IMPACTS OF WATER HYACINTH ON SOCIO-ECONOMIC ACTIVITIVES ON KAFUBU RIVER IN THE COPPERBELT PROVINCE

A Case Study of Ndola District, Zambia

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A Case Study of Ndola District, Zambia

By

Mercy Mbula

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master in Integrated Water Resources Management of the University of Dar es Salaam

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for examination by the University of Dar es Salaam a dissertation entitled: ***Impacts of Water Hyacinth on Socio-economic Activities on Kafubu River in the Copperbelt Province: A Case Study of Ndola District, Zambia***, in partial fulfillment of the requirements for the Degree of Master in Integrated Water Resources Management of the University of Dar Es Salaam.

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DECLARATION

AND

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I, **Mercy Mbula,** hereby declare that this dissertation is entirely my own work except where acknowledged in the text. The work in this dissertation has not and is not currently being submitted by me for any degree to any other university.

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DEDICATION

I dedicate this work to my parents Maybin Mbula and Jenipher Mbula, and to my beautiful daughter Joyce Kanyeba.

ABSTRACT

Water hyacinth is one of the top 10 worst aquatic weeds characterised by large vegetative reproduction output and has been a major problem in Kafubu River since the 1990s due to nutrients offload from anthropogenic activities, causing serious impacts on the socio-economic activities. Therefore, the aim of this study was to assess the impacts of water hyacinth on major socio-economic activities on Kafubu River. Data was obtained through questionnaires, interviews, and sampling stations were set up; ST1 (no weed), ST2 and ST3 (weed infested areas). Mean results showed that phosphate, nitrite, ammonia and nitrate levels were high in stations ST2 and ST3 than ST1 due to the effluent discharged into the river from Kanini and Lubuto Sewerage Treatment Plants. About 20.47% of the respondents reported that water hyacinth cause damage to fishing nets and makes it difficult for fishermen to paddle on the river, while 11.8% of the respondents observed that valuable time is wasted on laying nets due to the presence of the mat. About 70.1% of the respondents perceived that fish catchability was higher when water hyacinth coverage is low between November and April. Respondents reported that water hyacinth also reduces the amount of water received for irrigation, blocks the irrigation channels and brings along the organic nutrients. The SWOC and EFE analysis gave a low total weighted score for both external and internal evaluations of 1.99 and 2.14, respectively. This means that the institutional arrangement for management of water hyacinth in the river are weak internally while institution's strategies are not well designed to meet opportunities and defend the challenges in managing the weed.

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LIST OF ABBREVIATIONS AND ACRONYMS

CMA	Catchment Management Authority
DO	Dissolved Oxygen
DRC	Democratic Republic of Congo
EC	Electric-conductivity
EEA	European Environment Agency
FAO	Food and Agriculture Organisation
ITDG	Intermediate Technology Development Group
IUCN	International Union for Conservation of Nature
KSTP	Kanini Sewerage Treatment Plant
LSTP	Lubuto Sewerage Treatment Plant
MEWD	Ministry of Energy Water and Development
SANTREN	Southern Africa Network for Training and Research on the Environment
ST	Sampling Station
UN	United Nations
WUA	Water User Association
ZANIS	Zambia News and Information Services
ZESCO	Zambia Electricity Supply Corporation
ZRA	Zambezi River Authority

CHAPTER ONE

INTRODUCTION

1.0 General Introduction

Water hyacinth *(Eichhornia crassipes)* has been a challenging aquatic weed around the world since 19th century. Its origin is traced back to the Amazon River Basin, Latin America (Cilliers *et al*., 2003; Williams *et al.,* 2007; Shanab *et al*., 2010). The alien species has been rated as one of the top 100 alien species and among top 10 worst weed around the world (Shanab *et al*., 2010; Téllez *et al*., 2008; Gichuki *et al*., 2012; Patel, 2012).

Water hyacinth is a free floating aquatic weed, which is characterized by rapid and large vegetative reproduction output, and known to rapidly colonizing new areas, as a single plant it reproduces rapidly (Zhang *et al.,* 2010; Williams *et al.,* 2007). The weed has evaded many regions in the tropics and subtropics and caused serious impacts on the indigenous species, and people's livelihood (FAO, 2002; Patel 2012; Téllez *et al*., 2008; Villamagna, 2009). In the USA, water hyacinth was first reported in the 1880s, in the 1890's, in Australia and Southern Asia, while in China and the Pacific in the early 1900's (Julien, 2001).

Anthropogenic activities such as land use change into arable land offload nutrients such as nitrogen and phosphorus has lead to rapid growth and spread of water hyacinth through eutrophication of major water bodies across the world (Williams *et al.,* 2007). In Africa, the weed started infesting freshwater bodies massively during

1950's due to eutrophication of the water bodies that contributed the weed biomass, and countries that have experienced the problems associated with water hyacinth include; Zambia, Zimbabwe, Uganda, South Africa, Tanzania, Malawi, Kenya, Burkina Faso and Egypt (Kampeshi and Shantima, 1999). For example, since early 1990's the weed had invaded and spread across Lake Victoria in the East part of Africa, due to anthropogenic changes and has become a major problem economically for residents (Cilliers *et al*., 2003; Mailu, 2001: Williams *et al.*, 2007).

The rapid growth and infestation of the weed has a number of problems on the river environment including water quality and quantity for both domestic and productive use, reduced fish stocks, increase in vector borne diseases and clog water intakes at hydro-electric dams (Cilliers *et al.*, 2003; Mathur *et al.*, 2005; Williams *et al.*, 2007). In Zambia, water hyacinth was reported to infest massively freshwater bodies during the early 1960's and rapidly spread in many areas such as Kafue River, Lake Tanganyika, Lake Kariba and Kafubu River (Villamagna and Murphy, 2010). Kafubu River in Zambia is one of the rivers that has been deeply infested and affected by water hyacinth commonly known as Kafubu weed. The sewer effluents and wastewater from the sewerage company, agriculture and industrial activities contribute to the nutrient enrichment of the river (SANTREN, 2006).

The three popular control mechanisms for eradicating water hyacinth are biological, chemical and physical controls, with biological control the only cost efficient sustainable control option for water hyacinth (Cilliers *et al*., 2003). The most recent successful programme has been on Lake Victoria where the mats of the plant have been defeated using biological control (Lake Victoria River Basin Commission, 2016). Chemical control is not the best method to control the weed as the long term environmental and health effect still remains unknown. However, the most common control methods used are physical using dredgers and mechanical mowers methods, but are not suitable for large infested areas, very expensive and a short term control method (Mathur *et al.*, 2005). Dredgers have been employed to remove the weed in Kafubu River for the past several years yet the weed still keep appearing (Lumba, 2015).

1.1 Statement of the Problem

Rapid urbanisation, land use change and population growth along the Kafubu River appeared to have resulted in the degradation of the river for the past decade (Lusaka Voice, 2014). The river is also a recipient of both municipal wastewaters (SANTREN, 2006). Itawa and Dambo Sewerage Pump Stations located upstream of the river banks discharges raw sewer into the Kafubu River while the two sewerage treatment plants Kanini and Lubuto plants discharge effluents into the river way above the statutory limits (Ukzambia, 2011). Lusaka Voice (2014) reported that more than half of the river was covered by the weed, which reduced water supply from Kafubu River to the two drinking water treatment plants located along the river because the weed caused blockages to the pipes that supply water to the treatment plant affecting the major socio-economic activities such as fishing and farming.

It has also reported that the river has been subjected to pollution with fertilizer from small urban farms (Lusaka Voice, 2014). Some of the impacts of the water hyacinth include reduced dissolved oxygen and water quality, the weed allows breeding of pests and vector organisms that cause harm to human health, blocks waterways and irrigation channels, which disrupts fishing, and disrupts water flowing into crop fields (Ndimele *et al*., 2011; Minakawa *et al.*, 2008).

Unfortunately, not enough research has been conducted to assess impacts of water hyacinth on the major socio-economic activities on the Kafubu River such as fishing, agriculture and domestic water supply on the river. Therefore, this research will add and contribute more knowledge and will help come up with a proposed institutional framework for effective and sustainable management of the water hyacinth. This research will only focus on impacts of the water hyacinth on fishing and agriculture activities on the Kafubu River in Ndola District, Zambia.

Figure 1.1: Picture showing water Hyacinth being removed from the Kafubu River (Photo by Mbula)

1.2 Objectives of the Study

1.2.1 General Objective

The main objective for this study was to identify the impacts of water hyacinth on the on the socio-economic activities in Kafubu River in Ndola District and propose the necessary legislative framework for its control.

1.2.2 Specific Objectives

- To identify factors that promotes the growth and infestation of water hyacinth on the Kafubu River.
- To identify the impacts of water hyacinth on major socio-economic activities on Kafubu River.
- To assess institutional and legislative framework for management of water hyacinth on Kafubu River.

1.3 Research Questions

The questions below were answered:

- What are the factors that promote the growth and infestation of water hyacinth on Kafubu River?
- What are the impacts of water hyacinth socio-economic activities on the River?
- What is the institutional and legislative framework required to prevent the growth and infestation of water hyacinths?

1.4 Significance of the Study

Water hyacinth poses both environmental and human threats on Kafubu River. The threats include: reduction in dissolved oxygen, which has a negative effect on aquatic species especially fish stock in the river. The livelihood for the population along the river depends on the river for food and income. The alien invasive species also disrupts fishing activities and blocks water ways for irrigation channels. Little research has been conducted to identify the socio-economic impacts of the aquatic weed and effectiveness of the existing control strategies for the water hyacinth. Therefore, this research will add and contribute more knowledge and will help with the development of a proposed institutional framework for sustainable management of water hyacinth in Kafubu River.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Water hyacinth was introduced in different parts of the world as a beautiful garden plant (ITDG, 1999; Labrada *et al*., 1996; Shanab *et al*., 2010). It is characterized by rapid growth rate and infestation on large water area causing different problems (Shanab *et al*., 2010; Zhang *et al*., 2010). The weed affects solar light penetration into water bodies, reduces oxygen through decomposition, alters chemistry of water and substantially increases water evapotranspiration (ITDG, 1999).

Water hyacinth has spread in more than 50 countries worldwide and has become a problem especially in the tropics and sub- tropical countries like Latin America and the Caribbean, Southern United States of America, Southern Africa, West Africa, South-East Asia and the Pacific (ITDG, 1999; Labrada *et al*., 1996). In Africa, the water hyacinth has been a problem since the 1990's. It has infested the Nile River of Egypt, Tano Lagoon water areas of Ghana; Comoe River of Ivory Coast; Lake Victoria shared by Kenya, Uganda and Tanzania; Congo River in DRC; and Lake Kariba and Kafubu River of Zambia (Labrada *et al*., 1996; ITDG, 1999; SANTREN, 2006).

2.2 Factors promoting the growth and infestation of water hyacinth

The world has experienced rapid population growth, industrialisation, urbanization and land use change for the past years. These anthropogenic activities have often lead to increase in the waste generated and crop production to carter for the growing population (Harley *et al*., 1997). Industrial and domestics wastewater carry along nutrients and eventually find their way into water bodies as run-off (Harley *et al*., 1997). The unpredictable rapid growth rate of the weed is attributed by the eutrophication and absence of natural enemies of the plant in water bodies which cause the weed to bloom (Labrada *et al.*, 1996).

Cilliers (2003) observed that the South African River Vaal has experienced an increase in nutrients levels due to run-off which carry along fertilizer from agricultural practices, industrial and mining effluents, and wastewater from settlements. This in turn has caused rapid growth of water hyacinth in the River. Water hyacinth has grown rapidly in Lake Victoria due to run-off and wastewater carrying nutrients from agricultural activities and settlements which find its way into Lake (Williams *et al.*, 2007).

Wilson *et al.* (2007) considered temperature as one of the strongest determinants for the growth and reproduction of water hyacinth. The increase in temperature leads to rapid growth and reproduction of water hyacinth. These physical and chemical parameters will help identify the pollution sources that cause the infestation of water hyacinth in the River. In Zambia, the water hyacinth infested massively freshwater bodies during the early 1960's and rapidly spread in many areas such as Kafue River, Lake Tanganyika, Lake Kariba and Kafubu River (Villamagna and Murphy, 2010). For example, wastewater from the Kafubu and Water Sewerage Company contribute eutrophication of the river and which influences the growth of water hyacinth, which has serious consequences on socio-economic activities around Lake Kariba (Lusaka Voice, 2014).

2.3 Impacts of Water Hyacinth on Socio-economic Activities

Water hyacinth has serious impacts around the communities living near the water bodies and poses a threat to biodiversity, fishing, agriculture and hydropower activities (ITDG, 1999).

2.3.1 Disruption of Fishing Activities

The ability of the aquatic weed to reproduce rapidly affects socio-economic activities such as hampering fishing as the weed makes it difficult to access open areas, entangles boat propellers and clogs waterways (Ndimele *et al*., 2011; Patel, 2012). Water hyacinth makes it difficult to transport goods and reduces fish catch on water bodies, and more fuel is consumed when water hyacinth infestation is high (Labrada *et al.,* 1996). On Lake Victoria, water hyacinth reduces fish stock for Tilapia and young Nile Perch by limiting access to breeding, nursing, and feeding grounds (Twongo and Howard, 1998; Villamagna and Murphy, 2010). Fishermen also find it difficult in carrying out fishing activities due to the presence of water hyacinth infestation (ITDG, 1999).

2.3.2 Blockage of waterways hampering agriculture

Mailu (2001) reported that water hyacinth infestation on Lake Victoria blocks irrigation canals. The aquatic weed blocks irrigation channel and reduces the flow of water by 40% to 95%, which in turn affects and obstruct the amount of water reduced in crop fields (Jones, 2009).

2.3.3 Impacts on Hydropower

Water hyacinth causes high water losses through evapotranspiration and blocking turbines. The Owen Falls hydropower scheme on Lake Victoria has suffered the impact of the weed, hence plenty of time and money has been invested to clear and prevent the weed from entering the turbines, which may cause damage and power interruptions (ITDG, 1999). On Owen Falls hydropower scheme, the water hyacinth caused damage to water coolers and generators, prompting the power utility company to switch off generators for maintenance, and about 15 Megawatts of electricity were lost causing power cut in an urban area of Uganda (Labrada *et al.*, 1996).

Water hyacinth has been in the past years a major problem on Lake Kariba, which is a shared water resource between Zambia and Zimbabwe (ITDG, 1999). The water losses for power generation and blocking of turbines by the weed on Kariba Hydropower Station in Zambia, leads to loss of revenue of about US$15.00 every year by Zambia Electricity Supply Corporation (ZESCO, 2008). On Lake Kariba the water hyacinth has been controlled by using biological control (ZRA, 2016).

2.3.4 Pests and vectors breeding ground

The mat for water hyacinth maintains organisms that can cause harm to human health. Water hyacinth slows moving water, and increases breeding grounds for the malaria causing anopheles mosquitoes and Lake Kariba is a victim of this (Minakawa *et al.*, 2008). The weed acts as a breeding ground for *Mansonioides* mosquitoes, the vectors of human *lymphatic filariasis* causing nematode Brugia (Chandra *et al.*, 2006; Varshney *et al*., 2008). Vectors for the parasite of *Schistosomiasis* (Bilharzia) such as snails are found in the thick mat, while dangerous snakes habit in the weed mat (Borokini and Babalola, 2012).

2.3.5 Reduced oxygen and water quality

Water hyacinth limits oxygen diffusion between air and water surface, and decrease oxygen supply by plants (Villamagna and Murphy, 2010). During decomposition at the bottom of the water body, the weed takes up oxygen and depletes it (EEA, 2012). Reduced dissolved oxygen concentration in the water body can negatively affect fish that cannot adapt to new environment, while dead and decayed water hyacinth can deteriorate water quality, and this may increase the cost of treatment for drinking water (Patel, 2012; Mironga *et al*., 2011; Ndimele *et al*., 2011). About 75% of Zambians live in poverty, increasing the treatment of potable water entails increase in the water supply price. This will disadvantage the majority of Zambians as they will be unable to afford high price of water (Ndimele *et al*., 2011). Decrease in water quality has health risks for those who directly depend of the water from the Kafubu River. The main livelihood for the local people who live along the River is fishing and farming; the depletion of dissolved oxygen will reduce fish stock thereby affecting people’s livelihood and directly increase poverty.

2.3.6 Effect on Biodiversity

Biological alien invasions are one of the driving forces of biodiversity loss around the world (Pyšek and Richardson 2010; Vila *et al*., 2011). Water hyacinth has caused serious ecological loss of freshwater water bodies (Khanna *et al*., 2011; Gichuki *et al*., 2012). The weed out-competes the indigenous species due to its rapid reproductive ability, which poses a threat to aquatic biodiversity (Patel, 2012). Due to its colonization, the water hyacinth also prevents the growth of vital phytoplankton, and ultimately affects fisheries and other vital aquatic animals (Gichuki *et al*., 2012; Villamagna and Murphy, 2010).

2.4 Control Measures for water hyacinth

There are three main control methods for management of water hyacinth.

1. **Biological control** – This is a long-term control method and is recommendable for its user friendly and provides a sound economic and sustainable control method (ITDG, 1999). This method involves the host specific natural enemies to reduce the population density of the weed. Several insects such as weevils, moth and fungi are used as control agents for the water hyacinth (Cilliers, 2003). In Australia, the method has been successful through regular release of the weevils *Neochetina eichhorniae* and *N. bruchi*, and the moth *Sameodes albiguttalis,* and has successfully reduced the population density of water hyacinth (Labrada *et al.,* 1996). Also in Lake Victoria biological control under surveillance and regular monitoring has been successfully applied to defeat water hyacinth (Lake Victoria Basin Commission, 2016)

2. **Physical control** - Although this method is mostly used around the world, it is very expensive to apply and uses equipment such as mechanical mowers and dredgers. The method can only solve small infested areas hence is not a sustainable long term solution (ITDG, 1999). It requires fleet of vehicles to transport large quantities of water hyacinth after it has being removed and the mats of water hyacinth can have a density of up to 200 tonnes per acre (Harley *et al.*, 1997).
3. **Chemical control** - This method uses herbicides such as 2, 4-d, Diquat and Glysophate to control water hyacinth (Labrada *et al.*, 1996). It is ideal for small infestation areas not big areas. Application is done either on the ground or air with skilled operators. The method has environmental and health concerns as herbicides can be harmful, especially sources used for drinking and washing (ITDG, 1999). Apart from the three control methods, Harley *et al.* (1997) suggested that if the amount of nutrients entering any water body is decreased, this automatically reduces the infestation and growth of the water hyacinth.
4. **Integrated control approach** - Cilliers (2003) argues that to sustainably manage and control the spread of the alien species, an integrated control approach is required, where chemical, mechanical and biological controls are used together. Different control methods supplement each other and where possible have an additive effect.

2.5 Possible Practical Applications of Water Hyacinth

Although the water hyacinth has been labelled as a problematic weed in many parts of the world, the plant contains than 95% water content has a fibrous tissue with high energy and protein contents. Therefore, the weed can be used for different applications, which include:

1. **Paper -** Water hyacinth fibre blended with waste paper can be used to produce good paper. For example, Bangladesh, Philippines, India and Indonesia have been experimenting with paper production from the water hyacinth and successfully produced paper (Tacio, 2009).
2. **Biogas production** - Water hyacinth fibre can be converted into biogas where, organic matter of water hyacinth is used to produce methane gas by anaerobic digestion which can be used directly for energy such as electricity for cooking and lighting in homes (Ojeifo *et al.*, 2013).
3. **Basket work -** The weed can be used to make baskets and mats for domestic use and subsistence market such as crafts for tourists. For example, in the Philippines and India water hyacinth is used to make baskets by local people (Intermediate Technology Development Group, 1997).
4. **Purification -** Water hyacinth has the ability to trap pathogens. This makes it suitable to be used to purify drinking water in treatment plants (Vidya and Girish, 2014). Water hyacinth can be used to treat sewage as it can absorb metals such as copper, mercury and lead (Land Development Department, undated).
5. **Animal fodder and fertilizers -** Studies have shown that water hyacinth has nutrients and potential as animal feed (Ojeif*o at el.*, 2013). The organic matter

from the weed can be used as fertilizer and provides nutrients essential to crop growth (Vidya and Girish, 2014). In China and Malaysia, the water hyacinth is used as pig, duck and fish feed while mixed vegetable waste, salt and rice bran. (ITDG, 1997).

2.6 Policy and Institutional Framework

2.6.1 African Convention on the Conservation of Nature and Natural Resources (ACCNNR) (2013)

The African Convention on Conservation of Nature and Natural Resources (ACCNNR) was signed in the year 1968 and was revised in the year 2013. It carries the credit as the first convention to deal with sustainable development issues including land and soil, water and biological diversity, conservation and sustainable use. It is a regional treaty on the environment and natural resources, with the aim of mobilizing and committing African countries to protect the environment, sustainable use of natural resources and a collective approach to biodiversity conservation in the continent (Murimi, 2015). It also deals on alien invasive species such as water hyacinth. Thirty (30) African countries including Zambia have ratified to this convention.

2.6.2 SADC Regional Biodiversity Strategy (2003)

The purpose of the Regional Biodiversity Strategy is to provide a framework for regional cooperation in biodiversity issues that transcend national boundaries and to stimulate the combined and synergistic efforts by SADC Member States and their communities in biodiversity conservation and its sustainable use. It contributes to the achievement of SADC's goals of social and economic development and poverty eradication. All fifteen SADC member states have signed the Convention on Biological Diversity (CBD), including alien species like water hyacinth (Sub-Saharan Africa, 2015).

2.6.3 Laws and Policies Relevant in management of water hyacinth in Zambia

2.6.3.1 Water Resources Management Act, 2011 (No. 21 of 2011).

The Water Resources Management Act of 2011 is the main act for the protection and management of water in Zambia. The aim of the Act is to establish a regulatory and administrative framework for the management, development, conservation, protection and preservation of the water resource in Zambia and provides with respect to water rights and the equitable and sustainable use of water resources and related matters (Water Resource Management Act, 2011).

2.6.3.2 Environmental Management Act (EMA) of 2011

Environmental Management Act is aimed to "provide for integrated environmental management and the protection and conservation of the environment and the sustainable management and use of natural resources". The act "provide for the prevention and control of pollution and environmental degradation; provide for public participation in environmental decision-making and access to environmental information" (EMA, 2011). The act does not state anything on the management of alien invasive plants like water hyacinth.

2.6.3.3 National Biodiversity Strategy and Action Plan Policy Framework (NBSAP) (1999)

NBSAP is the guiding framework on biodiversity both at national and local level. The policy focuses on conservation, management and sustainable use biological resources; and equitable sharing of benefits from utilization of biological resources. The policy doesn't stipulate anything on alien species (CBD, 2011).

2.7 Institutions

Ministry of Energy and Water Development is the institution responsible for management of both ground and surface water. The main role for the ministry is 'development of policies and legislations related to water management'. Water affairs department is the department responsible for management and monitoring of the alien invasive species in water bodies such as rivers and lakes (MEWD, 2014).

2.8 Strengths, Weaknesses, Opportunities and Challenges (SWOC)

Strengths, weaknesses, opportunities and challenges (SWOC) and External Factor Evaluation (EFE) were used to analyze institution and policy framework for the management of water hyacinth. This is because SWOC presents a framework that identifies and prioritize the institutional goals and come up with strategies to achieve the goals, the framework is essential to researchers or planners (Omnani, 2011; David, 2009; Omman, 2011; Riston, 2008). It is a technique used to analyze Strength, Weakness, Opportunities and Challenges of any institutional arrangement (Omnani, 2011). External Factor Evaluation (EFE) is a strategic-management tool used to evaluate current performance of a company or institution (David, 2009;

Riston, 2008). The tools are ideal for visualisation and prioritization of the opportunities and threats that any business or institutional arrangement (Riston, 2008).

Ratings are assigned to internal and external factors with a number that ranges from 4 to 1 with 4-superior response, 3-above average response, 2-average response and 1-poor response for external factors. While for internal factors the numbers ranges from 4 to 1, where; 4 is major strength, 3 is minor strength, 2 is minor weakness and 1 is major weakness (David, 2009). Riston (2008) pointed out the benefits of external analysis, which include:

i. EFE Matrix is easier to understand because input factors have a clear meaning to everyone inside and outside an institution or company.
ii. Increases awareness on environmental management changes.
iii. The matrix is user friendly and consumes less time, it doesn’t require an expertise to build it.
iv. It focuses on key internal and external factors.
v. It helps decision makers to allocate resources efficiently.
vi. That matrix is a multipurpose tool which can be used to build SWOC analysis.

David (2009) pointed out some limitations for the EFE Matrix, which include;

i. It can be easily replaced by other matrix such as competitive profile matrix,
ii. Has a broad factor.

CHAPTER THREE

METHODOLOGY

3.1 Description of the Study Area

Kafubu River is located in three districts of Ndola, Luanshya and Masaiti of the Copperbelt Province in Zambia, though the project focuses on Ndola District alone. Kafubu River lies at an elevation of 1255 meters above sea level (Lusaka Voice, 2014). The Kafubu River catchment extends to the DRC border and covers an area of approximately 539 km^2. The population for Ndola District is 455,194 (Census Report, 2010). Figure 3.1 shows a map of the study area and sampling station in yellow circle.

The average mean annual runoff (MAR) is estimated at 85mm/year. The geology of Ndola area is characterized by numerous rock-types. It is mainly underlain by deep weathered sedimentary rocks of the Katanga Super group, which can be further subdivided into the Kundelungu Series, but also by the Mwashia Group and the Roan and Mine Groups. The characteristic features include the calcareous mudstone and siltstone along the Zambia - Congo DR border from the southeast to the northwest (Aegheore, 2006).

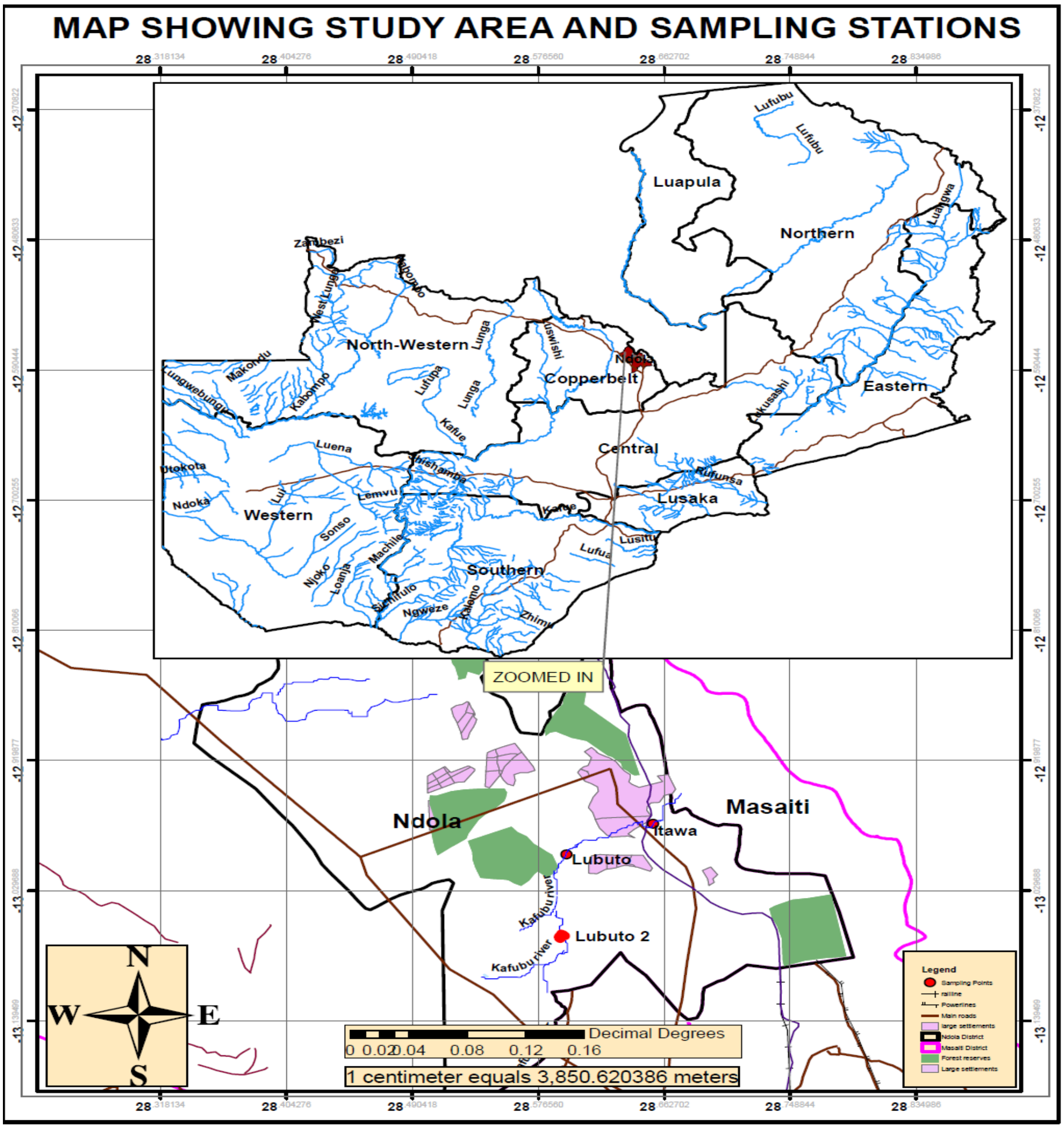

Figure 3. 1: Map of Zambia showing Ndola District and Sampling Stations

3.2 Primary Data

3.2.1 Sample Size

Krejcie and Morgan (1970) equation was used to determine the sample size for fishermen only. The formula was used to give a sample size that when drawn randomly from a finite population size, the sample will be within ±0.05 of the population proportion with a 95% level of confidence. The formula is given as shown by equation (1):

$$s = \frac{x^2 NP(1-P)}{d^2(N-1)+X^2P(1-P)} \quad \text{eq. (3.1)}$$

Where: s = the required sample size, X^2 = the table value of chi-square for one degree of freedom at the desired confidence level (0.05) which is equal to 3.841 (or 1.962), N = the population size, P = the proportion of the population, assumed to be 0.50 since this would provide the maximum sample size, d = Margin Error (0.05).

3.2.2 Questionnaire Survey

Primary data was obtained by administering structured questionnaires to 52 farmers and 127 fishermen. District Agriculture Office in Ndola provided the number of farmers in the study area which were only 52 and all of them were administered with questionnaires. Krejcie and Morgan (1970) equation (1) was used to calculate the sample size for fishermen, and sampling was done randomly assuming that the fishermen have similar residential areas within the district. The main aim for the questionnaire survey was to assess the impact of the water hyacinth on fishing and irrigation farming. Attached are Appendix 1 and 2 showing questionnaires used in the field for both fishermen and farmers. The questionnaires were divided into two sections for both fishermen and farmers. Section 1 for both questionnaires addressed the respondents profile such as sex, age, level of education and time period in the business. Section 2 for fishermen dealt with impact of the water hyacinth on fishing, fish quantities, and effects of water hyacinth on fish stock and prices and lastly additional cost incurred by fishermen as a result of the water hyacinth. Section 2 on the questionnaire on irrigation farming addressed extent of effect of water hyacinth on irrigation channels and effect of the water hyacinth on the amount of water received for irrigation, effect of water hyacinth on irrigation farming, and lastly additional impacts and costs of water hyacinth on irrigation.

Primary data on policy and institutions responsible for management of the weed was collected through interviews with the expertise from the Department of Water Affairs. The interview schedule guide was used (Appendix 3). The interview schedule had 7 parts; the first part addressed the institutional responsible for management of water hyacinth, the second part dealt with laws and policies governing the management of the water hyacinth, the third part addressed institutional structure, while parts 4 and 5 control measures for water hyacinth and past record of water quality data for the Kafubu river, and lastly part 6 and 7 dealt with internal and external challenges in the management of these water hyacinth strategies in place.

3.2.3 Observations

Direct observations were conducted in the field including sewage treatment plants, sewerage pumping stations and location of water hyacinth. These supplemented the survey data.

3.2.4 Data Analysis

Quantitative data for identification of impacts of water hyacinth on major socio-economic activities on the River was analyzed using descriptive statistics in Statistical Package for Social Sciences (SPSS) version 16.0 of 2007. Variables such as sex, age, number of years in business, impacts of water hyacinth on fishing activities and irrigation, and additional impacts of water hyacinth on fishing and irrigation were assessed. Before statistical analysis on the data was conducted, the raw data was screened to identify any missing data, outliers and any other gaps by means of cross tabulation and frequencies using SPSS software. Data from each section was separately analysed. Excel version 365 of 2010 was used to analyze and compare more than two variables such as water hyacinth coverage vis-a-vis fish catchabilities for four fish types, fish prices and amount of water received for irrigation farming.

Data on laws, policies and institutions for management of the water hyacinth in the Kafubu River were analysed using Strengths, Weaknesses, Opportunities and Challenges (SWOC) analysis and External Factor Evaluation (EFE). The internal and external indicators assessed include existing policies and institutional, government support, inadequate human capacity and equipments, inadequate data, knowledge and monitoring system, financial challenges, improved technology, rehabilitation of Kanini Treatment Plant, lack of coordination between stakeholders and inadequate awareness on protection of water resources. These indicators were subjected to weights by the stakeholders. The maximum weight for external and internal factor was one. Stakeholders rated the internal and external factors with the numbers ranging from 4 to 1. Where; 4 - superior response, 3 - above average response, 2 - average response and 1- poor response for internal factors; and 4 was major strength, 3 was minor strength, 2 minor weakness and 1 major weakness for external factors. The weighted score was calculated by applying David (2009) formula;

Weighted Score = Weight x Rating
Total Weighted Score = Summation of all individual Scores

3.2.5 Sampling procedure for water quality parameters

Primary data to determine causes of growth for water hyacinth was collected using grab sampling, which was done between 09.00 hours to 12.00 hours at the interval of two weeks for two months from three sampling stations; Itawa (ST1) upstream, Lubuto bridge (ST2) and Lubuto 2 (ST3) downstream (Figure 3.1). Figure 3.2 shows water sampling in progress at ST3.

Figure 3. 2: Water sampling in progress at Sampling Station ST3.

The cup was tossed away from the bank and a sample was scooped against the current taking care not to touch the bottom. The water was sampled against the flow direction of moving water of about 0.8 m depth and was transferred into a 250 ml Whirl-pak sampling bags. The procedure was repeated until 250 ml of sample was collected. These bags were stored in a cool box with ice packs and were transported to the laboratory for analysis within two hours of collection. Parameters analyzed in the laboratory include; Turbidity, Electric- Conductivity, Manganese, Nitrate, Ammonia, Nitrite, Phosphate, Faecal Coliform and Total Coliform. The pH, Temperature and Dissolved Oxygen were measured on site. All samples were analyzed at Seeds of Hope and Kafubu Water and Sewerage Company Limited laboratory in accordance with the Standard Methods for Examination of Water and Wastewater (2012).

3.2.5 Physico- chemical and Micro-biological analysis

The pH of the water sample was determined on-site by using a field pH meter (Sentron pH System 1001). Dissolved Oxygen and Temperature were measured using a portable Dissolved Oxygen Meter (YSI Model 57 Oxygen Meter) and a Thermometer. Manganese was measure using Flame Atomic Absorption Spectrometric Method. Turbidity was determined using Nephelometric Method and Electro-conductivity was determined using a portable conductivity meter model DEC-2, the total coliforms and faecal coliforms in water sample were analyzed using Membrane Filtration Membrane. Parameters were measured in accordance with Standard Methods for Examination of Water and Wastewater (2012). The raw data obtained is attached in Appendix IV.

Water quality sampled from Kafubu River, Kanini and Lubuto Sewerage Treatment Plants for pH, temperature, DO, turbidity, EC, ammonia and phosphate were compared by difference in means of a 2-tailed T-test using STATA. Two hypotheses were formulated as follows;

The Null Hypothesis (H_o): there's no significant difference in the measured parameters between water column in Kafubu River and sewage effluent.

The Alternative Hypotheses (H_1): there's a significant difference in the measured parameters between water column in Kafubu River and sewage effluent.

When $t_{computed}$ value is > than $t_{tabulated}$ value reject the null hypotheses if not at 5% level of significance.

3.2.6 Micro-biological analysis in plant tissue

To test for Faecal coliform and Total Coliforms in the roots and stem of the weed, membrane filter method was used (Standard Methods for Examination of Water and Wastewater, 2012). The 10 grams of the weed sample was weighed and put in 160 ml of demonized sterile water with 0.054M concentration of phosphate buffer solution with the ph of 6.8 for 5 to 10 minute. The solution from the plant tissue was shaken vigorously and was then decanted into a container before measuring concentration of Faecal coliform and Total Coliforms (Kalra and Maynard, 1991). The total coliforms and faecal coliforms were analyzed using Membrane Filtration Method (Standard Methods for Examination of Water and Wastewater, 2012). The following equation was used:

$$\frac{N}{Kg}\ weed = \frac{S_g - C_b * 0.054 * 160}{weight\ of\ weed} \qquad \text{eq. (3.2)}$$

Where: S_T is Sample extracted, C_B is Blank container

To measure nitrogen in the plant Kjeldahl method was used were the plant tissue of about 1.0g oven dried weed was weighed and put into a digestion tube. 7 mL of H_2SO_4 was added to the digestion tube. After 30 minutes $Na_2S_2O_3.5H_2O$ was added and the mixture was shaken thoroughly. After 15 minute 3 mL of H_2SO_4 acid was added and about 1.0g catalyst mixture and shack thoroughly titrate the distillate with 0.1M HCL (Kalra and Maynard, 1991). The following equation was used to get nitrogen:

$$N.\frac{N}{Kg}\, dry\ matter = \frac{S_T - B_T * 0.1 * 1.4 * 10}{weight\ of\ oven\ dry\ matter} \qquad \text{eq. (3.3)}$$

Where: S_T is Sample titrate, B_T is blank titre

To measure phosphate dry ash method was used. 1.0 g of over-dried ground weed (110 ^{0}C) was weighed and placed in a clean crucible. The weighed sample was placed into a cold muffle furnace. The furnace was switched on with sampled ash at 450^{0}C for 2 hours until the ash turned white. The crucible was cooled in a desiccators and ash was transferred quantitatively into a 100-mL beaker by means of 20 mL 1M HNO_3. The beaker was cover for about 30 minutes and the suspension was filtered using Whatman No. 42 filter paper, into 250-ml volumetric flask. The filter paper was washed several times with distilled water and a mark was made (Kalra and Maynard, 1991). The concentration of phosphate expressed in mg/L was measured using the Ultraviolet Spectrophotometric Screening Method.

3.2 Nutrients Analysis

Nitrate and Phosphate expressed in mg/L were measured using the Ultraviolet Spectrophotometric Screening Method. Colorimetric method was used to determine nitrite in the sample. Ammonia was measured using preliminary distillation step (Standard Methods for Examination of Water and Wastewater, 2012). To test for organic nitrogen in the plant tissue, the Kjedah method was used; while for Phosphate and Potassium Ultraviolet Spectrophotometric Screening Method was applied (Standard Methods for Examination of Water and Wastewater, 2012). (Appendix IV). The values for these water quality parameters are the averages of four replicates taken from the three sampling station in the River. The sewage effluents results for the parameters at Kanini and Lubuto Sewerage Treatment Plants were collected from Kafubu Water and Sewerage Company Limited for the year 2015.

3.3 Secondary Data

Secondary data was reviewed from various literatures and retrieved from Kafubu Water and Sewerage Company Limited, Water Affairs Department, Department of Agriculture and Livestock's Management Information System (MIS) database. Water quality data on pH, Temperature, Phosphate, Ammonia and Nitrate was acquired from Kafubu Water and Sewerage Company for the period of 2014 to 2015, which was used to graph the trend analysis for the aforementioned parameter using excel 365 versions (Appendix V).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Identifying the Factors that Promotes the Growth and Infestation of Water Hyacinth on the Kafubu River

4.1.1 Physico - chemical characteristics in water column and sewage

The pH for water hyacinth infested areas ST2 and ST3 were 7.14±0.18 and 7.32±0.26 mg/l, respectively (Table 4.1). These values are slightly lower than pH from open waters without water hyacinth with a mean value of 7.41±0.21 mg/l (Table 4.1). An increase in pH is not attributed to the sewer effluent discharged into the water body from the two plants because the pH value for the effluent discharged into the River is lower than the pH value of water with values of 7.08±0.2 for Kanini Sewerage Treatment Plant (KSTP) and 7.13±0.13 for Lubuto Sewerage Treatment Plant (LSTP) (Table 4.2). Photosynthetic plants can cause an increase in pH levels as a result of their carbon dioxide use during photosynthesis process (Semesi *et al.*, 2009). Water hyacinth can grow in both highly acidic and highly alkaline conditions, but maximum growth for the water hyacinth happens when the water pH is near neutral (Gopal, 1987; Haller and Sutton, undated). This confirms from the analysis that the pH in the Kafubu River has a potential for maximum growth of the water hyacinth.

The probability for water sampled at stations ST1 and ST2, and between water sampled at ST1 and sewage at Kanini Sewerage Treatment Plants were 0.11, while the probabilities between water sampled at ST1 and LSTP, ST2 and KSTP, and ST2 and LSTP were 0.43, 0.88 and 0.44, respectively ($p>0.05$) (Table 4.3). This means there was no significant difference between the values for water samples and sewage.

The average temperature for ST2 and ST3, which are water hyacinth infested stations were 29.12±0.23 ^oC (ST2) and 30.15±1.71 ^oC (ST3), respectively. These values are 2-3 ^0C higher than open water with temperature value of 27.88±0.55 ^oC (Table 4.1). It has been documented that water hyacinth also cause a slight increase in temperature as it blocks exchange of heat between the surface of the river and the atmosphere (Mironga *et al.*, 2011).

Temperature value for sewage effluent discharged at Kanini Sewerage Treatment Plant was 24.30 ±1.36 while Lubuto Sewerage Treatment Plant was 26.13±1.71 (Table 4.2). Using one-tailed T-test the results showed a significant difference at 5% level between the values for water sampled at ST1 and sewage effluent at Lubuto and Kanini Sewerage Treatment Plants as shown by the probability of 0.0006 and 0.002 being less than 0.05, respectively. The probability of water samples at ST1 and ST2 showed significant difference. There was no significant difference between the water sampled at ST2 and at Kanini Treatment plant with probability of 1.77 (Table 4.3).

Table 4. 1: Physical and Chemical Characteristics of Water Column in Kafubu River

Parameter	**Average Results**			**Zambian Standards**
	ST1	**ST2**	**ST3**	
pH	7.41±0.21	7.14±0.18	7.32±0.30	6.5-8.0
DO (mg/l)	8.7± 0.11	6.7±0.46	5.3 ±0.16	12
Temperature (^{o}C)	27.88±0.55	29.12±0.23	30.15±1.71	40
EC (µS/cm)	495±4.15	376±21.46	469±12.99	1,500
Turbidity (NTU)	1.24±0.007	9.33±0.011	5.85±0.007	5
Manganese (mg/l)	0.0045±0.00005	0.006±0.0004	0.002±0.0004	0.1
Phosphate (mg/l)	0.31±0.05	0.67±0.03	0.45±0.11	1.0
Ammonia (mg/l)	0.05±0.01	0.06±0.15	0.58±0.04	1.0
Nitrite (mg/l)	0.23±0.04	0.53±0.03	0.32±0.01	1.0
Nitrate (mg/l)	3.51±0.41	4.84±0.07	4.17±0.12	10
Faecal Coliform (CFU/100mL)	23.4±0.06	1.7 x 10^4	45.5±0.38	0
Total Coliform (CFU/100mL)	1.7 x 10^4	2.7 x 10^3	2.1 x 10^3	20

In water hyacinth infested areas, dissolved oxygen was relatively lower with values of 6.7±0.45 mg/l (ST2) and 5.3 ±0.15 mg/l (ST3) than areas without water hyacinth (ST1), which recorded the mean concentrations of 8.7± 0.11 mg/l. (Table 4.1). This was also confirmed by Gichuki *et al*. (2012) who reported that water hyacinth limits phytoplankton’s growth and abundance, which are major contributors to dissolved oxygen in the water bodies. Water hyacinth also does not release oxygen into the water like phytoplankton, resulting in decreased dissolved oxygen concentration (Meerhoff *et al*., 2003). Kasulo (1999) noted that the water hyacinth prevents the vertical diffusion of dissolved gases and blocks oxygen entrance into the water than carbon dioxide going out, as the latter gas is highly soluble in water. This ultimately affects fisheries and other aquatic animals (Villamagna and Murphy, 2010). The DO value for sewerage effluent discharged at Kanini Sewerage Treatment Plant was 16.59±4.92 mg/l, while Lubuto Sewerage Treatment Plant was 17.33±4.351 mg/l. The results showed that there was a significant difference between water samples in the River at ST1, ST2 and sewage effluent at Lubuto and Kanini Sewerage Treatment Plants with probabilities of 0.0003, 0.00007 and 0.0003 ($p<0.05$). The analysis showed no significant difference between the water hyacinth infested area ST2 and the two sewer treatment plants with probabilities of 0.2 and 0.12 being greater than 0.05, respectively (Table 4.3).

Electro conductivity values for infested areas were lower with the mean values of 376±21.46 µS/cm for ST2 and 468±12.99 µS/cm for ST3, respectively, than open waters without the water hyacinth with a mean value of 495±4.15 µS/cm as shown in Table 4.1. Mironga *et al.* (2011) observed that the water hyacinth was commonly found in water areas where there is mineralization. Therefore, the weed proliferation was influenced by domestic and industrial wastewater and agricultural runoff. The conductivity values for all the sampling stations were within the Zambian Standard. EC value for sewerage effluent discharged at Kanini Sewerage Treatment Plant was

548.04±112.29 µS/cm while Lubuto Sewerage Treatment Plant was 723.62±101.90 µS/cm (Table 4.2).

Analysis showed a significant difference in the EC values between ST1 and ST2 (0.002), ST1 and sewage effluent at Lubuto Sewerage Treatment Plant (0.004), ST1 and Kanini Sewerage Treatment Plants (0.0065), and ST2 and Kanini Sewerage Treatment Plant (0.009) level ($p<0.05$). There was no difference between water sampled at ST2 and Lubuto Sewerage Treatment Plant 0.06 (Table 4.3).

Table 4.2: Physical and chemical characteristics of sewage effluent at Kanini and Lubuto Sewerage Treatment Plant

Parameters	Results (Kanini)	Results (Lubuto)	Zambian Standard
pH	7.08±0.20	7.13±0.13	6.0 - 9.0
Temperature (^{o}C)	24.30±1.36	26.13±1.72	40
DO (mg/l)	16.59±4.92	17.33±4.35	12
Turbidity (NTU)	44.67±44.18	112.19±28.79	15
EC (µS/cm)	548.04±112.29	723.63±101.99	4300
Ammonia (mg/l)	3.709±0.88	9.49±1.12	10
Phosphate (mg/l)	2.21±0.33	3.12±0,28	6

Table 4.3: Probability levels for parameters of water in Kafubu River (ST1 and ST2) and sewage effluent at Lubuto and Kanini Sewerage Treatment Plant

Parameters	Probability level between ST 1 and ST2	Probability level between ST 1 and KSTP	Probability level between ST 1 and LSTP	Probability level between ST 2 and KSTP	Probability level between ST 2 and LSTP
pH	0.11	0.11	0.43	0.88	0.44
Temperature (^oC)	0.02	0.0006	0.002	1.77	0.00013
DO (mg/l)	0.00003	0.00007	0.0003	0.2	0.12
Turbidity (NTU)	$9.7x\ 10^{-6}$	0.002	0.04	0.16	0.03
EC(µS/cm)	0.002	0.0044	0.0065	0.009	0.06
Ammonia (mg/l)	$4.3\ x\ 10^{-5}$	0.0036	0.00033	0.0036	0.0004
Phosphate (mg/l)	0.12	0.03	0.002	0.023	0.002

NS- not significant, p>0.05

Turbidity for the infested areas was slightly higher ranging with an average value of 9.33±0.011 NTU for ST2 and 5.85±0.007 NTU for ST3, respectively (Table 4.1). The mean value for turbidity for open waters (ST1), which is located upstream of the sewerage disposal point was 1.24±0.007 NTU. Turbidity for water hyacinth infested areas were beyond the Zambian standard, which is attributed by the raw sewage pumped into the river at Itawa and Dambo Sewerage Pumping Stations, which are located near two sampling stations. High turbidity values indicate the potential pollution in the Kafubu River. Turbidity influences the quality of effluents which contribute to the growth of water hyacinth. Turbidity value for sewerage effluent discharged at Kanini Sewerage Treatment Plant was 44.67±44.18 NTU while Lubuto Sewerage Treatment Plant was 112.19±28.79 NTU (Table 4.2). The results show there was a significant difference between water column in the river between ST1 and ST2 ($9.7x\ 10^{-6}$), ST1 and sewage effluent at Kanini Sewerage Treatment Plant (0.002), ST1 and Lubuto Sewerage Treatment Plant (0.04), ST2 and Lubuto Sewerage Treatment Plant probabilities of 0.03 ($p<0.05$). Water column at ST2 and effluents at Kanini Sewerage Treatment Plants showed no significant difference (0.16) as shown in Table 4.3.

Station ST2 had the highest concentration of manganese in the water column of 0.0058±0.0004 mg/l, while ST3 had the least concentration of 0.002±0.0004 mg/l. Station ST1 had a slightly higher mean value of manganese of 0.0045±0.00004 mg/l than ST3. Manganese values were all within the recommended standards (Table 4.1). Total Suspended Solids in the water column had the average value ranged from 264.15±0.76 to 380.75±0.83 mg/l with ST1 having the highest value and ST2 the least. TDS levels for all stations were within the Zambian Standard as shown in Table 4.1. Murray Regional Algal Coordinating Committee (2002) reported settling matter on stream substrate can increase light infiltration into water column and if it's combined with high level of nutrients can lead to algae or aquatic weed bloom.

4.1.2 Nutrients in water column and sewage

Table 4.1 shows that phosphate in the water column in Kafubu River ST2 had the highest level of phosphate concentration of 0.67±0.03 mg/l and ST3 phosphate level of 0.45±0.11 mg/l, respectively while ST1 had the least concentration of 0.31±0.05 mg/l of phosphate. The major source that contributes to the nutrients in the Kafubu River is the sewage from Kanini and Lubuto Sewage Treatment Plants, which is discharged into the river. These treatment plants work with capacities of 11,000 m^3/day and 27,000 m^3/day, respectively. The average phosphate value for sewerage effluent discharged at Kanini Sewerage Treatment Plant is 2.21±0.33, while at Lubuto Sewerage Treatment Plant is 3.12±0.28 mg/l (Table 4.2). According to Wilson *et al.* (2007) apart from temperature, nutrients are one of the strongest determinants for the growth and reproduction of water hyacinth in water bodies. High nutrient level cause rapid growth of the weed.

Figure 4.1 shows a part of Kanini Sewerage Treatment Plant. Raw sewage is drained into Kafubu River without treatment at the Itawa Sewerage Pump Station and at the Dambo Sewerage Pump Station upstream whose capacities are unknown (Muma, 2011). Mashingaidze (2003) reported reproduction for water hyacinth is higher in waters with high concentrations of mineral nutrients especially nitrogen and phosphate from effluent discharged from semi-processed and unprocessed wastewater into rivers. For example, Manyame River Basin inland lakes and rivers have experienced the problem of water hyacinth as a result of sewage effluent from the metropolis of Harare and Chitungwiza (Moyo and Phiri, 2002). The probability between water sampled at stations ST1 and ST2 was 0.12, which shows no significant difference between the water sampled at the two stations. Between ST1 and KSTP, ST1 and LSTP, ST2 and KSTP, and ST2 and LSTP the probabilities were 0.03, 0.002. 0.023 and 0.002, respectively. The analysis showed that there was a significant difference ($p<0.05$) as shown in Table 4.3.

Figure 4. 1: Kanini Sewerage Treatment Plant (Capacity of 11,000 m^3/day)

The ammonia concentration at ST3 had the highest concentration of 0.58±0.04 mg/l while ST3 had a concentration of 0.06±0.15 mg/l. Station ST1 had the least concentration value of ammonia 0.05±0.01 mg/l. This is attributed by sewer effluents discharged into the River, which has caused the rapid growth of the water hyacinth. The results showed that the ammonia value for sewerage effluent discharged at Kanini Sewerage Treatment Plant was 3.708±0.88 mg/l while at Lubuto Sewerage Treatment Plant was 9.49±1.12 mg/l (Table 4.2). The analysis showed there was a significant difference in the water sampled between ST1 and ST2, ST1 and sewage at both Kanini and Lubuto Sewerage Treatment Plants, and water sampled at ST2 and sewage at both plants with values of 4.3 x 10^{-5}, 0.0036, 0.00033, 0.0036, and 0.0004, respectively.

Nitrite concentration at ST2 was 0.53±0.03 mg/l which was the highest value, ST3 had nitrite concentration of 0.32±0.01 mg/l, while ST1 had the least concentration of 0.23±0.04 mg/l. Station ST2 had the highest concentration of nitrate of 4.84±0.07mg/l and ST1 had the least concentration of 3.51±0.41mg/l. All the three stations were within the recommended Zambian standards. Despite this, nutrients levels at ST2 and ST3 which are hyacinth infested areas were higher than the open area ST1. Agriculture runoff with fertilizer and wastewater from unplanned settlements find their way into the river and contribute to the infestation of the alien species (Muma, 2011).

4.1.3 Microbiological characteristics in water column and sewage

Faecal and Total Coliforms were detected in all stations and were above the Zambian Standard as depicted in Table 4.1. The Faecal Coliform in the water column at ST1 was 1.7 x 10^4 CFU/100 ml while at ST2 and ST3 were 2.7 x 10^3 and 2.1 x 10^3 CFU/100 ml, respectively. This is as result of Kanini and Lubuto Sewerage Treatment Plants which discharge effluents below statutory limits into the Kafubu River. The effluents discharged into the river by the two plants have 7.1 x 10^4 CFU/100 ml of Faecal Coliforms and 9 x 10^4 CFU/100 ml of Total Coliform. In accordance with Zambian Standards for effluents the limit for the Total Coliform is 2.5×10^4 CFU/100 ml while faecal coliform is 5×10^3 CFU/100 ml (Muma, 2011).

4.1.5 Nutrients and Microbiological Characteristics in the stem and roots of water hyacinth

Water hyacinth is known to remove pathogens and absorb nutrients from the water column (Aoi and Hayashi, 1996; Zimmels *et al.*, 2007). Water hyacinth uptake nutrients higher than other macrophytes, despite nutrients contributing to its growth water hyacinth has potential to significantly reduce nutrient concentrations in a water body depending on the extent of cover and density (Pinto-Coelho and Greco, 1999; Rodríguez-Gallego *et al.*, 2004). Table 4.4 shows that in the roots and stems of the water hyacinth plants there were traces of all nutrients. Nitrate in both stem and root tissues was 1.72 mg/l and 1.70 mg/l, respectively, was beyond recommended Zambian Standard. The Faecal Coliform in the plant root was 3.1×10^2 CFU/mg and in the stem was $1.5 \times 10^{3.}$CFU/mg. The total coliforms present in the roots and stem for the weed were 3.2×10^2 CFU/mg and 1.9×10^2 CFU/mg, respectively. Water hyacinth has a capacity to absorb nutrients and trap pathogens; therefore, it can be used as a potential biological alternative to secondary and tertiary treatment for wastewater (Ho, 1994; Cossu *et al.*, 2001).

Table 4. 4: Nutrients and Microbiological measurements in Stem and Roots of Water Hyacinth

Parameter	Average Results	
	Roots	**Stem**
Phosphate (mg/l)	0.5	0.56
Nitrate (mg/l)	1.72	1.7
Faecal Coliform (CFU/mg)	3.1×10^2	1.5×10^3
Total Coliform (CFU/mg)	3.2×10^2	1.9×10^2

4.1.6 Trend Analysis for Physical Parameters and Nutrients

Data was obtained from Kafubu Water and Sewerage Company Limited MIS database for water quality parameters for the period 2014 to 2015, while for January and February, 2016 was measured and analysed at Seed of Hope Laboratory.

4.1.6.1The pH and Temperature Trends

Figure 4.2 shows that the pH level in water column has been increasing by 0.299% for the past two years, which is a significant increase. The temperature in the water column has been increasing significantly from 2014 to February, 2016 (Figure 4.2). This is as a result of sewer effluents discharged into the River by Kafubu Water and Sewerage Company Limited which are beyond the statutory limit.

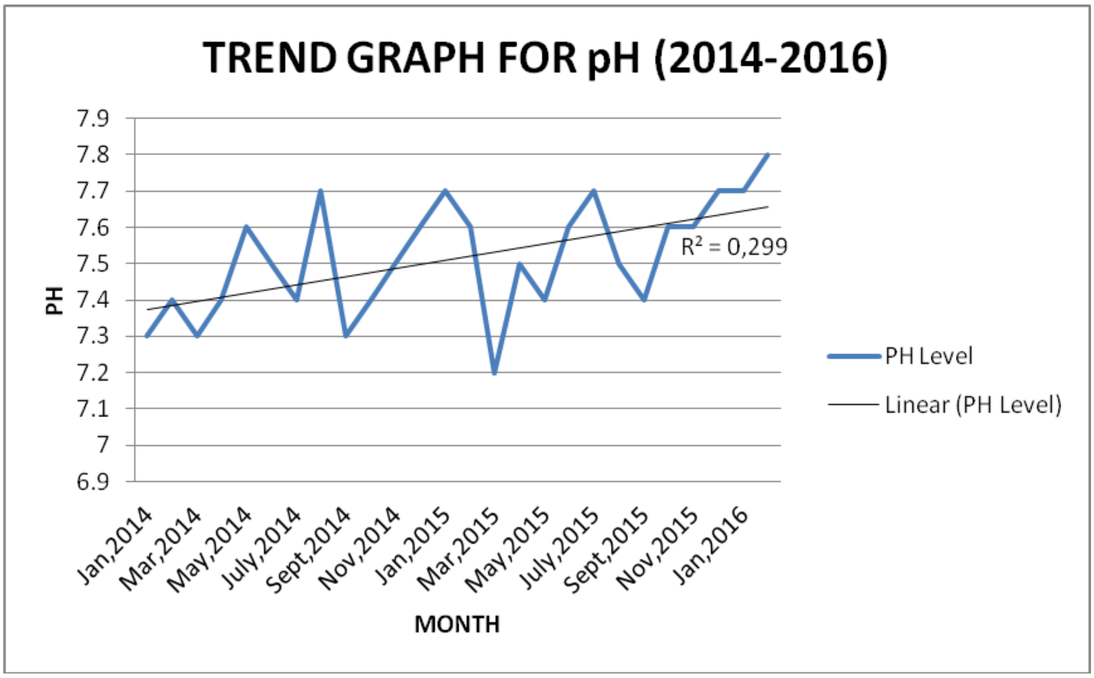

Figure 4. 2: Trend for pH trend in Kafubu River

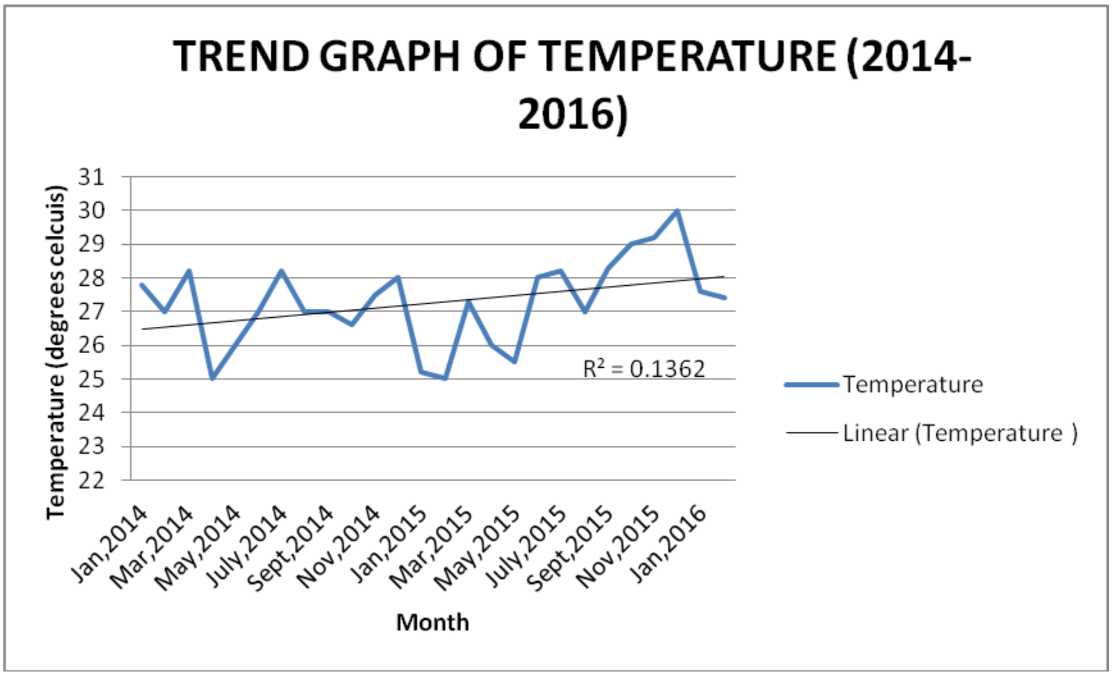

Figure 4. 3: Trend graph showing temperature trend in Kafubu River

4.1.6.2 Nutrients Trend

The study shows that phosphate has been increasing by 0.69 in the water column for the past two years. This can be attributed from wastewater that is discharged into the river from Kanini and Lubuto Sewage treatment plants and runoff from agriculture practices along the River. This confirmed Moyo and Phiri (2002) study in Zimbabwe, that most rivers which received sewage, increases the level of phosphate causing a major problem of the water hyacinth infestation.

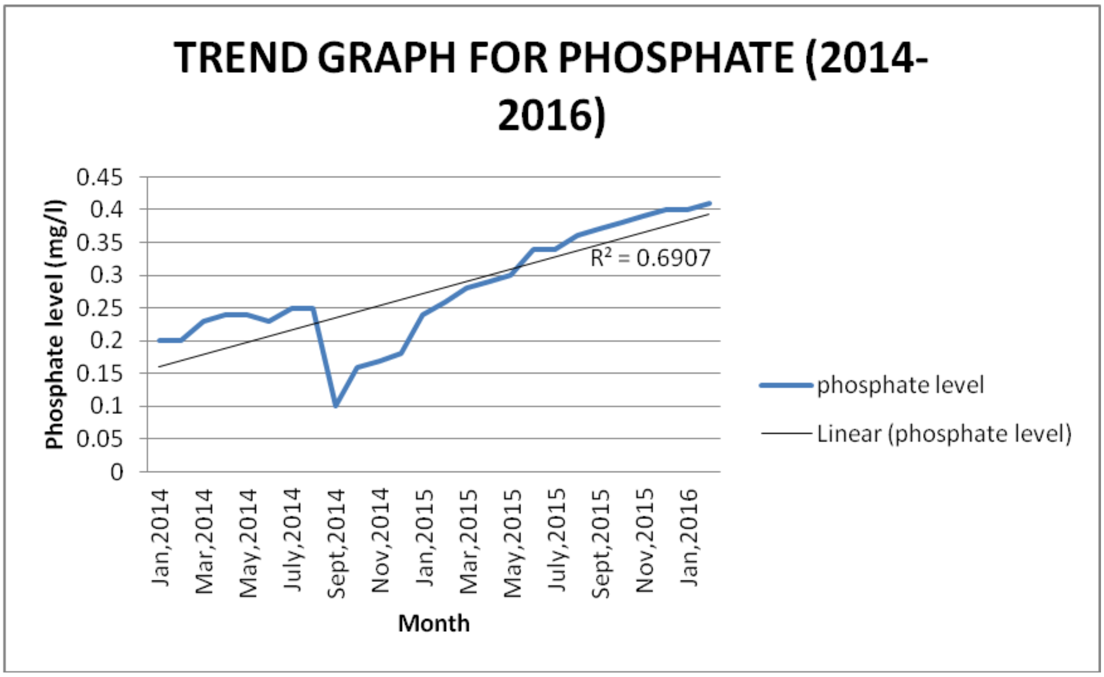

Figure 4. 4: Trend graph for phosphate concentration in Kafubu River

Figure 4.5 shows that ammonia concentration in water column for the period of 2014 to February 2016 has been increasing in the water column. Anthropogenic activities around the river have increased in the number of years, runoff from agriculture practices with fertilizers and wastewater from settlements find its way into the River.

Muma (2011) noted that agriculture runoff with fertilizer and wastewater from unplanned settlements is the main contributors of ammonia found in the River and explode the population density of the alien species.

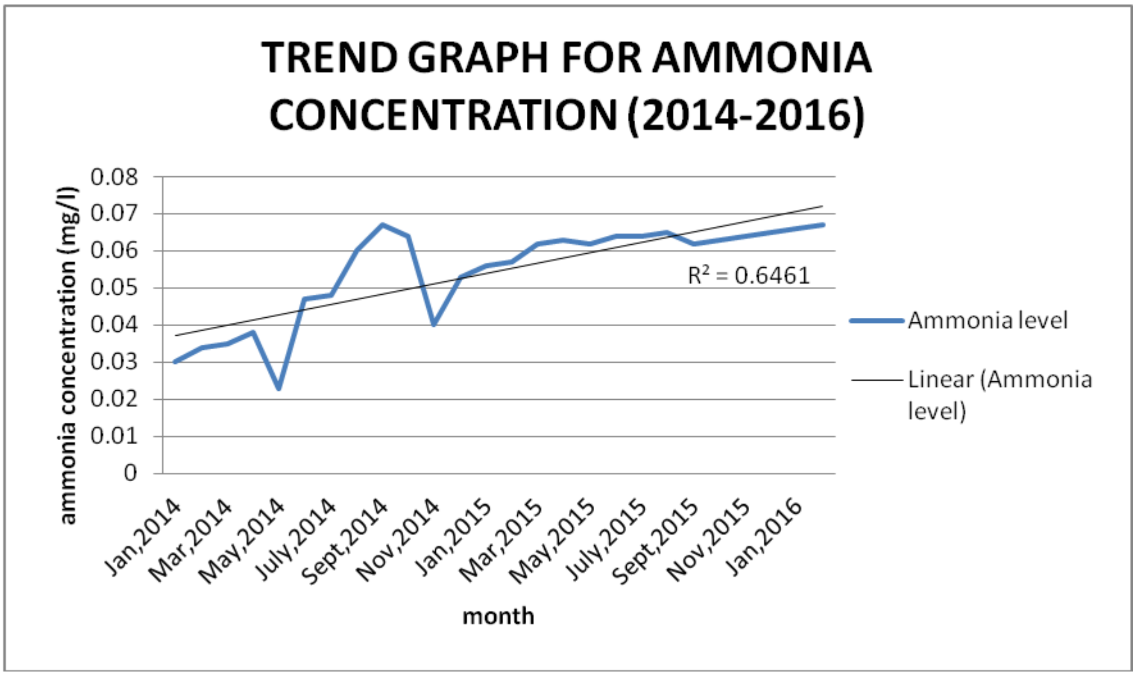

Figure 4. 5: Trend graph for ammonia concentration in Kafubu River water column

Figure 4.6 shows that nitrate concentration in water column for the period of 2014 to February 2016 has been an significant increase of 0.732. This is as a result of sewage effluents discharged into the river at Kanini and Lubuto Sewerage Treatment Plants and agriculture runoff carrying fertilizer from farms along the river.

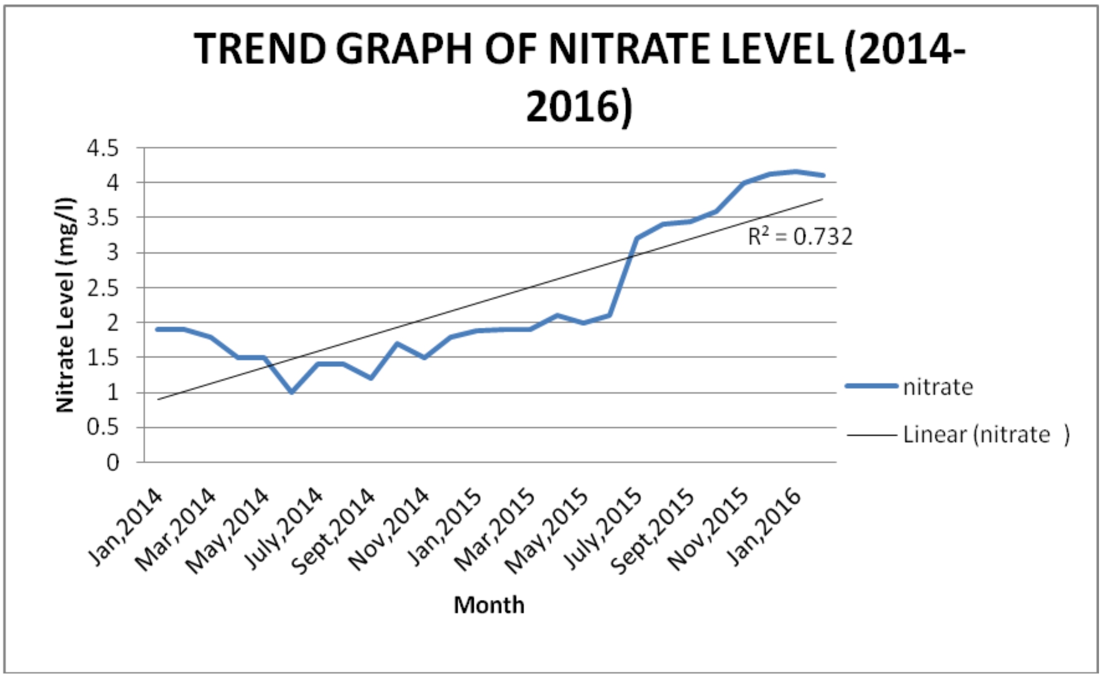

Figure 4. 6: Trend graph for nitrate in Kafubu River

4.2 Impacts of Water Hyacinth on Major Socio-Economic Activities

There are two major socio-economic activities along the Kafubu River include fishing and farming, which the communities depend on for their day to day livelihood. To ascertain the impacts of the water hyacinth on fishing, it was important to establish the sex, age and education level for the respondents.

4.2.1 Impacts of Water Hyacinth on Fishing

The total number of respondents was 127 with 72 being female (56.69%) and 55 (43.31%) males. This shows that majority of fishermen are dominated by women and minority are males. The age distribution of fishermen ranged from 22 to 46 years. About 41.7% of fishermen were 42 to 46 years of age. The class between 22 to 26 years had the least respondent of about 5.5%, while class of 37 and 41 years accounted for 27.6% as shown in Figure 4.7. In general, the data were considered reliable as it was obtained largely from experienced population in the fishing industry.

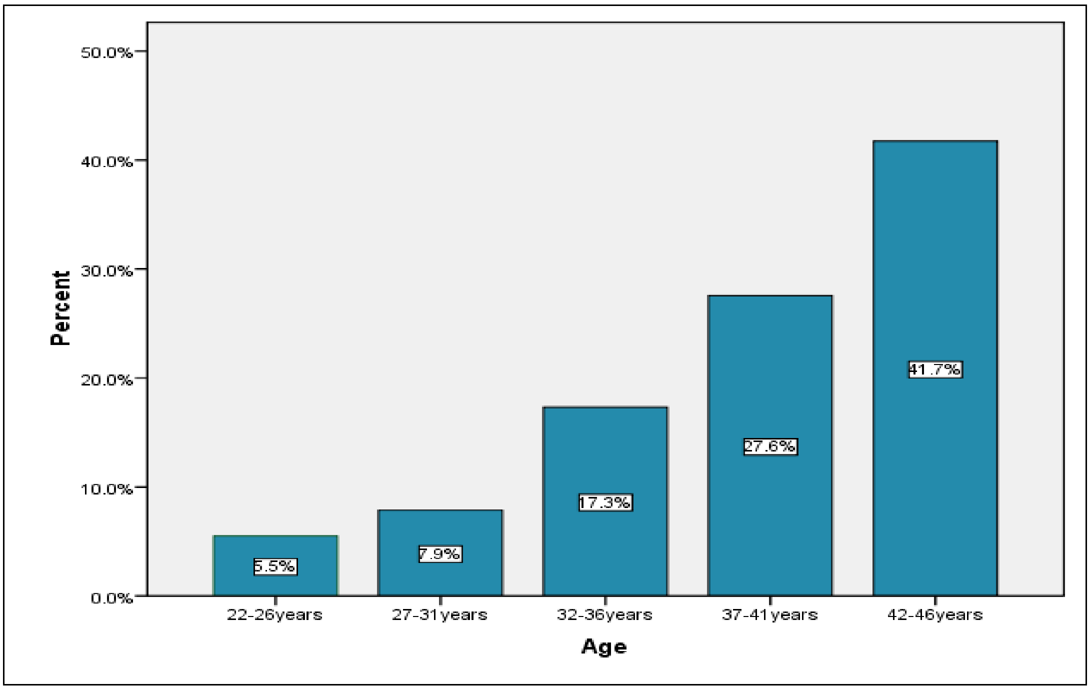

Figure 4. 7: Graph showing Age Classes of Fishermen

The educational level for the respondents ranged from primary to tertiary education (Table 4.5). About 59.1% have been through tertiary education, which showed that fishermen around Kafubu River were extremely knowledgeable of their environment and issues affecting the river ecosystem. Minority of the respondents of about 12.6% have attended primary school. Figure 4.8 shows that about 34.5% have practiced fishing for more than 9 years, 28.4% have been fishing for between 7 to 9 years, 22.1% between 4 to 6 years and the least 15.0% between 1 to 3 years. This indicated that majority of the respondents have sufficient knowledge on the impacts of the water hyacinth on the fishing industry in the Kafubu River.

Table 4.5: Table showing education level and number of respondents

Education level	Frequency	Percent
Primary	16	12.6
Secondary	36	28.3
Tertiary	75	59.1
Total	127	100.0

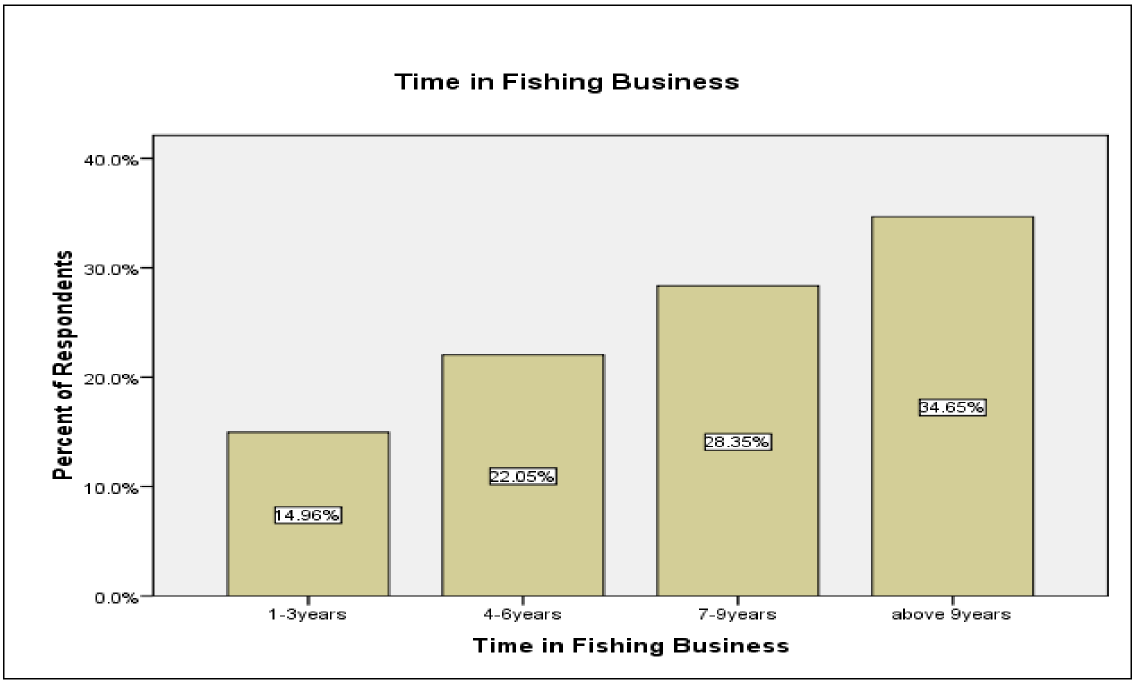

Figure 4. 8: Experience of fishermen in fishing business

Figure 4.9 shows that 21.3% of respondents reported that water hyacinth cause damage on the fishing hook while 20.5% of respondents reported that the weed cause damage to the fishing nets. Similar observations were made by Labrada *et al.* (1996) who observed that it's difficult to place fishing nets with water hyacinth present and causes damage to any type of fishing net. About 20.5% of respondents find it difficult to paddle in a boat as the weed covers the water body. According to Patel (2012) water hyacinth entangles with boat propellers, and makes it difficult for fishermen to move as it is an impenetrable barrier to canoes. Water hyacinth in water bodies create a difficult scenario for fishermen to access fishing sites, which leads to loss of fishing equipment as a results of nets entangling into the root systems of the weed (ITDG, 1999). About 14.2% of the respondents noted that the food that is hooked on fishing hooks to attract fish is carried along by the decay weed which is moving. About 11.8% of fishermen observed that the weed tends to slow water velocity, which is positive to fishermen as this increases fish catch. Less-sensitive fish benefits from the provision of weed cover and an enhanced food supply by the water hyacinth's complex root system (Chapman, 1996). About 11.8% of respondents reported that time is wasted to lay fish nets as fishermen have to be careful when putting the net as the weed might cut the net. A study by Labrada *et al.* (1996) on Lake Victoria showed that the water hyacinth covers fishing areas, which makes it difficult and time consuming for fishermen to locate open water and spend more time on a journey. Instead of canoe journeys of half an hour or less, fishermen are forced to spend two or three hours reaching fishing grounds.

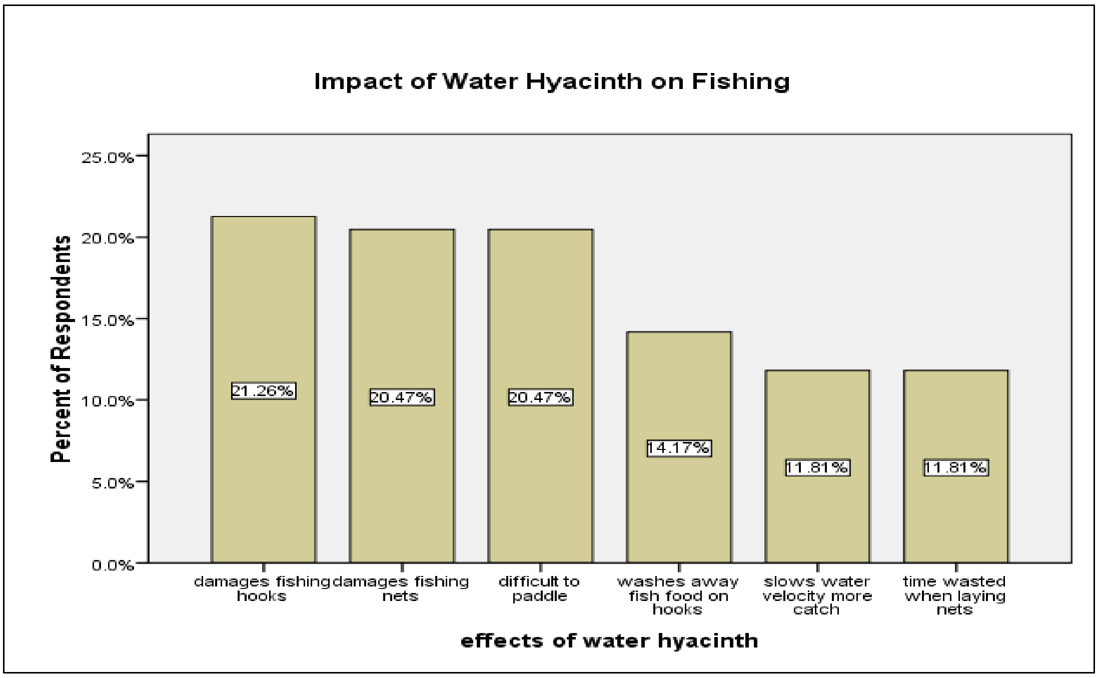

Figure 4. 9: Impact of water hyacinth on fishing

4.2.1.2 Water Hyacinth Coverage

The study area has a tropical climate with three distinct seasons: the warm-wet season, stretching from November through April; cool dry cold season from May to July, and the hot dry season are experienced from August to October. Figure 4.10 shows that 55.9% of the respondents observed that the water hyacinth coverage is higher from May to July, while 37.8% reported that there's a slight coverage of the weed from August to October, but only about 5.3% of fishermen reported that in hot season the river experiences the lowest coverage of water hyacinth.

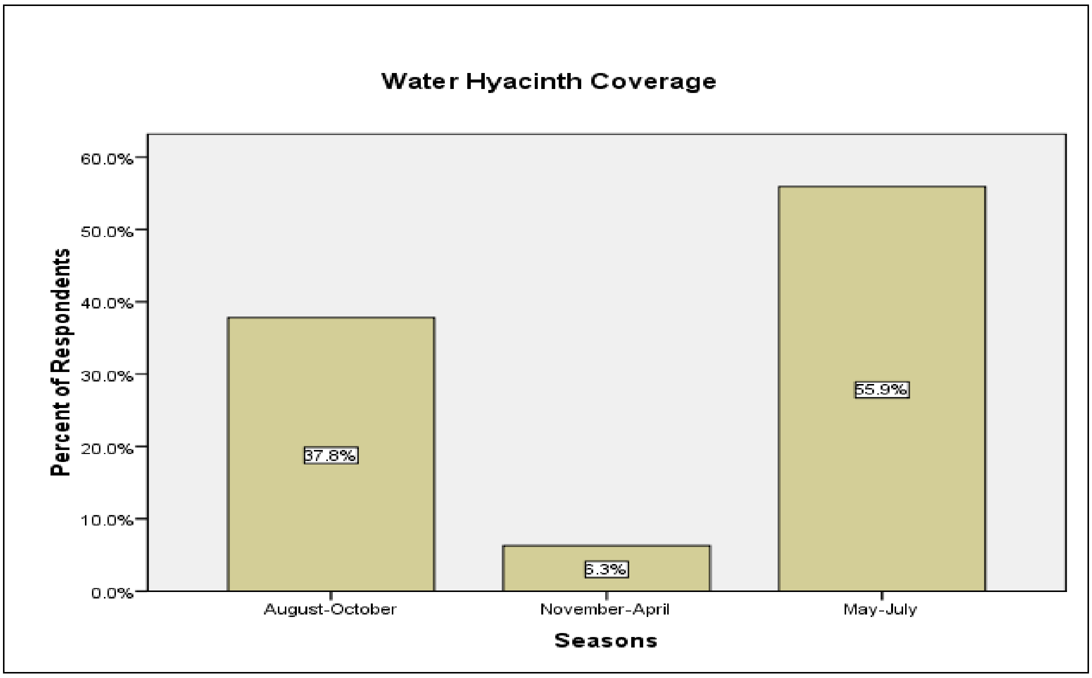

Figure 4. 10: Water hyacinth Coverage in the River per Season

4.2.1.4 Fish Catchability

Tilapia render

The quantity of fish were grouped in accordance with the three seasons; August to October, November to April and May to July. There are four major fish species found in Kafubu River namely; *Tilapia render***,** *Tilapia sparmanil, Oeschromis andersonil* and *Bubble fish*. Impacts of the water hyacinth on fish communities depend on the initial community composition and structure, the existing food web, and water hyacinth density or area cover (Grenouillet *et al.*, 2002; Lewin *et al.*, 2004). Figure 4.11 shows that 59% of the respondent perceived that the fish catchability for *Tilapia renderi* is high in November to April, when the water hyacinth coverage is extremely low covering about 6.3% as shown in Figure 4.10. On the other hand 11% of respondents reported that fish catchability is very low from May to July when water hyacinth coverage perception by respondents is high. Figure 4.11 shows that 30% of respondents perceived that fish catchability is moderate in August to October when water hyacinth coverage perception by respondents is at 37.8%. This is supported by Labrada *et al.* (1996) who observed that fewer fish, by number and weight, are found in water hyacinth areas with smaller fish diversity. For example (*Tilapia* spp.) are commonly found in open area, but find it difficult to adopt in weed infested areas. The study showed that dissolved oxygen in water hyacinth infested areas was lower than in open waters. Dissolved oxygen which is less than 5 mg/ l adversely affect function and survival of most fish, while below 2 mg /l can lead to fish death (Chapman, 1996).

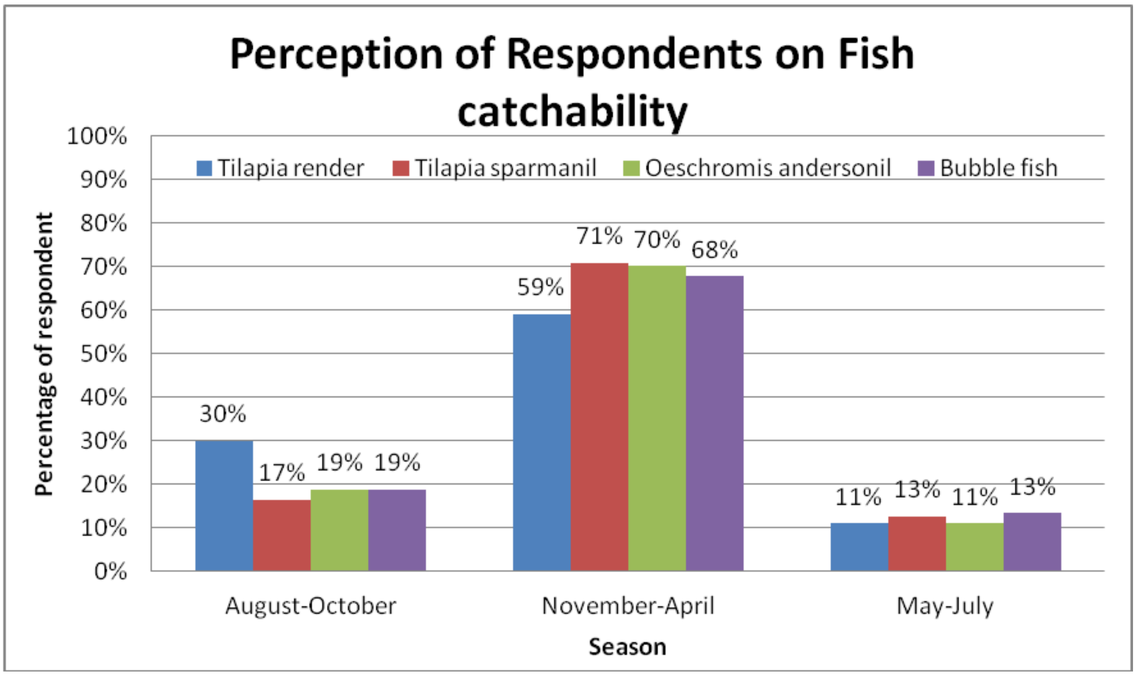

Figure 4. 11: Graph showing fish catchability for per season

***Tilapia sparmanil* and *Oeschromis andersonil* Catchability**

Figure 4.11 showed that 71% of respondents perceived fish catchabilities for *Tilapia sparmanil* and *Oeschromis andersonil* was higher from November to April, when the perception of water hyacinth coverage is low shown in Figure 4.11. While 11% of respondents reported that from May to July fish catchability is very low with high water hyacinth coverage higher, but 19% and 17% of respondents, respectively, observed that fish catchability for both *Tilapia sparmanil* and *Oeschromis andersonil* is low in August to October, when water hyacinth coverage is high. The structure of water hyacinth on the water surface restrict vegetation growth beneath the water, which affects and reduces fish as the surface of water is modified and fish cannot adapt to a new environment (Meerhoff *et al.*, 2006; Meerhoff *et al.*, 2007). The dissolved oxygen is reduced during decomposition process of dead debris, which negatively affects fish catchability.

Bubble fish catchability

Figure 4.11 shows that 68% of the respondents reported that fish catchability for bubble fish is higher between November and April, when water hyacinth coverage is low. On the other hand 13% of respondents observed that fish catchability is very low from May to July when water hyacinth coverage is high. About 19 % of respondents observed that fish catchability in August to October is moderate when water hyacinth coverage perception is 37.8%. Water hyacinth affects fish catchability especially when dissolved oxygen is reduced as a result of dense water hyacinth mats, this risk killing the fish (Kateregga and Sterner, 2009).

4.2.1.3 Fish prices

Respondents reported that the fish price increases from an average of 8 Kwacha to 9 Kwacha for all fish types when the Kafubu River is largely covered by water hyacinth between May and July (Figure 4.12). Fishermen observed that the fish price increase from 6 Kwacha to an average of 7 Kwacha between August and October, while other respondents reported that the fish prices decreases from 4 Kwacha to 2 Kwacha from May to July when water hyacinth coverage is low (Figure 4.112). The respondent also reported that fish prices are also affected by fish ban experienced from November to March every year. This shows that water hyacinth has a direct impact on the fish prices which are determined by traders themselves. Kateregga and Sterner (2009) noted that in Lake Victoria, fish catchability decreased as the mats blocks access to fishing areas, and increased fishing costs such as materials.

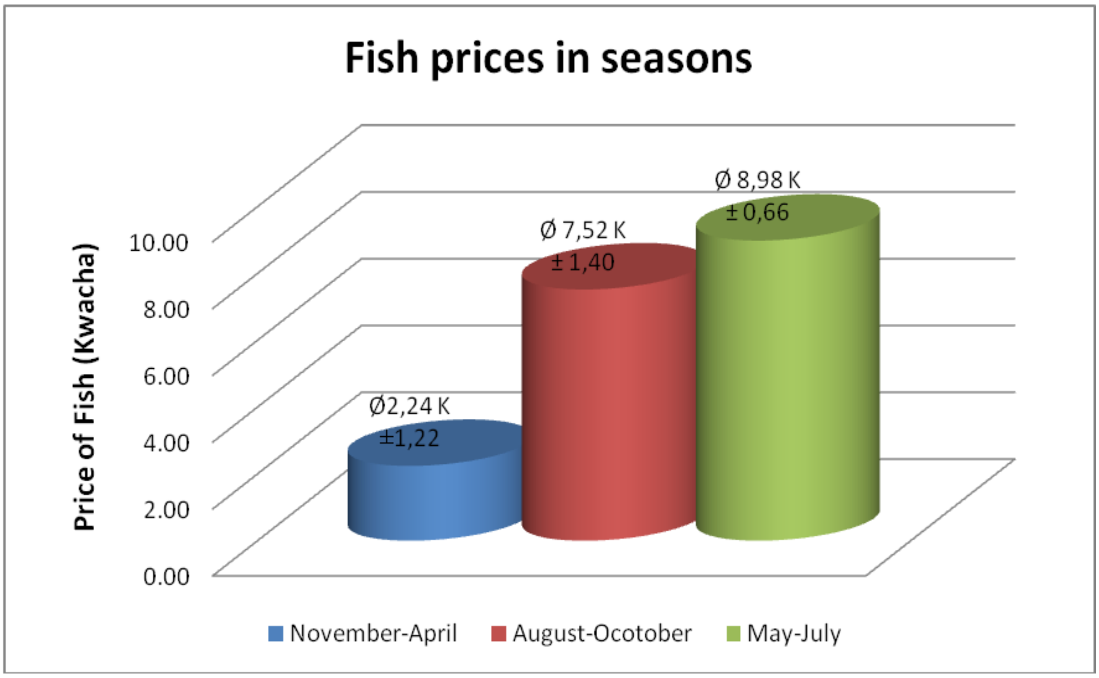

Figure 4. 12: Graph showing fish price in season

4.2.1.4 Additional Impacts incurred by Respondents

Figure 33 shows that about 48.0% of respondents perceived that additional costs are incurred such as manual removal of the weed due to the presence of the water hyacinth. About 24.4% of respondents reported that fish nets are repaired after they are damaged by the weed, and 23.6% of respondents observed that new fishing hooks which were destroyed by the weed are bought almost every after 6 months. It was also noted that about 3.9% of respondents reported that money is spent buying fish food after the initial food was carried together with the weed.

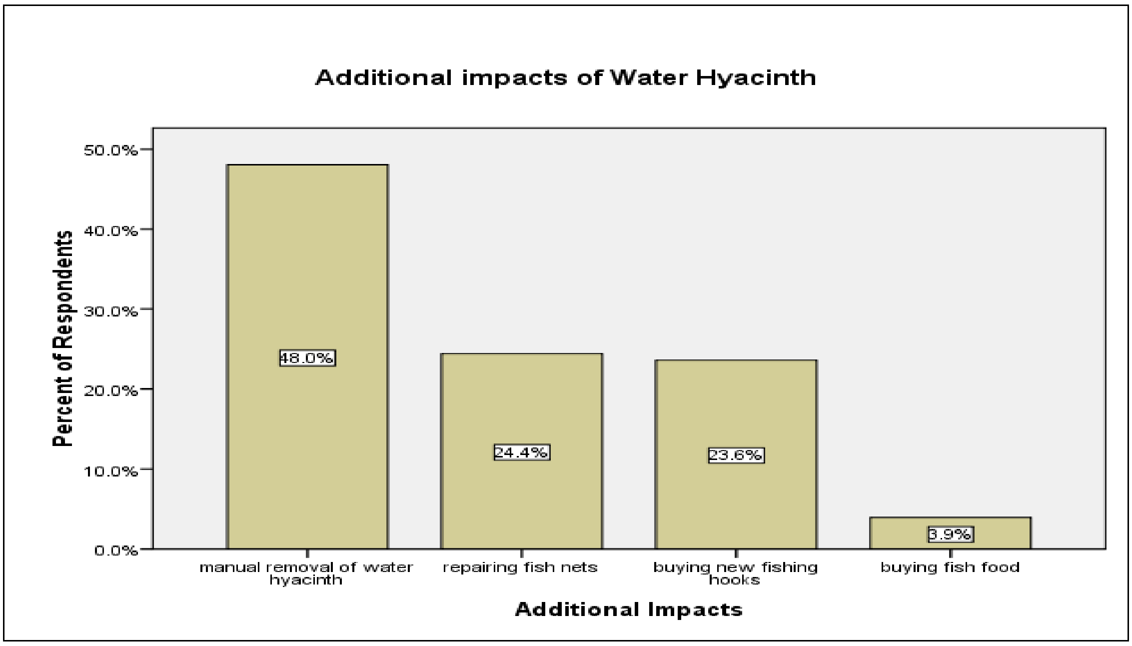

Figure 4. 13: Additional Impacts incurred by Respondents

4.2.2 Impacts of Water Hyacinth on Farming

To assess the impacts of the water hyacinth on farming, one of the major socio-economic activities for the people along the Kafubu River, 52 farmers were interviewed. The study showed that 53.85% were female while 46.15% were males.

Figure 4.14 shows 21.15% of the respondents were between the age of 27-31 and 37 to 41 years, the least represented about 9.62% between the ages of 16-21years. This shows that the majority of respondents are old enough to give credible information on impacts of water hyacinth on farming. Majority of farmers have been through secondary and tertiary school and 84.6% and have done some training on farming systems and were knowledgeable about farming and environment.

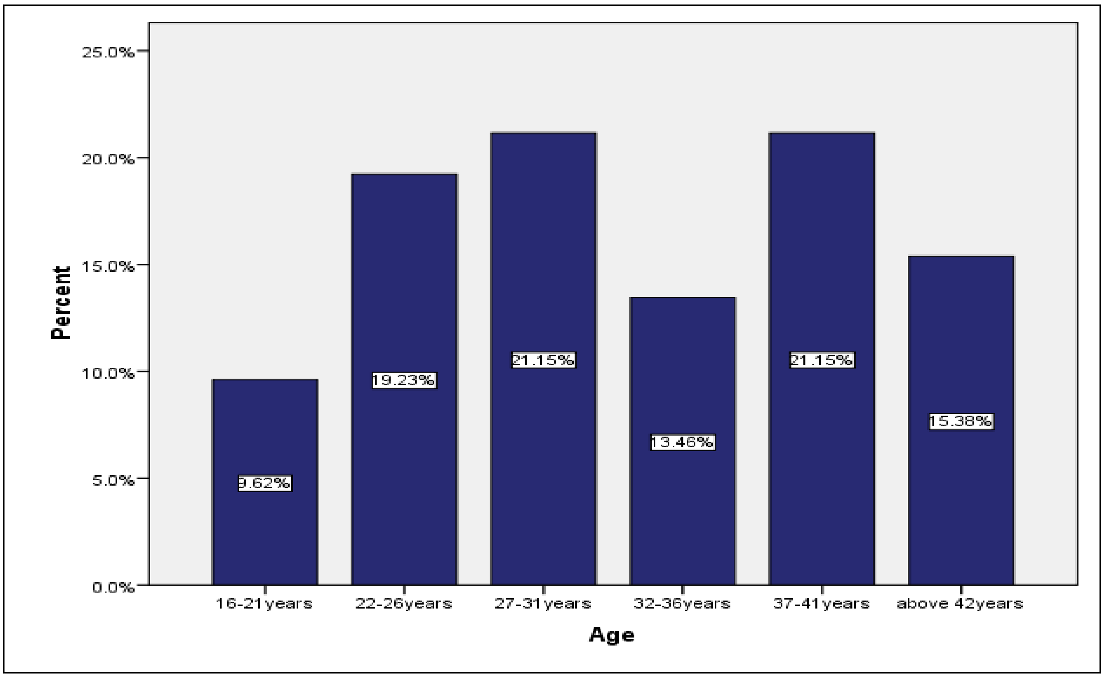

Figure 4. 14: Graph showing age group for farmers

About 38.5% of respondents have been in farming business between 7 to 9 years and 28.9% have been in the business for more than 9 years (Figure 4.15). This indicates that the data is credible because the respondents have experience.

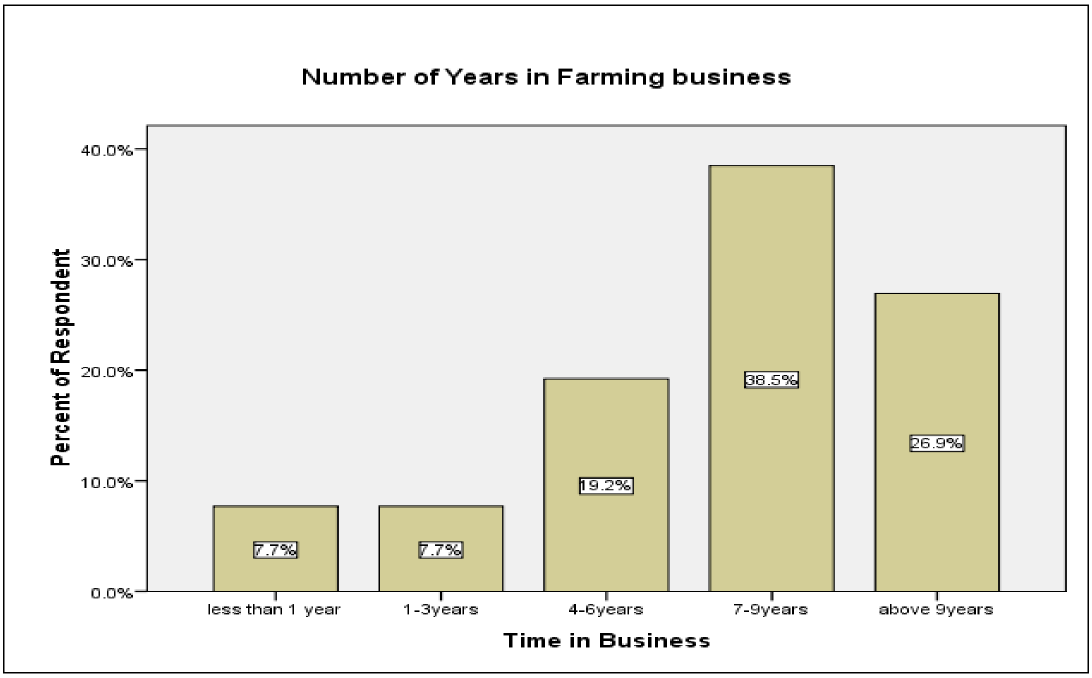

Figure 4. 15: Graph showing number of years in farming business

4.2.2.1 Effect of Water Hyacinth on Farming

About 34.6% of respondents reported that water hyacinth reduces the amount of water received for irrigation, while 34.62% perceived that the weed blocks the irrigation channels (Figure 4.16). About 23.08% of the respondents observed a positive impact of the weed as it brings along the organic material which helps in the growth of the crops. This was also reported by Kateregga and Sterner (2009) and Patel (2012) who noted that water hyacinth has a great impact on pipe system for agriculture; blocks irrigation channels and reduces water flow into the crop fields.

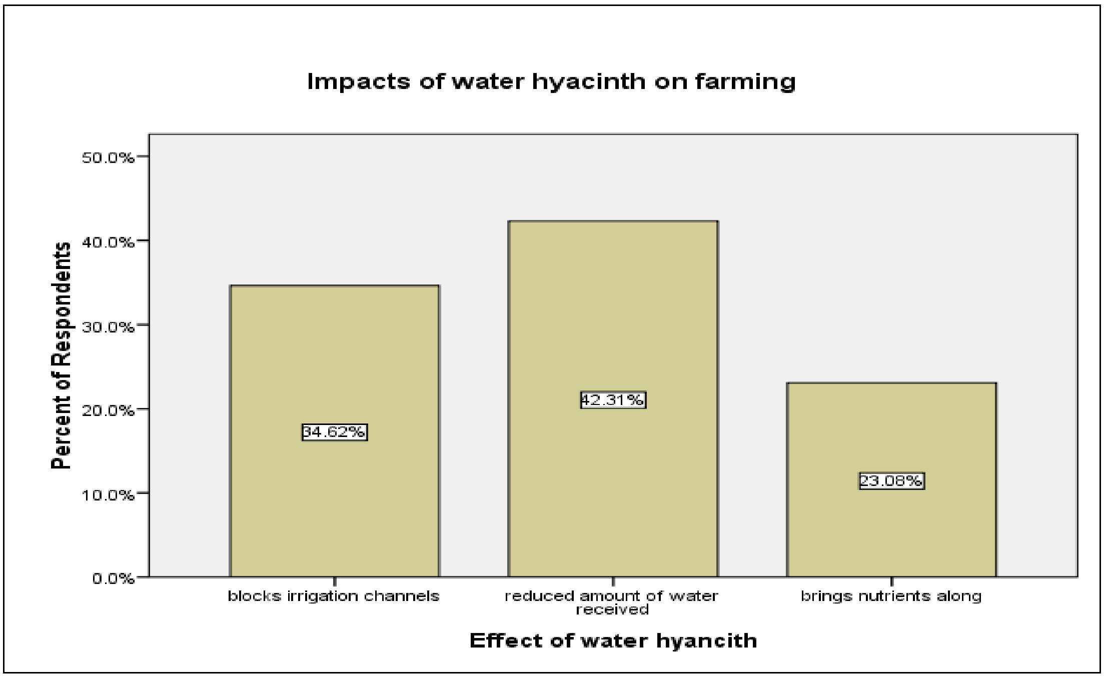

Figure 4. 16: Effect of water hyacinth on irrigation

4.2.2.2 Effect of Water Hyacinth on Water for Irrigation

Figure 4.17 shows about 59.2% of respondent observed that more water is received when the river has completely no water hyacinth, while about 25.0% of respondents reported that water is received when the river is partially covered by the weed. 5.8% of respondents observed that water is received when the river is completely covered by the water hyacinth. Water hyacinth slows water flowing into irrigation channels and restricts access to water for irrigation, which may cause severe flooding (Jones, 2009; Ndimele *et al*., 2011; Patel 2012).

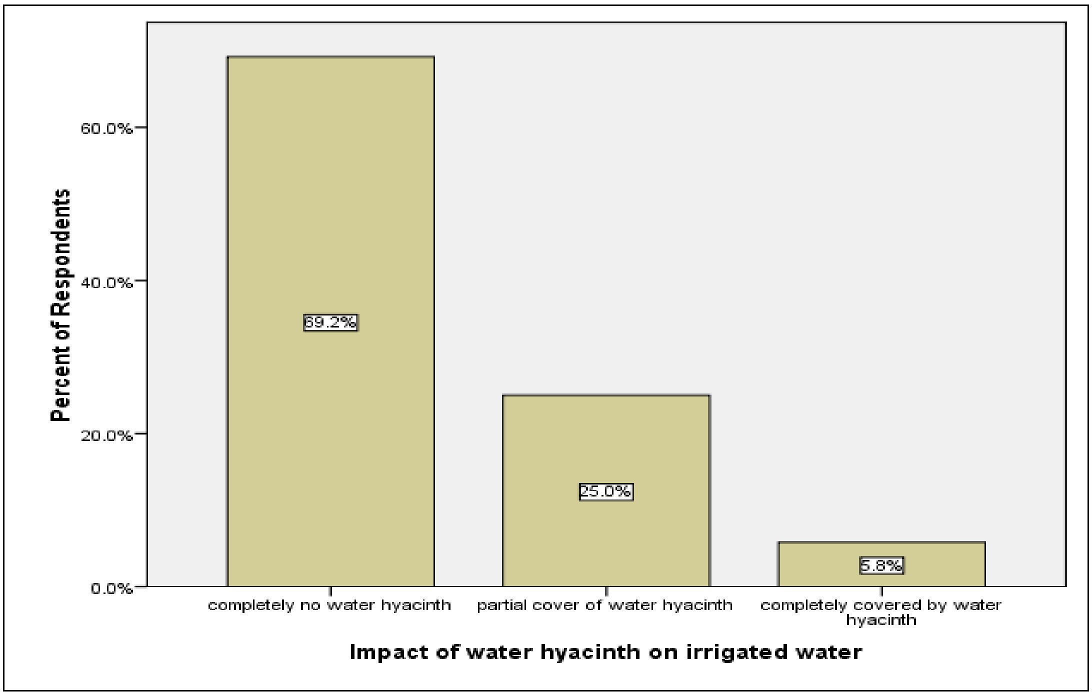

Figure 4. 17: Impact of water hyacinth on irrigation

4.2.2.3 Additional Impacts Incurred

The majorities of respondents of about 38.5% reported that water hyacinth is removed manually from the river and people are hired to remove it to avoid blockage to irrigation channels (Figure 4.18), the farmers noted that about 600 Kwacha is spent annually on this cost. About 34.6% of farmers observed that time is wasted when removing the weed from blocked irrigation channels, while about 26.92% of respondents remove the weed by using different chemicals such as weed killer and 1000 Kwacha is spent of chemicals.

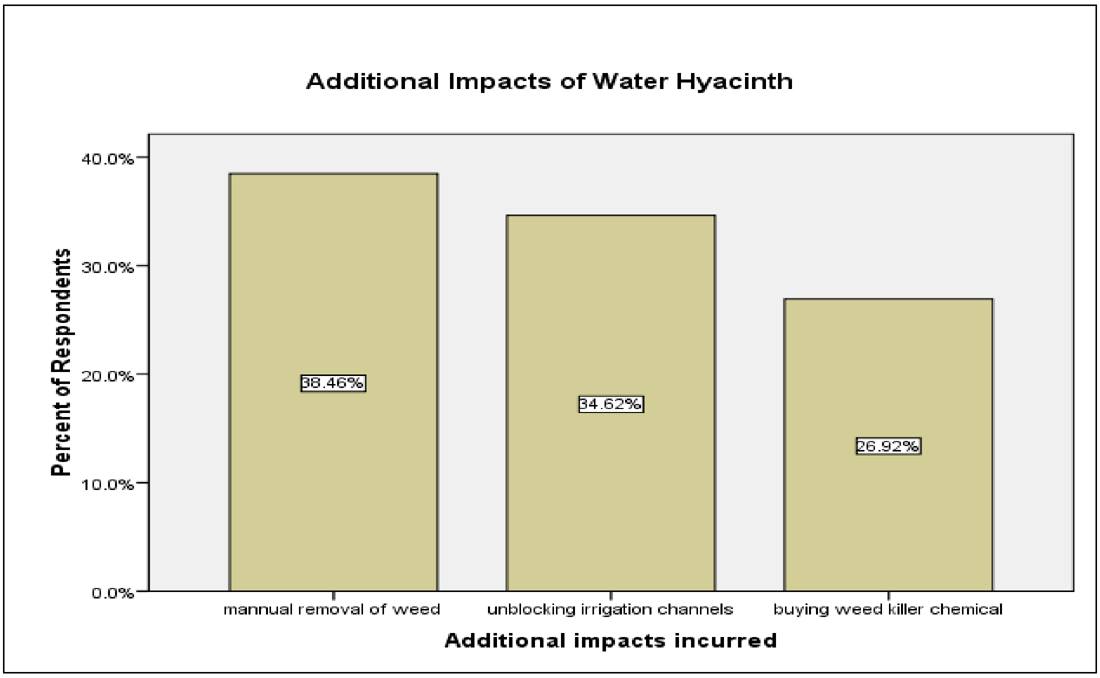

Figure 4. 18: Graph showing additional impacts incurred due to water hyacinth

4.3 Assessment of Institutional and Legislative Framework for Management of Water Hyacinth on Kafubu River

4.3.1 Management of Water Hyacinth in Zambia

4.3.1.1 Institutional and Legal framework

The Water Resources Management Act of 2011 is the building block of Zambia's water legislation which replaced and repealed the Water Act of 1948 following the IWRM approach, under the auspices of the Water Resources Action Program (WRAP). This act focuses both on ground and surface water resources. The aim of the act is to establish a regulatory and administrative framework for the management, development, conservation, protection and preservation of the water resource in Zambia and provides with respect to water rights and the equitable and sustainable use of water resources and related matters (Water Resource Management Act, 2011). It is in agreement with the Dublin Principles of 1992 and is the bottom-top management of water. However, the Water Resources Management Act of 2011 is silent on the management of alien species such as the water hyacinth in water bodies (FAOUN, 2012). For better management of the water hyacinth, there is need for policy reforms to incorporate alien species management in water bodies.

According to the Water Act of 2011, the main ownership of the water resources is vested in the President of the Republic of Zambia. The Ministry of Energy and Water Development is the main governing body for management of both ground and surface water, with the Department of Water Affairs (DWA) and the Water Board having overall responsibility for Water Resources Management and Development (MEWD, 2014). The main role for the ministry is 'development of policies and legislations related to water management'. The Department of Water Affairs and Water Board controls, develops and manages all waters in Zambia such as rivers and lakes. Figure 4.19 shows the current organisational structure for the Department of Water Affairs. The institutional structure for the management of water in Zambia is a top-up approach, which is not good for the management of water because there is little participation of stakeholders and water users in decision making. Therefore, following the Dublin principles of 1991 which emphasises the bottom-up approach for management of water resources, a new institutional structure for water affairs should be developed for effective management of water resources in Zambia at three administrative levels; national, regional and local level. Figure 4.20 shows a proposed bottom-up institutional structure for water affairs. The catchment management forum and catchment management committee report directly to catchment management authorities. There should be interlink between the CMA, NGOs, municipality council and water users for effective stakeholder participation in the community in decision making of water management. Water User Association should report to the CMA, while CMA to the Provincial Water Department at regional level. The Provincial Water Department should report to the Director of Water affairs, the Director to Permanent Secretary of that ministry and reports to the Minister of Energy and Water Development. The Minister reports to the Cabinet and Water Board Association (Figure 4.20).

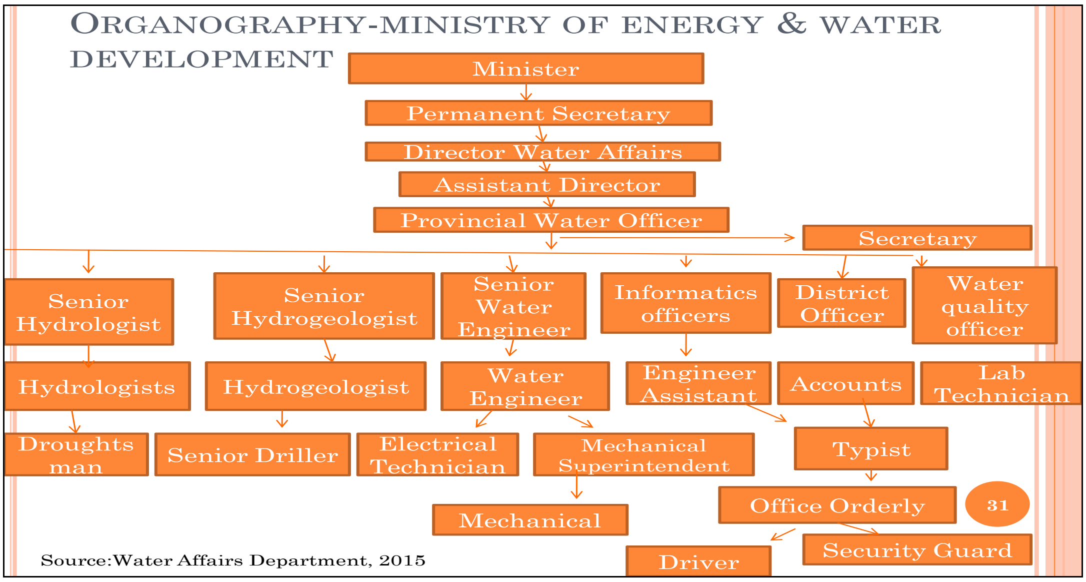

Figure 4. 19: Existing Organizational Structure for Water Affairs Department

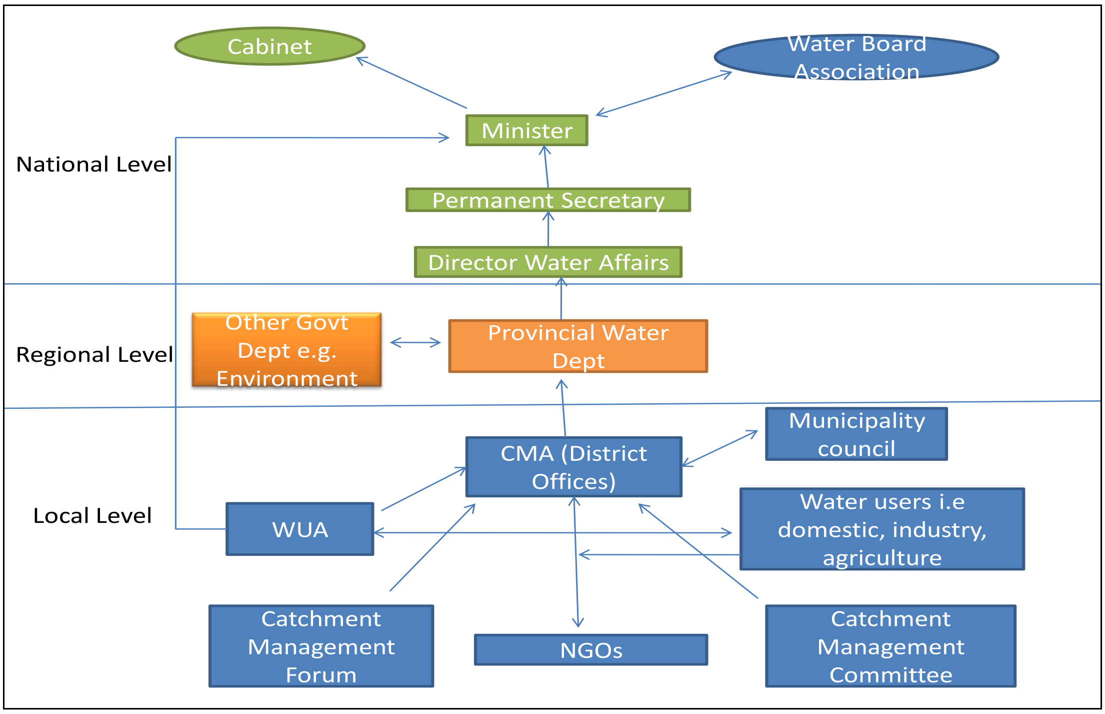

Figure 4. 20: Proposed Institutional Organograph for the Water Affairs Department

4.3.2 SWOC Analysis

SWOC and EFE were used to evaluate institutional and policy framework for the management of the water hyacinth. Weights were assigned to Strengths, Weakness, Opportunities and Challenges by stakeholders through interviews. The internal and external factors were obtained through interviews with the responsible authority for management of the water hyacinth, and were subjected to weights by the stakeholders. Stakeholders also rated the internal and external factors with the numbers ranging from 4 to 1. Where; 4 - superior response, 3 - above average response, 2 - average response and 1 - poor response for internal factors; and 4 was major strength, 3 was minor strength, 2 minor weakness and 1 major weakness for external factors. The weighted score was calculated by applying David (2009) formula;

Weighted Score = Weight x Rating
Total Weighted Score = Summation of all individual Scores

The total weighted score is 2.14 indicating a low total score. This indicates that the institutions arrangement for the management of the water hyacinth in the Kafubu River is weak internally.

The institution and policy strengths for management of the water hyacinth in the Kafubu River Department include; already established institution such as water department, existing policies such as the National Water Policy of 2011 and the Water Act of 2011 for the management of water, and support from the Government of Zambia in terms of providing financial assistant in the management of the weed (Table 4.7). The Water Department internally faces challenges as an institution as it has inadequate human capacity and equipment to manage the water hyacinth efficiently in the Kafubu River. The institution only has 9 qualified personnel and lacks monitoring system equipment. The institution has inadequate data on the water hyacinth such as the extent of its coverage and little knowledge is known on the impact of the water hyacinth. Although there are policies and laws that govern the management of the water hyacinth in the Kafubu River, these policies and acts do not stipulate anything on alien species management, making them weak on this part. The Department of Water Affairs has inadequate financial capacity for sustainable removal and monitoring system of the water hyacinth only 7.6million kwacha is allocated annually yet the department requires 100million kwacha. The Government of the Republic of Zambia purchased two dredgers to remove the weed from the River, though other operational costs and maintenance are contributed by four stakeholders for example Ndola City Council can contribute fuel for dredgers while Zambia Environmental Management Agency man power. This has lead to the removal of the weed as a short term measure. Information sharing between stakeholders is limited and in many cases it is nonexistent. In performing the EFE analysis showed that the total weighted score was below the average score as it indicated a 2.14 score while the recommended average score is above 2.5. This indicates that the institution's arrangement for the management of the water hyacinth in the Kafubu River is weak internally (Table 4.6). There is need to strengthen the external challenges in order to achieve sustainable management.

There are many opportunities that the water department takes advantage of. For example, the Swedish government donated $450 million in 2015 to Kafubu Water and Sewerage Company Limited for the rehabilitation of Kanini Sewerage Treatment Plant and at the time of data collection for this project the construction works were underway. This will improve the quality of effluents discharged into the Kafubu River. Environmental awareness on water protection and conservation are conducted annually in conjunction with private stakeholders. Improved technology has been an advantage to management of water quality such as mapping of the Kafubu River using GIS (Table 4.7).

Table 4. 6: Policy and Institutional Internal Factor Evaluation

Internal Factors	**Weights**	**Rating**	**Weighted Score**
STRENGTHS			
1. Existing policies on water and environment	0.07	4	0.28
2. Existing institutions	0.25	3	0.75
3. Support from the central government	0.15	3	0.45
Total	**0.47**		**1.48**
WEAKNESSES			
4. Inadequate human capacity and equipments	0.20	1	0.20
5. Inadequate data and knowledge	0.07	1	0.07
6. No policies on alien invasive species such as water hyacinth	0.02	2	0.04
7. Financial challenges	0.09	1	0.09
8. Inadequate monitoring systems	0.04	1	0.04
9. No information sharing	0.11	2	0.22
Total	0.53		0.66
Total weighted score	**1.00**		**2.14**

External treats in the management of the water hyacinth include; lack of coordination between participating stakeholders, lack of communication between stakeholders as each stakeholder can do anything without informing the others. The communities around the Kafubu River know little about the laws governing the protection and pollution of water. Lastly, there are a lot of mining developments upstream of the sampling point. Currently there are 3 mines mining lime and 3 making cement. The Water Affairs Department has faced a big challenge in monitoring what is discharged into the river from the mines. The EFE was used to evaluate these opportunities and challenges as shown in Table 4.7. The total weighted score for external evaluation is 1.99, which is low, indicating that the institution's strategies are not well designed to meet opportunities and defend the challenges around management of the water hyacinth in the river. Therefore, the Department of Water Affairs should formulate strategies that will address and overcome the challenges.

Table 4. 7: Policy and Institutional External Factor Evaluation

External Factors	Weight	Rating	Weighted Score
OPPORTUNITIES			
Funding from the Government	0.18	3	0.54
Rehabilitation of Kanini Sewerage Treatment plant	0.09	4	0.36
Improved technology	0.05	1	0.05
Environmental awareness sensitization	0.07	1	0.07
Total	0.39		1.02
CHALLENGES			
Lack of coordination between participating stakeholders	0.14	1	0.14
Inadequate awareness on the protection of water resources	0.06	2	0.12
Lack of communication	0.20	2	0.40
Law ignorance	0.16	1	0.16
Increasing mining industries upstream	0.05	3	0.15
Total	0.61		0.97
Total weighted score	**1.00**		**1.99**

4.3.3 Control Measures

On Kafubu River the Government of the Republic of Zambia spends about K7.6 million almost every year to purchase dredgers to remove the weed from the river yet the weed resurfaces after a short period of time (Lumba, 2015). The removal of the weed is a short term measure as the debris for the weed is not sustainably dumped or utilised. It is dumped along the river banks of the Kafubu River after removal and finds its way back into the water column and re-reproduces. Figure 4.21 shows dredger used to remove the weed in Kafubu River.

Figure 4. 21: Dredgers removing the weed from the Kafubu River

The biological control method is the most sustainable, easier and economic friendly long term method, which has been widely used to control the water hyacinth on water bodies (ITDG, 1999). Under suitable conditions, biological control using the weevils *N.eichhorniae* and *N.bruchi* reduces weed infestations to between 20% and

5% of its original cover within 3-5 years (Mashingaidze, 2003). For example, in Australia, it has been reported that this method has been successful through regular release of the weevils *Neochetina eichhorniae* and *N. bruchi*, and the moth *Sameodes albiguttalis*, which reduced the population density of the water hyacinth (Labrada *et al.*, 1996). Many countries that have introduced the biological control method to eradicate the water hyacinth have reported successfully (Ajuonu *et al.*, 2003; de Groote *et al.*, 2003; Julien and Griffiths, 1998). In the Eastern and Southern African regions; Lake Chivero and the Manyame river systems in Zimbabwe and Lake Victoria in East Africa where the rivers and lakes have high nutrient levels with nitrogen and phosphorus content, biological control against the water hyacinth has been less successful as the biological control agent populations fail to keep pace and control the rapid growth of the water hyacinth (Julien, 2001).

Wilson (2002) found that above a threshold of 0.1 mg/l of phosphate concentration in the water, the water hyacinth growth could not be restrained by biological control agents. The weed infestation on Lake Chivero was controlled through a combination of biological, chemical and mechanical control and this declined from 42% in 1976 to 22% in 2000 (Mashingaidze, 2003). Therefore a highly eutrophic river like Kafubu, an integrated control approach will defeat the explode population of the weed where chemical, mechanical and biological means are used in effective combinations. Integrated control should be implemented in such a way that the different control methods supplement each other and where possible have an additive effect and chemical control should be reduced as biological control gains momentum (Cilliers, 2003).

CHATPER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- The study revealed that nutrients such as phosphate, ammonia and nitrate from agricultural runoff and sewer effluent discharged at Kanini and Lubuto Sewerage Treatment Plants into the River were beyond the statutory limits. This has caused rapid growth of the water hyacinth in the Kafubu River. The trend analysis for the nutrients for the period 2014 to 2016 shows that the nutrient levels in the River has been increasing significantly. The study established that the weed has capacity to trap nutrients, e-coli and total coliforms in the water. Therefore, the trapping of pathogens makes the water hyacinth a potential biological alternative to secondary and tertiary treatment for wastewater.
- The study established that the water hyacinth has a great impact on fishing activities on the river. From the respondent's perception the impact include; damage to fishing nets and hooks, the weed causes difficult for the fishermen to paddle in a boat as the weed covers the water body. It also washes away the fish food that is hooked on fishing hooks, and also a lot of time is wasted just laying fishing nets to avoid the weed from damaging the nets. The Water Hyacinth has an impact on fish catchability as when there is low weed coverage, the fish catchability is high and vice versa. The study also established that fish price increases when the Kafubu River is covered completely by the water hyacinth to an average price from 8 kwacha to 9

kwacha and the fish prices decreases when the river has completely no water hyacinth with an average price from 4 kwacha to 2 kwacha.

- The study revealed that the water hyacinth reduces the amount of water received for irrigation as it blocks the irrigation channels and the weed also carry along the organic material which helps in the growth of the crops which was a positive impact.
- The study established that there is no institutional arrangement for the management of the water hyacinth in the Kafubu River. The control method used to remove the water hyacinth in the Kafubu River is a physical method by the use of dredgers which is a short term control measure and the Government of the Republic of Zambia spends about K7.6 million almost every year to purchase the dredgers. The debris unfortunately dumped along the river banks allowing the weed to return to the river within months of removal.

5.2 Recommendations

- It is recommended that the water hyacinth should be used by Kafubu Water and Sewerage Company Limited as a potential biological alternative to secondary and tertiary treatment for wastewater due to its ability to trap pathogens. The sewerage utility responsible for the effluents and the two sewerage treatments plants should rehabilitate the Sewerage Treatment Plants to meet statutory limitation of effluent disposal.
- Since there are no laws and policies on alien species, it is recommended that the country should embark on formulating policies and laws at national and

local levels that deal with alien invasive species for sustainable management of the water hyacinth for sustainable management.

- To defeat the infestation of the water hyacinth in the Kafubu River and reduce impacts on fishing activities and irrigation farming in the long run, it is recommended that an integrated control approach should be used where chemical, mechanical and biological means are used in effective combinations with a long term surveillance and monitoring of weed populations using remote sensing and other survey methods. The debris should be used to make paper, baskets, fibre boards, animal fodder and fertilizer or manure, biogas production and purification of water for domestic purpose. It is also recommended that public awareness on the importance of conserving water should be conducted at a regular basis in Ndola.

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APPENDICES

Appendix I: Questionnaire for Fishing

Dear Respondent,

This questionnaire seeks information that will help in accessing the impacts ***of water hyacinth on the community around Kafubu River in Ndola Town to be precise,*** where you have been selected to help out provide necessary information required in this study. Your views are very important.

For that reason, I am kindly requesting that you fill this questionnaire. Please note that the information will be treated with confidentiality and shall only be used for the study purpose.

Please do not write yours names on the questionnaire.

Thank you.

Mercy Mbula.

Section 1: Respondent's Profile

1. Please tick your gender

☐ Male ☐ Female

2. Age

10-15

16-21

22-26

27-31

32-36

37-41

42-46

3. Level of Education

Primary ☐ Secondary ☐ Tertiary ☐

4. What socio-economic activities are you engaged in?

☐ Fishing industry

☐ Transport business

☐ Tourism

☐ Farming

☐ Others (specify)

5. How long have you been in this business?

☐ Less than 1 year

☐ 1-3years

☐ 4-6years

☐ 7-9years

☐ Above 9 years

<u>Section 2: Fishing Industry and Water Hyacinth</u>

4. How does the water hyacinth affect your fishing activities on the river?

____

5. Please indicate the type of fish in the table and circle the number indicating quantities fish in the three climatic seasons of the year.

Key: 1 = Low; 10= High

Type of fish	August – October	November – April	May – July
	1 10	1 10	1 10
	1 10	1 10	1 10
	1 10	1 10	1 10
	1 10	1 10	1 10

6. In your own opinion, do you think water hyacinth has an effect on the fish quantities?

- ☐ Yes
- ☐ No

7. If yes, explain how does it affect the fish stock?

____

8. When do fish prices increase or decrease?

Price increases when….. ……………………………………………

August-October, by how much?

November to April, by how much?

May to July, by how much?

Price decreases when……

August-October, by how much?

November to April, by how much?

May to July, by how much?

9. What additional costs are incurred due to the presence of water hyacinth on the river?

____

____

Appendix II: Questionnaire on farming

Dear Respondent,

This questionnaire seeks information that will help in accessing the impacts ***of water hyacinth on the community around Kafubu River in Ndola Town to be precise,*** where you have been selected to help out provide necessary information required in this study. Your views are very important.

For that reason, I am kindly requesting that you fill this questionnaire. Please note that the information will be treated with confidentiality and shall only be used for the study purpose.

Please do not write yours names on the questionnaire.

Thank you.

Mercy Mbula.

Section 1: Respondent's Profile

1. Please tick your gender

☐ Male ☐ Female

2. Age

10-15

16-21

22-26

27-31

32-36

37-41

42-46

2. Level of Education

Primary ☐ Secondary ☐ Tertiary ☐

3. What socio-economic activities are you engaged in?

☐ Fishing industry

☐ Transport business

☐ Tourism

☐ Farming

☐ Others (specify)

4. How long have you been in this business?

☐ Less than 1 year

☐ 1-3years

☐ 4-6years

☐ 7-9years

☐ Above 9 years

Section 5: Farming and Water Hyacinth

5. What are the effects of water hyacinth on farming?

6. To what extent would you say the following are affected by the water hyacinth in this area?

Aspects	**Not at all (1)**	**To a limited extent (2)**	**To moderate extent (3)**	**To a great extent (4)**
irrigation channels				
amount of water received				

7. When do you receive enough water for irrigation? Indicate below.

when…..……………………………………………

When the river has completely no hyacinth

How much amount of water

When water in the river is partially covered by hyacinth

How much amount of water

When water in the river completely covered by Hyacinth

How much amount of water

8. What extra cost is incurred due to the problem caused by water hyacinth?

Appendix III: Interview Schedule Guide for Institutions and Policy Framework

Dear Respondent,

This questionnaire seeks information that will help in accessing the impacts ***of water hyacinth on the community around Kafubu River in Ndola Town to be precise,*** where you have been selected to help out provide necessary information required in this study. Your views are very important.

Therefore, am kindly requesting for **45 minutes** of your time in order to answer some question pertaining to this study. The following questions will be asked if permission is granted.

1. What institutions are responsible for management of water hyacinth?
2. Is there any laws governing the management of water hyacinth?
3. How is the institutional structure?
4. How is water hyacinth control? Constraints of technology used to control
5. What is water quality in the lake for past years?
6. What are the Internal and external challenges in management of these water hyacinth
7. What strategies for control of water hyacinth are in place, any challenges for implementing them

Appendix IV: Sampled Water Quality Parameters

ST1	ST2	ST3
ph-ST1	ST2	ST3
7,2	6,9	6,89
7,43	7,1	7,6
7,3	7,23	7,35
7,7	7,33	7,42
7,624045	**7,14**	**7,315**
0,211062	**0,160779**	**0,261773**

Temperature-ST1	ST2	ST3
28,5	29	29
27	28,9	28
28,1	29,5	31,4
27,9	29,1	32,2
27,875	**29,125**	**30,15**
0,549432	**0,227761**	**1,710994**
DO-ST1	ST3	ST2
8,7	5,9	5,4
8,6	6,7	5,1
8,7	7,1	5,5
8,9	6,9	5,2
8,725	**6,7**	**5,3**
0,108972	**0,45607**	**0,158114**
		5,3
EC (µS/cm)		
497	345	467
500	367	453
490	400	489
494	393	467
495,25	**376,25**	**469**

phosphate-ST1	ST2	ST3
0,3	0,27	0,46
0,4	0,27	0,7
0,5	0,4	0,6
0,6	0,3	0,65
0,45	**0,31**	**0,6025**
0,111803399	**0,053385**	**0,033587572**

nitrate-ST1	ST2	ST3
3,43	4,13	4,87
4,2	4,34	4,7
3,12	4,2	4,9
3,31	4	4,87
3,515	**4,1675**	**4,835**

ammonia-ST1	ST2	ST3
0,04	0,6	0,7
0	0,5	0,6
0,06	0,6	0,4
0,04	0,6	0,8
0,035	**0,575**	**0,625**
0,021794495	**0,043301**	**0,147901995**

nitrite-ST1	ST2	ST3
0,2	0,5	0,34
0,3	0,56	0,32
0,23	0,57	0,3
0,2	0,5	0,3
0,2325	**0,5325**	**0,315**

turbidity-ST1	ST2	ST3
1,24	9,32	5,86
1,24	9,31	5,85
1,23	9,3	5,84
1,25	9,33	5,85
1,24	**9,315**	**5,85**
0,007071	**0,01118**	**0,007071**

E.Coli -ST1	ST3
23,44	45
23,44	45,7
23,5	46
23,6	45,3
23,495	**45,5**
0,065383484	**0,380789**

Appendix V: Water Quality Parameters Sampled Monthly by Kafubu Water and Sewerage Company

months	Ammonia level
Jan,2014	0,03
Feb,2014	0,034
Mar,2014	0,035
Apri,2014	0,038
May,2014	0,023
Jun, 2014	0,047
July,2014	0,048
Aug,2014	0,06
Sept,2014	0,067
Oct,2014	0,064
Nov,2014	0,04
Dec,2014	0,053
Jan,2015	0,056
Feb,2015	0,057
Mar,2015	0,062
Ap,2015	0,063
May,2015	0,062
Jun,2015	0,064
July,2015	0,064
Aug,2015	0,065
Sept,2015	0,062
Oct,2015	0,063
Nov,2015	0,064
Dec,2015	0,065
Jan,2016	0,066
Feb,2016	0,067

months	Temperature
Jan,2014	27,8
Feb,2014	27
Mar,2014	28,2
Apri,2014	25
May,2014	26
Jun, 2014	27
July,2014	28,2
Aug,2014	27
Sept,2014	27
Oct,2014	26,6
Nov,2014	27,5
Dec,2014	28
Jan,2015	25,2
Feb,2015	25
Mar,2015	27,3
Ap,2015	26
May,2015	25,5
Jun,2015	28
July,2015	28,2
Aug,2015	27
Sept,2015	28,3
Oct,2015	29
Nov,2015	29,2
Dec,2015	30
Jan,2016	27,6
Feb,2016	27,4

months	nitrate
Jan,2014	1,9
Feb,2014	1,9
Mar,2014	1,8
Apri,2014	1,5
May,2014	1,5
Jun, 2014	1
July,2014	1,4
Aug,2014	1,4
Sept,2014	1,2
Oct,2014	1,7
Nov,2014	1,5
Dec,2014	1,8
Jan,2015	1,88
Feb,2015	1,9
Mar,2015	1,9
Ap,2015	2,1
May,2015	2
Jun,2015	2,1
July,2015	3,2
Aug,2015	3,4
Sept,2015	3,45
Oct,2015	3,6
Nov,2015	4
Dec,2015	4,12
Jan,2016	4,16
Feb,2016	4,1

months	phophate
Jan,2014	0,3
Feb,2014	0,4
Mar,2014	0,35
Apri,2014	0,37
May,2014	0,38
Jun, 2014	0,39
July,2014	0,4
Aug,2014	0,41
Sept,2014	0,42
Oct,2014	0,43
Nov,2014	0,44
Dec,2014	0,45
Jan,2015	0,46
Feb,2015	0,48
Mar,2015	0,35
Ap,2015	0,5
May,2015	0,52
Jun,2015	0,54
July,2015	0,55
Aug,2015	0,56
Sept,2015	0,58
Oct,2015	0,59
Nov,2015	0,6
Dec,2015	0,64
Jan,2016	0,614
Feb, 2016	0,645

months	PH Level
Jan,2014	7,3
Feb,2014	7,4
Mar,2014	7,3
Apri,2014	7,4
May,2014	7,6
Jun, 2014	7,5
July,2014	7,4
Aug,2014	7,7
Sept,2014	7,3
Oct,2014	7,4
Nov,2014	7,5
Dec,2014	7,6
Jan,2015	7,7
Feb,2015	7,6
Mar,2015	7,2
Ap,2015	7,5
May,2015	7,4
Jun,2015	7,6
July,2015	7,7
Aug,2015	7,5
Sept,2015	7,4
Oct,2015	7,6
Nov,2015	7,6
Dec,2015	7,7
Jan,2016	7,7
Feb,2016	7,8