The wetlands surrounding Lake Victoria face major environmental challenges such as encroachment of wetlands for the expansion of anthropogenic activities in light of the high population growth rate (Were *et al*. 2013). According to Muthuri *et al.* (1989) papyrus has a notable ability to absorb nutrients particularly nitrogen and phosphorus compared to other emergent aquatic plants.

It was also established that Lutembe community members are organized into the Lutembe Wetland Users Association (LWUA) which is a group of adjacent community members who use the wetland and its surroundings for their livelihood (NatureUganda, 2014). The aim of LWUA is to promote nature conservation, poverty reduction and promote tourism among the community members deriving benefits from Lutembe Ramsar sites the bay and wetland inclusive. More so, this association aims to guard against prohibited activities such over exploitation of the wetland and its resources (NatureUganda, 2014)

5.2 Major provisioning ES derived from Lutembe bay wetland

The main provisioning ES activities observed in and around Lutembe bay wetland include sand mining, clay mining and fishing. Clay mining, sand mining and other activities like cultivation of crops are slowly encroaching on this papyrus dominated wetland. These observations were similar to those made by Byaruhanga and Nalwanga (2006) at Lutembe bay wetland area. They reported that this area being in close proximity to Uganda’s capital city, Kampala has high potential for income-generation through not only eco-tourism but other developments such as sand mining for ready market in the city. However this study advised that these developmental activities need to be monitored to evaluate their potential impact on the wetland and its surroundings. The major provisioning ES activities of the past in this study includes fishing, water abstraction and crop production. These findings were similar to those conducted in a study by Arinaitwe (1997) where the wetland was important in supporting local community wellbeing through provision of water for domestic use, fish for food and local materials for crafts and building.

Clay and sand mining are some of the key ES activities carried out by the local community members of Lutembe bay wetland. These activities have increased due to the increased demand for building material as a result of the high population growth rate. Clay mining involves digging pits on the fringes of the wetland to extract clay that is used to make bricks that are sold to generate income. There is less clay mining in the rainy season because of flooding and lack of drying materials. According to FGD the members who mine clay are also involved in sand mining and carry out both activities interchangeably depending on the season. Sand mines are owned by different proprietors who hire the community members for manual labour. The sand is loaded onto trucks and transported to construction sites. According to NatureUganda (1999), sand mining is carried out around Nakaga stream and is gradually encroaching on Lutembe bay wetland.

FGD revealed that a variety of fish were found at Lutembe bay wetland in the 1960s before the wetland was stressed with pollution and encroachment. The fish species harvested during that time but have since been lost include; Kisinja (*Barbus altianalis*), Kasulu (*mormyrids*), Amadoola, Mukene (*Rastrineobola argentea*), Njunguli, Eningu (*Labeo victorianus*) among others. The total number of fish species has declined in 2015 to mainly catfish and only one species of Nile tilapia as opposed to four species of Nile tilapia in past. Fishing as one of the major provisioning ES is normally carried out in the open waters of Lutembe bay and Lake Victoria but rarely in Lutembe bay wetland. This observation is similar to findings carried out by NatureUganda (1999) where it was reported that fishing was mostly carried out at Kakindu bay (near Lutembe bay) and open waters of Lake Victoria. Although some research about the challenges facing fisheries resources such as habitat modification, water pollution and fishing malpractice has been previously conducted, no detailed studies concerning wetland fisheries exist (Oduor *et al*., 2015). The scarcity of fish in Lutembe bay wetland may be attributed to wetland (habitat) degradation (pollution, sedimentation, damping of garbage), over fishing which was backed up by 82.5% of respondents reporting that fish catch has reduced and the decrease of Lake Victoria water level by 2.5m between 2000 and 2006 exposed the papyrus wetlands (Awange and Ong'ang'a (2006). Studies carried out in Nyando Wetland in Kenya have revealed that both lake and wetland fisheries were characterized by a marked decline (Obiero *et al*., 2012).

5.3 Water purification in Lutembe bay wetlands

The pH observed in the bay was more alkaline than that recorded at Nakaga stream owing to an increase in phytoplanktonic productivity at the bay in which primary producers assimilate dissolved carbon dioxide, decreasing the calcium ion (Ca^{2+}) concentration and raising the pH in the process (Hamilton, *et al*., 2009). The temperatures recorded at the bay in this study were within the ranges previously recorded in a study conducted by Hecky (1993) of Lake Victoria waters in Tanzania where the temperatures ranged from 24.2 to 26.2 ^{0}C. They were also similar to values according to a study conducted by Kishe (2004) who reported a range of 24.5^{0}C to 25.8 ^{0}C also in Lake Victoria.

The electrical conductivity observed at both Nakaga stream and the bay decreased during the sampling period from December to February. This is possibly because of the change in rainfall pattern with the short rainy season from October to December and the dry seasons follows there after (Kizza *et al*., 2009). A previous study conducted by Banadda (2011) on the the shores of Lake Victoria, Uganda showed higher EC value concentrations during the rainy season owing to runoff which carries sediment laden with ions that contribute to the EC values. The mean EC observed downstream of Nakaga stream as the inlet to the wetland was 173.1 µS/cm. This observation was higher than the value reported by NatureUganda (1999) upstream of Nakaga stream where a value of 55µS/cm was reported. However, the EC value in this study is slightly lower than the 195.4 µS/cm reported by Adhiambo (2013) downstream of River Mereronyi wetland in Kenya and Kanyiginya *et al.,* (2010) in Natete wetland in Uganda where a much lower value of 490 µS/cm was recorded. The mean value observed in the bay during this study was 126.3±4.1µS/cm which was higher than the 80µS/cm reported by NatureUganda (1999) in Lutembe bay and was similar to a mean of 127.6±7.8 µS/cm recorded by Adhiambo (2013) at the outlet of Mereronyi wetland. The lower electrical conductivity at the bay compared to the rivers may be attributed to removal of ions by complexation, deposition and uptake by the vegetation as the water passes through the wetland as well as uptake by phytoplankton in the bay (NatureUganda, 1999).

A significant role of wetlands in aquatic ecosystems is the removal of nutrients and suspended particle loads from running waters (Jones *et al*., 2001; Jordan *et al*., 2003; Akratos *et al*., 2006; Palmeri and Treppel 2002). Since they play an important role in the improvement of the environmental quality of catchments, special attention has been given to the conservation and restoration of natural wetlands (Tsihrintzis *et al*., 1995). In Lutembe bay wetland nitrate, soluble reactive phosphorus, total phosphorus and TSS concentrations at Nakaga stream and the bay were significantly different using two tailed t-test. However, ammonium, nitrite and total nitrogen concentrations at Nakaga stream and bay were not significantly different.

The higher concentration of nutrients recorded at the bay may be attributed to deteriorating water quality of Lake Victoria as a result of anthropogenic factors such as siltation, water pollution and eutrophication (Okungu *et al*., 2005; EAC, 2008). Lutembe bay is not completely cut off from the main body of Lake Victoria (Byaruhanga and Nalwanga, 2006) implying that there is some degree of mixing of water between the bay and Lake Victoria. These observations were similar to those made by NatureUganda (1999) in Lutembe bay where it was noted that only small volumes of water flow in an out of the bay. This suggests that there is some degree of mixing as seen by the similarity between mean concentrations of nitrate (0.1mg/l) and total phosphorus (0.8mg/l) recorded in 1999 and in this study (0.111±0.014mg/l and 1.00±0.19mg/l respectively) in Lake Victoria inner Murchison bay area.

The higher ammonium and lower nitrate concentration at the bay maybe due to ammonification and denitrification. Ammonification of organic nitrogen can happen both under aerobic and anaerobic conditions (Pinay *et al*., 2002). When NO_3-N from external sources flows into lakes, it is taken by autotrophs and bacteria and transformed into organic matter. In relatively standing waters such as at Lutembe Bay, the organic nitrogen mineralization process occurs thereafter resulting in accumulation of ammonia (Quirós, 2003). Lakes with high concentration of organic matter have the potential to accumulate ammonium and in anaerobic conditions denitrification would prevail (Stumm and Morgan, 1996).

The higher proportion of soluble reactive phosphorus to particulate phosphorus in both Nakaga stream and the bay may be attributed to delivery of diffuse loads which is seasonal and varies from one catchment to another. The highest concentration of soluble reactive phosphorus of was recorded on 17/12/2015 with a value of 3.3mg/l may be explained by the fact that samples were taken immediately after watering of cattle from the same source point. According to Mainstone and Parr (2002) the majority of the diffuse nutrient load is transported in surface run-off attached to soil particles though much higher proportions of soluble phosphorus occur when livestock excreta in forms such as slurry or soluble inorganic fertilisers are washed off the land shortly after application. Residents surrounding Lutembe bay wetland carry out subsistence agriculture where they grow crops such as beans, cassava and sweet potatoes and rear cattle along the fringes of the wetland (NatureUganda, 1999).

The above ground biomass recorded in this study was higher than that reported by Kanyiginya *et al.* (2010) in Natete wetland in Uganda (1kgDW/m^2) and was within the range of 6.61 kgDW/m^2 to 11.54 kgDW/m^2 observed in a study conducted by Jones and Muthuri (1997) and Boar *et al*., (1999) for Naivasha, Kenya. Wetland macrophytes play an important role in removing nutrients through incorporation of nitrogen and phosphorus in plant tissue to produce plant biomass (Sekadende *et al*., 2014).

In relation to nutrients and suspended solids retention, wetlands are often shown to be effective at reducing nutrient loadings from the catchment (Mitch and Gosselink, 1986). However Lutembe wetland showed higher nutrient concentration values in the outlet than the inlet. This may be attributed to changes in activities around the wetland which may impact negatively on the wetland functionality. Wetlands can be ineffective at reducing nutrient loadings and in some cases act as sources of nutrients and according to UusiKamppa *et al* (1997) retention of soluble phosphorus in many wetlands is much less efficient than the retention of particulate phosphorus.

The lower TSS concentrations recorded in the bay may be due to the enhancement of residence time as water flows through the wetland vegetated zones and in the process allowing particle removal (Knight *et al*., 1999) and decreasing the rate of particle resuspension (Lopez and Garcia 1998). Additionally, suspended particle may be removed by getting attached on to the surfaces such as the roots and leaves of wetland vegetation (Leonard *et al*., 1995)

Wetlands provide an environment for the interconversion of all forms of phosphorus. Soluble reactive phosphorus is taken up by plants and converted to tissue phosphorus or may become sorbed to wetland soils and sediments. Organic structural phosphorus may be released as soluble phosphorus if the organic matrix is oxidized. Insoluble precipitates form under some circumstances, but may re-dissolve under altered conditions (Kadlec and Knight, 1996).

5.4 Relationship between provisioning ES and water purification function of Lutembe bay wetland

A comparison of NH_4-N, NO_3-N, NO_2-N, TN and TP concentrations of the bay in this study with their respective concentrations studied by NatureUganda in 1999 showed an increase in all nutrients. This is may be attributed to increase in wetland activities such as clay mining, agriculture and sand mining. This is in line with respondents' perceptions on possible reasons for the decline in Lutembe bay wetland fisheries, water quality and water abstraction. According to some community members this is due to destruction of the wetland by activities such as commercial farming, sand mining and clay mining. According to NatureUganda (2014) increased agriculture, continued pollution of the wetland, rapid transitions of urban centres and infrastructure development threatens Lutembe ecosystem both the wetland and the bay. This is in line with a study conducted by NatureUganda (1999) where by potential impacts of major provisioning ES on wetland integrity and functionality were reported. It was observed in that study that clay and sand mining may was likely to encroach and drain the wetland potentially affecting its water purification function. Commercial and subsistence agriculture may also encroach on the wetland which may lead to destruction of fish breeding grounds and deterioration of water quality. On the other hand, overfishing or use of poison in fishing within wetlands can lead loss of biodiversity and wetland degradation.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATION

6.1 HYPOTHESES REVIEW AND CONCLUSIONS

6.1.1 Hypotheses

1. With regard to the results, the hypothesis that there is no significant difference in the provisioning services at present (2015/2016) and before developments in 1999 at Lutembe Bay wetland is rejected.

2. Based on the results for nutrients and total suspended solids concentration retention, the hypothesis that there is no significant difference in the capacity of Lutembe Bay Wetland in retaining nutrients is accepted but rejected with respect to total suspended solids retention.

3. Due to no significant correlations between the major provisioning ES and Lutembe Bay Wetland purification function, the hypothesis that there is no significant relationship between nutrient concentration and most important provisioning services between 1999 and 2015/2016 of Lutembe Bay wetland is accepted. However a positive correlation exists indicating some degree of relationship between regulating and provisioning services.

6.1.2 Conclusions

Lutembe bay wetland provided in the past and still provides a variety of ES from which the local community derive benefit.

1. The major provisioning ES activities in Lutembe wetland at present include; fishing, clay mining, sand mining while the major activities in the past include; fishing, water abstraction and cultivation of crops. Fishing is important mainly because it is a source of food and also generates income for the community. Clay mining and sand mining are sources of livelihood since the products harvested from these activities are sold to generate income. Water abstracted is mainly for domestic use. These major provisioning ES are not utilized by the community members in the same magnitude both in the past and at present.

2. Nutrients; ammonium, nitrate, nitrite, total nitrogen, soluble reactive phosphorus and total phosphorus were not retained by the wetland since their concentrations were higher in the outlet than the inlet hence the wetland acted as source. However, TSS was retained by Lutembe bay wetland since the concentration was lower in the outlet than the inlet.

3. Major provisioning ES influence the nutrient concentration at Lutembe Bay as observed by the deterioration of the water quality at the bay since 1999. Activities like clay mining and sand mining are increasingly encroaching on the wetland thus reducing its water purification function.

6.2 Recommendations

1. Since communities derive a wide variety of benefits from Lutembe bay wetland, this study recommends sensitization of the public about conservation and sustainable use of Lutembe bay wetland by conducting field training visits and workshops. This will aid in reducing overexploitation of some ES at the expense of others. Lutembe community members can be made aware of the potential negative impacts that activities such as sand mining may have on wetland water quality.
2. Since relationships between multiple ES is not well understood by the Lutembe bay wetland beneficiaries, it is recommended that more studies be undertaken to broaden our knowledge about wise use of multiple ES, tools for assessing their relationships and economic valuation.
3. Alternative economic activities such as Small and Medium Enterprises (SMEs) should be suggested to the local communities. This will reduce unnecessary anthropogenic pressures on the wetland hence maintaining the wetland integrity.
4. Cultural ES services such as educational tours and ecotourism should be promoted in close collaboration with the local communities. This will broaden the benefits derived from Lutembe bay wetland and in the process reduce the pressure of encroaching on the wetland to enhance activities such as clay and sand mining.

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APPENDICES

Appendix 1: General questionnaire survey

Table 1: Background information

Name of enumerator	
Phone number of enumerator	
Interview date	
Name of respondent/ES beneficiary	

A) Wetland Provisioning Services

1 (a) Do you and your household members derive or harvest any natural product (craft raw material, fish, wild animals etc.) from the wetland? Yes or No ________________

(b) If yes, give details below;

Table 2: Natural products harvested from the wetland

Natural Products	**Name**	**Use**
Fish		
Crop production		
Papyrus		
Clay		

(c) If no give reasons; ________________

B) Important Provisioning Services

(d) Of these natural products, which would you say are the most important to the community members? **3-Most Important, 2- Important, 1- Least Important**

Natural Products	**Importance level**	**Reason**

Fish		
Crop production		
Papyrus		
Clay		

Appendix 2: Changes in wetland products before and after developments

2 (a) Are there important natural products which used to be harvested in 1999 but are now not available? Yes or No ________________

(b) If yes, give details below;

(c) When (Year) did you start noticing changes in the supply of these natural products?

____

(d) When comparing wetland products provision now and before developments (Flower farms, construction of buildings), is there any change? Yes or No________________

(e) If yes, give details below;

(Tick where applicable);

Natural product	**Increased availability**	**No change**	**Decreased**	**Lost**	**Reasons**
Fish					
Agricultural produce					
Papyrus					
Water quality					

Appendix 3: Questionnaire for Focus Group Discussion

3(a) What is the total number of Lutembe Bay Wetland users?

____

(b) What is the total number of Lutembe Bay Wetland users who are registered?

____

(c) Do you and your household members derive or harvest any natural product (craft raw material, fish, wild animals etc.) from the wetland? Yes or No ________________

(b) If yes, give details below;

(c) How many community members per group e.g. Fishermen, mat makers directly benefit from these natural products?

Number of Fishermen' ________________

Number of Farmers' ________________

Number of brick makers' ________________

(d) Of these natural products, which would you say are the most important to the community members? 3-Most Important, 2- Important, 1- Least Important

Product (I)

Product (II)

Product (III)

Thank you for taking part in this survey.